**The University of the Witwatersrand**

# Developing pedagogic content knowledge using climate change as a theme to teach Physical Sciences Concepts to grade 11 learners a self-study.

Master's in Education (MEd)

A research report submitted to the Faculty of Humanities, University of Witwatersrand, Johannesburg, South Africa, in partial fulfilment of the award of Masters of Education

Terrence T. Chigura

Student No: 748794

Supervisors: Dr. M Nakedi and Prof. R Kizito

## TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

**LIST OF GRAPHS**

**DECLARATION**

I declare that this self-study is my work and that all the sources in this research report are cited to maintain the veracity of this study. The self-study has not been submitted before for any degree in any other university.

Terrence T. Chigura

*TTChigura*

Date 30.04.2021

## ACKNOWLEDGEMENTS

I would like to give glory to God for the gift of life and all the blessings that has enabled me to do the best I could to finish this project. Special mention goes to my mentors and supervisors Prof. R Kizito and Dr. M Nakedi for seeing something in me that was of value in academia. Prof. Kizito's words of encouragement, criticism, belief and patience in the self-study are appreciated. I have learnt valuable lessons that I will carry for the rest of my life. My collegiality was vital in this research: Mr R Nyapokoto and Mr J. Z Mudara being PhD students themselves were a constant motivation and the knowledge and skills gained in interactions with them were valueless.

# ABSTRACT

This self-study is my own personal experience of teaching the topic of climate change to learners doing Physical Sciences in Grade 11 as I look at the shifts and portrayal of my Content Knowledge and Pedagogical Content Knowledge at Sandtonview secondary school. Climate change is one of the most critical socio-scientific issues in the global community as it impacts the continuity of species. It has been observed that the effects of climate change have become more severe in the last decades. In South Africa, studies have called for scientific climate change education. However, teachers' specialized knowledge for teaching socio-scientific themes is under researched and difficult for teachers to portray in their practice. This study focuses on my personal learning journey, as a teacher studying how I develop, portray and observe shifts in my own Content Knowledge and Pedagogical Content Knowledge. I undertook a self-study methodology to explore my teaching of climate change as a context when teaching Grade 11 Physical Sciences. To induce trustworthiness in my study, all my activities are opened to a collaborative team of critical peers that constitute my colleagues and supervisor. In this study, PCK is my conceptual framework and the Learning for Teaching through Participation model the framework for studying the learning environments and an analytical tool to capture and portray my shifting knowledge in my planning and teaching of climate change. Climate change is not a topic in the current curriculum, the ploy used was teaching it as a theme in teaching the relevant chemistry topics at Grade 11. In this way exploration of its place in the current Physical science curriculum is possible. As an outcome of my study I was able to capture, portray and obsrve shifts in my CK and PCK by framing and reframing my thinking and executions in the classroom. The self-study is qualitative research with nominal quantitative calculations that made use of two-staged prior and post concept mapping and CoRes, entries into a reflective journal and teaching artefacts. Drawing from socio-cultural and cognitive perspectives, the LTtP model in conjunction with PCK, offered pre-determined categories to portray my PCK of climate change. I found that my Content and Pedagogical Content Knowledge for teaching climate change had shifted during the course of the self-study. I was more conscious of my Content and Pedagogical Knowledge as my misconceptions on teaching this topic had been exposed and confronted to develop my professional knowledge for climate change pedagogy in terms of my classroom practice. The implications of this study is that teachers may create stories of teaching to grow their own specialized content knowledge for teaching and for other practitioners that may be a source of teachers' PCK in specific teaching contexts.

## ABBREVIATIONS

IPCC: ............ Intergovernmental Panel on Climate Change

CK: ............ Content Knowledge

PCK: ............ Pedagogical Content Knowledge

CoRe: ............ Content Representations

PaP-eRs: ............ Professional and Pedagogical-experience Repertoires

CAPS: ............ Curriculum Assessment Policy Statement

DoBE: ............ Department of Basic Education

STS: ............ Science, Technology and Society

FET: ............ Further Education and Training

LTtP: ............ Learning Teaching through Participation

GHE: ............ GreenHouse Effect

$CO_2$: ............ Carbon dioxide

C: ............ Carbon

NOS: ............ Nature Of Science

VASI: ............ Views About Scientific Inquiry

LPMCs: ............ Learners' Pre-Conceptions and Misconceptions

LSSR: ............ Learners' Socio-scientific Reasoning

CS: ............ Curriculum Saliency

LPK: ............ Learners' Procedural Knowledge

RMAR: ............ Representations, Models, Analogies and Resources

TCD: ............ Topic Comprehensible Difficulty

VoCC: ............ Views on Climate Change

CFCs: ............ ChloroFlouroCarbons

**CHAPTER 1:**

## BACKGROUND

### 1.1. Introduction

The teaching of socio-scientific topics such as climate change is an intricate undertaking that requires specialized knowledge and skills (O' Donoghue, 2013; Nakedi & Rollnick, 2012). Many curricula documents have identified learning climate change as an important objective to concoct citizens to deal with an ecological crisis in a world shaped by anthropogenic climate change (International Panel of Climate Change, 2014). Consensus in the scientific community is that current climate change is anthropogenic however, the knowledge and skills to make it teachable in classrooms is minimal (Ward, 2016). One reason cited is that anthropogenic climate change is a complicated socio-scientific construct with unpredictable effects on the livelihoods of people in various communities (Herman & Clough, 2017). The global weather incidences have stimulated a call from the citizenry to make sense of anthropogenic climate change (Sharma, 2012). Pre-service teachers and secondary school learners in the Australian States have shown limited knowledge to deal with the growing conundrum of climate change (Boon, 2010). In South Africa, two studies by Nakedi (2014) showed the difficulties that science teachers experienced when teaching global warming and atmospheric chemistry under the chemical systems theme in the South African curriculum. Therefore, it is desirable that science teachers develop knowledge for teaching climate change sensibly.

The art of science teaching is an exercise of developing teaching methodologies that merge specialized knowledge forms that Shulman in 1987 coined as PCK (Carlson, Stokes, Helms & Gess-Newsome, 2015). The teachers' PCK is the knowledge and skills germane to making subject content of a specific topic accessible to learners (Mavhunga, 2018). This specialized knowledge specific for teaching is intricate and teachers find it difficult to develop and portray to others (Cooper & Loughran, 2015). The concealed knowledge of teaching may, however be captured with tools such as CoRes and Professional and PaP-eRs (Park & Suh, 2015). These tools of pedagogy may be used to develop knowledge and skills that underpin teaching experiences (Lubben & Bennett, 2008).

One of the core contentions in current science pedagogy is that sensible classroom science is useful in learners' everyday lives (Sjostrom & Eilks, 2018). Scientific literacy, as a component of science teaching, may depict the interconnections of science with society and technology (Linder, Ostman, Roberts & MacKinnon, 2011; Nakedi & Rollnick, 2012). This shift in science teaching is visible in many global curricula reform documents and literature on climate change (Sadler, Romine & Topcu, 2016). This view of pedagogy is pinned down by studies that support the teaching of science topics in specific contexts (Schwartz, Lederman, & Khalick, 2012). The new CAPS curriculum, in one of its broad objectives states that learning Physical sciences must develop skills to deal with socio-scientific conundrums (DoBE, 2011). Contrary to this objective there is a retraction of social themes in the science topics in Grades 10 to 12 (Nakedi, Taylor, Mundalamo, Rollnick, & Mokeleche, 2012). The lacuna betwixt curricula intentions and classroom content has led to a decline in socio-scientific topics in Physical Sciences (Nakedi *et al.,* 2012). Science teachers must possess a specialized knowledge of teaching socio-scientific contexts to convey the current curriculum's objective of learning science constructs that connect to everydaylife (Nakedi, 2014). Climate change is an experience that could be used to explore classroom science that connects to learners' social settings (Wise, 2010).

Self-study offers a solution for teachers to develop their own CK and PCK for teaching climate change from pertinent classroom experiences. Current educational studies point out one role of self-study as to develop teachers' PCK in practice (Gess-Newsome, 2015). Self-study in pedagogy involves concretization of personal investigation on the knowledge that underpins teaching and learning processes (Demirdogen *et al.,* 2015). A self-study is thus valuable in investigations to capture the teachers' thinking and doings in their practice (Lunenberg, Zwart, & Korthagen, 2010; Nakedi & Rollnick, 2012). This research is a self-study that looks at how my CK and PCK when teaching climate change as a social theme to Grade 11 learners doing Physical Sciences.

## 1.2 Context

There is an increase in studies that examine teaching science using the thinking of scientific literacy that subscribe to authentic science that involve learners' world experiences (Linder *et al.,* 2011). The stirred interest in science constructs with socio-scientific themes is to show the interconnections between science and society (Khalick & Zeidler, 2015). One objective of science education in various curricula reform documents in the world is to develop learners' socio-scientific thinking (Bartos & Lederman, 2014). The curricula reforms in the CAPS documents foresee that learning Physical Sciences develops a consciousness of ecology (DoBE, 2011). Parallel to this philosophy is the call to advance teachers' PCK to ensure meeting this end (Linder *et al.,* 2011). However, science teacher training in South Africa is inconsistent with curricula reforms and the demands of society (Nakedi & Rollnick, 2012; Lelliott, 2014). This is one of the factors that has limited the teachers' professional knowledge of science topics with a social theme (Booi & Khuzwayo, 2019).

Valuable science education is when teaching develops scientific skills useful in learners' everyday lives (Sadler *et al.,* 2016). The contentious and social conundrum of climate change fits as a theme to teach specific topics that apply to learners' daily experiences (Hodson, 2003). Climate change is a specific socio-scientific setting with constructs that develop learners' literacy in science (Mc Ginnis, Mc Donald, Hestness, & Breslyn, 2016). Climate change is one of the most critical socio-scientific issues in the global community (Linder *et al.,* 2011). Studies have observed that the effects of climate change have become more intense in the last decades (IPCC, 2014). Therefore, it is critical that teachers develop the competencies for teaching this socio-scientific topic. This self-study investigates my teaching experiences of climate change when teaching Physical Sciences to Grade 11 learners at Sandtonview School in South Africa.

### 1.3 Statement of the problem

Teachers may have the CK of a topic, but teaching concepts call for specialized teaching knowledge and skills to make concepts understandable (Lederman, 2006). Teachers' limited PCK creates misconceptions in learners' conceptual model of socio-scientific constructs (Sullivan *et al.,* 2014). Furthermore, teachers find it difficult to portray the professional knowledge in their classrooms when teaching specific topics (Nakedi, 2014; Carlson *et al.,* 2015). Mc Ginnis *et al*. (2016) posit that teaching climate change is a problem in science classrooms.

The theme of anthropogenic climate change is concealed in some science curriculum documents, so teaches exclude it in classroom content (Herman, Feldman, & Hernandes, 2017). The uncoupling of social experiences and science content in the classrooms does not promote the teaching and learning of authentic science concepts (Garritz & Villa, 2012). In the South African context the teaching of social themes are constricted to depictions in the broad objectives of the CAPS document (O'Donoghue, 2013). Teaching science topics without socio-scientific themes disconnects science classroom and learners' home experiences (Linder *et al.,* 2011). There is a retraction in socio-scientific themes in the current CAPS Physical Science curriculum at FET level (Nakedi *et al.,* 2016). It is critical that climate change constructs be teachable to realize the objective of teaching authentic science (Herman *et al.,* 2017). The self-study investigates the teachers' CK and PCK shifts when teaching climate change prior to and at the end of the study**.**

### 1.4 Rationale of study

The knowledge to use socio-scientific themes in teaching science makes classroom science relatable to learners' everyday lives (Herman *et al.,* 2017). The learners' experiences to climate change impacts substantiate its use as a theme in Physical Science so that learners may relate their prior experiences with science classrooms content. Using a social theme may stimulate classroom science that may develop learners' scientific literacy (O'Donoghue, 2013).

The role of the self-study is to position the construct of climate change as a critical theme in the current Grade 11 Physical Science curriculum. Climate change is now included as a critical topic in science curricula in a number of countries (Sharma, 2012). Teachers can incorporate social contexts into science topics to help students gain knowledge and skills in socio-scientific topics (Sharma, 2012). Science teachers can use the theme of anthropogenic climate change to illustrate STS's impact on global ecology (Veron, Marbach, & Ozbay, 2016). One of the International Panel on Climate Change's goals is to deal with anthropogenic climate science by using education as a tool to educate students about ecological quandaries such as climate change (IPCC, 2014). Classroom science, according to the thinking, is a conceptual space for teaching climate change in order to develop scientific literacy (Herman *et al.,* 2017).

The self-study method is appropriate for investigating teachers' specialized knowledge and skills in order to customize their classroom practices. Self-study is a conceptual tool in pedagogy used to model teachers' CK and PCK of specific topics. According to research, shifts in teachers' thinking about their PCK on a specific topic can be developed for best practice (Hamilton & Pinnegar, 2000; Mavhunga & Rollnick, 2013). Self-studies meet the goal of concretizing teaching experiences and pinning down the thinking that directs classroom experiences from the practitioner's perspective. Self-studies enable teachers to cross-examine complexities in classroom teaching and learning situations (Samaras & Freese, 2006). In this self-study, I capture and depict my CK and PCK regarding climate change.

**1.5 Aim of study**

The objective of this self-study is to concretize my experiences of teaching climate change to my Grade 11 Physical Science learners. A teachers' style of teaching may be a template to pin down their professional experiences which are useful in a community of teachers. One of the objectives in the Physical Sciences CAPS document is to develop learners' scientific knowledge and skills (DoBE, 2011). Therefore, it is critical that teachers develop their CK and PCK to make classroom content more comprehensible.

**1.6 Research questions**

The following are the specific questions that have guided my self-study

1. What are my conceptions of Content Knowledge and how are they shifting when teaching the Chemistry of climate change to Grade 11 learners doing Physical Sciences?
2. How is the portrayal of my Pedagogical Content Knowledge when teaching the Chemistry of climate change to Grade 11 learners?
3. How is my Pedagogical Content Knowledge shifting throughout the self-study when teaching the Chemistry of climate change to Grade 11 learners?

The first question may be answered by examining my prior and post idea maps, which illustrate my CK of climate change. Concept maps are visual aids that help organize concepts (Roth & Bernhardt, 2016). Concept maps are useful for determining a teacher's expert CK in a particular subject (Aderet-German & Dromi, 2017). The second issue is addressed via the use of PaPeRs, lesson transcripts, teachers' journals, and classroom artefacts that demonstrate my PCK of climate change. The

PaP-eRs are extensive explanations of key aspects of the lesson that demonstrate how a teacher incorporates PCK principles into their instruction (Loughran *et al.*, 2006). The third question is answered by comparing the pre and post CoRes in terms of large concepts and prompts that reveal particular aspects of PCK. CoRes demonstrate instructors' conceptual understanding of how to transform topical material into content appropriate for teaching a particular subject (Carlson *et al.*, 2015).

**1.7 Synopsis of the research methodology**

The research is mostly qualitative in nature but includes some quasi-quantitative methodologies. This research employs a self-study methodology. Self-studies represent a change away from the conventional method of external experts developing teachers' knowledge for their work and toward knowledge generated by instructors in particular classroom contexts (Chiu-Ching & Chan, 2009). A self-study is a systematic examination of one's own instructional experiences (Lunenberg *et al.,* 2010). The qualitative components comprise data collecting from text sources such as CoRes, PaP-eRs, teachers' journals, and instructional artefacts to explain my pre- and post-climate change knowledge (CK and PCK). The quasi-quantitative approach use concept maps to measure the teacher-knowledge researcher's and teaching practice about climate change. and entails a sustained examination of individual experiences (Lunenberg *et al.,* 2010). Self-studies in teaching have been shown to improve students' ability to teach subject in the classroom (Samaras & Freese, 2006; Lunenberg *et al.,* 2010; Watson, 2013). When instructors do objective investigations into the reasoning that underpins classroom activities, they may hone their specialized expertise for teaching (Hamilton & Pinnegar, 2000).

The tools for data collection are pre- and post-concept maps to examine my pre and post CK of climate change. PaP-eRs, journals and teaching artefacts portray my PCK and the pre and post CoRes capture and trace my shifts in PCK when teaching climate change. Teachers' concept maps capture and portray CK in a specific topic, CoRes are pedagogic tools that capture a teachers' PCK, PaP-eRs are narratives of the critical parts of the lesson that display various PCK elements, a reflective journal is a systemic record of the teachers' reflections on their thoughts, beliefs and reasons of teaching experiences.

The triangulation of data sources substantiates observations in self-studies (Coia & Taylor, 2009). The community of practice interact to introduce trustworthiness and credibility to make the self-study objective (Watson, 2013). The teacher and collegiality consolidate observations and legitimize the observations in self-investigation (Lunenburg *et al.,* 2010).

## 1.8 Overview of the data analysis

Text descriptions map out the data gathered to provide answers to the study questions. In self-studies, pre-defined categories may direct text descriptions (Krippendorff, 2018). Data from pre and post concept maps, CoRes, PaP-eRs, teachers' journals, and teaching artefacts with text descriptions are analyzed to capture and display content and specialized knowledge. Spider graphs show the scores of pre- and post-concept maps. My CK shifts are depicted in pre- and post-concept maps. The comparison of pre and post CoRes demonstrates my shifting PCK of climate change. My analytical framework is Nakedi's LTtP model. The LTtP model's six pre-set categories of PCK extract teachers' PCK from PaP-eRs, teachers' journals, audio-recorded lessons, and teaching artefacts.

## 1.9 Outline of study

This self-study course is divided into five chapters. The first chapter covers the introduction, study context, rationale, study questions, an overview of self-study as a methodology, and analytic models. The critical literature that underpins the conceptual model and analysis of the self-study is laid out in Chapter 2. The methodology is the focus of Chapter 3. The findings, data analysis, and discussion of results are presented in Chapter 4, and the final chapter summarizes the implications for the future, submissions for teaching climate change as a socio-scientific topic, and the conclusion.

## 1.10 Conclusion of Chapter 1

This chapter introduced the self-study. The objectives, context, rationale and an overview of the methodology are set. Chapter 2 will present the literature review, conceptual and analytical models in the self-study.

**CHAPTER 2:**

## LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

### 2.1 Introduction

This chapter reviews the literature that serves as a conceptual underpinning to this study. Literature review is a critical look at the importance of the topic in a specific discourse (Bell, 2010). This chapter critically looks at the literature of theories that inform the study, key concepts in the study and the conceptual and analytical frameworks.

### 2.2 Conceptual framework

My research is based on the perspectives of situative and cognitive constructivism. In the self-study, these perspectives describe my underlying assumptions about CK and PCK. In the self-study, the conceptual model justifies my research methodology and data analysis choices.

#### 2.2.1 Situative standpoint

The situative standpoint is a social theory that asserts that knowledge emerges in social contexts (Leach & Scott, 2003). Social connections foster the development of thinking models and skills for making sense of the world (Wertsh, 1985). According to the situative viewpoint, our conceptual models and worldviews are shaped by our social environments (Lave & Wenger, 1991). Learning is the expansion of one's knowledge and skills in social situations (Brown, Collins & Duguid, 1989). Social interactions in the context of pedagogy socialize learners in a community of legitimate practices with specific knowledge and skills (Bowen, 2003). Brown et al. (1989) emphasize that conceptual change is a shift in thinking models in a natural social setting. Specialist communities interact and exchange useful skills and knowledge. According to the situative perspective, social interactions are necessary for learning to occur (Lave & Wenger, 1996). As a result, learning is a social act in which individuals share knowledge in specific social activities (Bowen, 2003). The use of social tools to develop specialized knowledge of practice may contribute to the development of a teacher's knowledge and skills (Henzle & Van Driel, 2015). Signs, symbols, and language can all be used as social tools. A community of practice cultures individuals into specialists by socializing them into specific discourses, and collegiality is a source of socio-cognitive tools for creating knowledge in social interactions (Brown et al, 1989).

A self-study is a methodological tool used by skilled teachers to question their thinking through social interactions in order to develop alternative practices (Brown, 2010). Teachers' PCK develops from personal experiences and in social settings within communities of practice, where the pedagogue may use social tools to increase the teachability of concepts in classrooms, according to pedagogy researchers (Lave, 1996; Henzle & Van Driel, 2015).

### 2.2.2 Cognitive constructivism

Constructivists believe that learning takes place through specific experiences (Matthews, Cook, & Acia, 2019). As a result, it is critical for teachers to develop their knowledge and skills in authentic classroom settings. Teachers' role in the classroom is to create conditions in which students can construct correct conceptual models. Constructivists argue that conceptions of the world emerge when intuitions are challenged (Carr, Backer, & Bell, 1994). Individuals hold a variety of intellectual perspectives on specific topics, all of which are based on prior assumptions (Driver, Squires, & Rushworth, 1994). Prior to knowing scientific constructs, common sense thinking develops from everyday experiences (Taber, 2018). As a result, it is critical in teaching to rethink the practice in order to develop knowledge and skills for teaching, because new knowledge is derived from prior conceptual models (Driver *et al.,* 1994). Prior conceptions are the result of an individual's social environment, language, ideologies, and ways of thinking (Leach and Scott, 2016). It is critical to confront their prior thinking in order to develop new ways of thinking in order to expose a misconception (Scott, Asoko, & Driver, 1994).

## 2.3 Literature review content

My literature review focuses on studies that have been done in teachers' CK and PCK of climate change and other related constructs. The critical look at literature will expose the prior and current knowledge of teachers' CK and PCK of climate change and the links to my self-study.

### 2.3.1 Content Knowledge

Shulman defined a teacher's CK in 1986 as the conceptual knowledge required to teach a specific subject. This comprehension of CK has evolved into knowledge of how to teach a specific topic. Ball et al. (2008) hypothesize that CK is divided into two classes: common and specialized. The common CK is a set of mathematical knowledge and skills used to solve problems in everyday life, whereas the specialized CK is a set of mathematical knowledge and skills used to carry out teaching activities. While Ball et al. (2008) define CK in terms of Mathematics, I will refer to specialized CK in terms of Physical Sciences in this study. What is the teachers' specialized knowledge and skills? CK is the knowledge and skills required to make a specific topic teachable to learners. A teacher's CK can be seen in how he or she thinks about concepts in a topic, how they use specific contexts when teaching, and how they use specific discourses to develop learners' understanding of concepts (Ball *et al.,* 2008).

### 2.3.2 Climate Change Overview

Climate change is one of the most pressing socio-scientific issues of the modern era (Widiyawati, 2019). As a result, it is vital that learners comprehend this subject in order to provide them with the information and abilities necessary to address this problem. Numerous research has been conducted to teach and conscientize students on climate change in order to foster scientific literacy. However, few research has examined how teachers' climate change CK and PCK may be developed. Climate change is an interdisciplinary field of study that encompasses biology (ecological consequences), chemistry (chemical processes that result in the GHE and global warming), and physics (temperature and energy transmission) (Widiyawati, 2019).

### 2.3.3 Studies of teachers' Content knowledge in climate change

Some South African science teachers have misconceptions about anthropogenic climate change (Anyanwu, Grange, & Beets, 2015). The progression of ozone depletion into global warming is a common misconception among teachers (Wise, 2010). This demonstrates that teachers have erroneous perceptions of anthropogenic climate change (Wise, 2010). Teachers' limited knowledge of anthropogenic climate science may lead to misconceptions among students in the classroom (Veron *et al.,* 2016). Climate change misconceptions spread to students, such as the belief that global warming is caused by ozone depletion caused by the ozone hole. Correct canonical science concepts aid in the teaching of anthropogenic climate change (Anyanwu *et al.,* 2015). When climate change constructs are incorrect, misconceptions will persist in learners' mental models (Veron *et al.,* 2016). Science teachers who teach incorrect concepts contribute to students' misconceptions about climate change (Branch, Rosenau, & Berbeco, 2016).

Climate change is a socio-scientific topic that science teachers find difficult to teach (Branch *et al.,* 2016). When teaching about climate change, teachers frequently fail to confront students' misconceptions (Hadiyanti, Widodo & Rochintaniawati, 2015). If teachers investigated learners' misconceptions about climate change when teaching the topic, the concept would be more teachable to students (Veron *et al.,* 2016). However, some teachers are unaware of their students' prior knowledge and misconceptions (Anyanwu *et al.,* 2015). As a result, it is prudent to investigate teachers' knowledge of climate change and knowledge of how to teach it in order to reduce learners' misconceptions in science classrooms. Wise (2010) emphasizes the importance of teaching the history of science in developing coherent learners' conceptual models in socio-scientific topics. Mc Ginnis et al. (2016) insist on confronting learners' misconceptions in socio-scientific topics such as climate change when teaching the NOS. Teaching the NOS as part of a topic makes it easier to teach in science classrooms (Esa, 2010).

The enhanced GHE conceptual model explains anthropogenic climate change. According to Branch et al. (2016), some teachers confuse the GHE and the enhanced GHE. The GHE is a critical ecological process that uses greenhouse gases (Greenhouse gases) to warm the earth and sustain life on the planet (Anyanwu *et al.,* 2015). Excess greenhouse gases increase GHE, which absorbs IR energy from the surface and warms the planet (Wise, 2010). Anyanwu and his colleagues discovered that teachers in South Africa had mixed prior conceptions about the causes of climate change in a study they conducted. Some secondary school science teachers had difficulty identifying water vapour as the most common greenhouse gas and explaining the increased GHE (Anyanwu *et al.,* 2015). According to Anyanwu, teachers had good content knowledge of simple concepts in climate change but limited conceptual knowledge of higher order concepts in climate change (Anyanwu *et al.*, 2015). As a result, they lacked understanding of complex concepts such as the enhanced GHE model for explaining anthropogenic climate change (Anyanwu *et al.,* 2015).

Climate change will not be teachable in classrooms unless teachers have CK of the difficult concepts. A teacher's understanding of learners' misconceptions is an important component of a teacher's CK for teaching (Anyanwu *et al.,* 2015). Correct CK of the topic is required for a teacher to identify learners' misconceptions. This claim is supported by Esa, who claims that teachers have limited abilities to rethink their CK into forms that are understandable to students (Esa, 2010). When teachers have conceptual gaps in their content knowledge of a specific topic, the subject becomes unteachable in the classroom. A teacher's CK is an important aspect of teaching (Anyanwu *et al.,* 2015). Learners enter science classrooms with prior knowledge that may or may not correspond to scientific content (Branch *et al.,* 2016). The CK for teaching a socio-scientific topic is irrelevant to the learners' social contexts (Wise, 2010). According to Mc Ginnis et al. (2016), when classroom content is consistent with learners' lived experiences, they develop knowledge and skills to solve problems in their communities.

The CAPS document's goal of developing global citizens with knowledge and skills to solve the conundrum of anthropogenic climate change in their communities will be realized if teachers have good climate change knowledge (O' Donoghue, 2013). This is why I'm researching climate change in my self-study.

### 2.3.4 Topic Specific Pedagogical Content Knowledge

Shulman (1986) defined PCK as "specialist knowledge" used by teachers to make classroom content teachable to students. Teachers' PCK consists of knowledge and skills needed to teach concepts in ways that students can understand. PCK has evolved from a knowledge standpoint that embodies teachers' classroom practices to include the thinking that underpins teachers' teaching (Gess-Newsome, 2015). PCK is specialized knowledge and thinking for teaching that results in meaningful learning experiences for students (Garritz & Villa, 2012). The teacher presents CK that is appropriate for the learners' conceptual models so that they can access concepts in a topic (Nahum *et al.,* 2006).

Shulman classified PCK in 1987 as teachers' knowledge of: (i) subject reconstructions, (ii) learner canonical misconceptions, (iii) what they value as good teaching, (iv) curriculum policy documents, (v) interactions of social contexts in the classroom, and (vi) educational objectives

(Shulman, 1987). To make the content teachable, these PCK components incorporate teachers' knowledge and skills in the classroom. Teachers' professional knowledge and skills (PCK) are a collection of various knowledge and skills that govern teaching activities in specific contexts (Shulman, 2015). The various perspectives from which PCK is observed form a continuum of the construct that is difficult to isolate (Carlson *et al.*, 2015). Teachers' PCK can include dispositions, convictions, and worldviews in their practice as well as knowledge and skills of teaching (Rollnick & Mavhunga, 2014). PCK is a teacher's thinking and actions to transform CK into forms that are appropriate for learning (Gess-Newsome, 2015). The construct of PCK has various dichotomies; however, in this study, my PCK of climate change is the way I think about and execute my lessons when teaching climate change to Grade 11 Physical Sciences students.

Teachers' PCK is focused on a specific topic, and they use it in their daily teaching as specialists (Shulman, 2015). As a result, PCK is not a neutral concept, but is affected by the topic as well as classroom settings (Gijlers & De Jong, 2005). Previous studies to capture and depict PCK have been conducted on key secondary school Chemistry topics such as chemical bonding, stoichiometry, and chemical equilibrium (Mavhunga, 2018). According to Roberts (2011), there is a gap in studies of PCK in socio-scientific topics. A few pedagogical studies show teachers' PCK of socio-scientific topics (Nakedi 2014).

Topic Specific Pedagogical Content Knowledge is a key concept that explains how specific topics are taught (Park & Suh, 2015). The teachers' Topic Specific PCK is a complex construct that necessitates the use of specialized methodologies to depict the teachers' thinking and actions in the classroom (Baxter &Lederman, 1999). In this study, I will refer to my content knowledge for teaching climate change using Topic Specific PCK. Teachers' PCK may develop when they rethink their teaching in order to make content teachable (Loughran, 2010). Gess-Newsome (2015) supports this viewpoint by arguing that teachers can critically rethink their teaching in order to improve their practice. (Gijlers & De Jong, 2005) insists that when teachers reflect on their classroom experiences, their PCK evolves. When teachers reflect on their teaching, they become aware of their students' prior beliefs and concepts that are difficult for them to grasp in the topic (Carlson *et al.*, 2015). As a result, when teachers reflect on their practice, it is critical to examine how they develop their specialized knowledge of teaching a specific topic. The self-study aims to capture and depict the specialized knowledge and skills of teaching climate change, as well as to observe how it shifts throughout the study.

### 2.3.5 Studies of teachers' Pedagogical Content Knowledge of climate change

Climate change is a topic on which science teachers have limited PCK. According to studies, teachers struggle to teach the big idea that anthropogenic CO2 causes increased GHE (O' Donoghue, 2013). Some teachers' classroom content is low order concepts that do not expose students to the complexities of climate change. Simple content in the GHE is commonly taught in secondary school classrooms. Because the graphics are hidden when teaching, the use of diagrams and graphs to explain abstract concepts leads to learner misconceptions. Analogies of abstract constructs to prior concepts of learners may make the content teachable (Branch *et al.,* 2016). When teachers draw on their students' experiences, science concepts become more relevant to their daily lives. When teaching about climate change, it is critical to use analogies that connect to students' everyday lives in order to make abstract and difficult concepts understandable in the classroom.

Climate change is a complex socio-scientific issue that can be resolved by pinning a continuum of anthropogenic activities and their impacts on specific communities (Veron *et al.,* 2016). Certain concepts are difficult for students to grasp due to the intricate intertwining of science, society, and ecology in the topic of climate change. Socio-scientific themes in science education help students understand how science relates to society (Anyanwu *et al.,* 2015). This is evident when classroom structures are linked to learners' daily lives (Wise, 2010). One method is to teach using case studies. Case studies make climate change education more relevant by focusing on a real-world setting affected by anthropogenic climate change (Ward, 2016). The use of a crosscutting view in case studies accounts for specific experiences in various communities and connects to prior experiences of different learners. Case studies of socio-scientific themes and scientific philosophies are useful tools for teaching students scientific reasoning and procedural skills. It is critical to demonstrate the causes of increased GHE and anthropogenic climate change when teaching about climate change. Using historical case studies to map out conceptual models that relate CO2 levels to global temperatures is one way to make socio-scientific themes teachable (Ward, 2016).

Science education that does not emphasize learners' procedural skills in science perpetuates learners' misconceptions about how science works (Veron *et al.*, 2016). Science classrooms conceal the teaching of socio-scientific concepts and procedural skills (Roberts *et al.,* 2011). In science classrooms, there is a lack of instruction in the teaching of scientific constructs, scientific connections with society, and the history of climate science (Roberts *et al.*, 2011). As a result, students develop inadequate knowledge of observations and models of anthropogenic climate change. Climate change concepts are disconnected from authentic experiences of learners in their communities when classroom science content is devoid of the nature of science (Veron *et al.*, 2016). According to Bektas et al. (2013)'s study, some teachers have good CK on scientific tenets but this is not reflected in their teaching. According to Veron et al. (2016), teachers' science activities do not include data handling methods, which are critical skills for developing learners' procedural knowledge.

According to Roberts et al. (2011), knowing the relationships of science to society, technology, and ecology is a key goal in teaching socio-scientific topics. Various scholars believe that teaching social themes in science will develop learners into citizens capable of critical thinking in order to solve ecological problems in communities (Roberts *et al.,* 2011; Veron *et al.,* 2016). This viewpoint, however, undervalues teachers' PCK, which limits content teaching in the classroom. It is my contention that teachers' PCK underpins authentic learning of socio-scientific topics, allowing students to develop knowledge and skills that will help them in their daily lives.

The GHE model, as well as the circuitous causes and impacts of climate change, are difficult concepts to teach (Veron *et al.,* 2016). The improved GHE model is a novel approach to explaining current anthropogenic climate change. According to Bartos and Lederman (2014), some science teachers have incorrect models of NOS, such as the belief that concepts are tentative and change in light of new evidence. When new evidence challenges conventional wisdom, canonical knowledge shifts (De Boer, 2000). As a result, when teaching socio-scientific topics, teachers must understand certain NOS tenets.

Secondary school science teachers may have a high level of NOS knowledge but lack the specialized knowledge required to teach socio-scientific topics such as climate change (Wise, 2010). According to Esa (2010), teachers' poor PCK to teach concepts of climate change consists of incoherent analogies and models. The use of such analogies may reinforce students' misconceptions. There are no cases in the history or philosophy of science taught (Wise, 2010). Teaching for scientific literacy necessitates the use of case studies in order to make science topics more teachable (Bartos & Lederman, 2014; Esme, 2014;). Show the data, observations, models, and conclusions that scientists construct in order to come up with new knowledge in authentic settings in the history of science (Esme, 2014). This type of instruction may make it easier for students to understand the enhanced GHE. To make the concepts teachable, the teachers' CK on NOS must be reworked using specialized teaching knowledge.

Veron et al. (2016) discovered that teaching about climate change is a difficult task. Educators identified one constraint as a curriculum that undervalues the theme of climate change. Nakedi et al. (2012) attribute the lack of socio-scientific themes in secondary school science to curriculum documents that undervalue climate change. Despite the CAPS document's stated goal of science with justice for ecology, climate change is not a topic in Physical Sciences in South Africa (Nakedi, et. al., 2012). As a result, the new CAPS curriculum is devoid of authentic socio-scientific topics that are relevant to learners' daily lives. According to Wise (2010), such curriculum disparities do not promote learners' scientific literacy. Branch et al. (2016) agree with this conclusion, stating that ecological themes provide opportunities for learners to develop scientific skills. My curricula saliency is critical in this self-study to include big ideas of the NOS and climate change when teaching.

### 2.4 The conceptual and analytical framework of the self-study

In this section, I will discuss my study's conceptual and analytical frameworks. The conceptual model is a structure composed of the constructs and ideas derived from my literature in order to make my self-study understandable (LaBoskey, 2004). These concepts are CK and PCK in this study. The conceptual model is applied to the data, resulting in the analytical framework for the self-study (Loughran, Mulhall, & Berry, 2004).

Teachers' professional development is topic-specific, and its value for teaching is critical for classroom practice. The current state of PCK has resulted in a plethora of PCK models in pedagogy to make sense of various teaching experiences. PCK has been studied extensively over the last three decades, with various dichotomies developed to depict teachers' CK for teaching (Mavhunga & Rollnick, 2013). Furthermore, a teacher's PCK is difficult to isolate in their daily practice (Loughran *et al.,* 2004). The LTtP model proposed by Nakedi in 2014 to decipher teachers' PCK in the context of a self-study indicates that a teacher's CK for teaching can develop in classroom settings with the goal of making topics teachable. This self-study is part of a larger project to look into secondary school teachers' use of the LTtP model when teaching about climate change. As a result, the way I portray my PCK of teaching the topic of climate change is based on Nakedi's LTtP model. The adoption of Nakedi's LTtP model stems from the situative idea that a teacher's specialized knowledge and teaching skills can develop through teaching practice.

The LTtP model is a conceptual tool for examining how a teacher's prior and current classroom experience can be reconciled (Nakedi, 2014). The model emphasizes the importance of teachers' pre and post-teaching thinking in developing teaching knowledge. The model categorizes teachers' PCK into knowledge domains, such as knowledge and perspectives, action and practice, and stimulation and challenge. The domain of knowledge and beliefs consists of the teachers' beliefs about good practice. The domain of action and practice encompasses the execution of teaching by teachers. The domain of stimulation and challenge entails collaboration to investigate teaching processes (Nakedi, 2016). When teachers rethink their CK and PCK concepts, there may be visible shifts in their practice (Nakedi, 2014). A reassessment of classroom practice elicits teachers' knowledge in order to make specific topics teachable (Bishop & Denley, 2007).

Curriculum saliency, knowledge of learners' socio-scientific reasoning, knowledge of learners' prior and misconceptions, knowledge of learners' procedural skills, knowledge of content representations, and knowledge of concepts that are difficult for learners are the PCK elements in the LTtP model, according to Nakedi (2014). When teaching climate change to Grade 11 students, the self-study will provide a pre- and post-setting to observe CK and PCK shifts. When teachers are critical of their own classroom activities, they gain knowledge and skills for making concepts relevant in the classroom (Loughran, 2002). In the self-study, my conceptual framework is a modified 'spinning top' of the LTtP model. From the model I took the PCK elements and conceptualized my knowledge, and classroom practice with the object to frame and reframe my knowledge of teaching. From the model these knowledge areas interact to develop more knowledge of teaching.

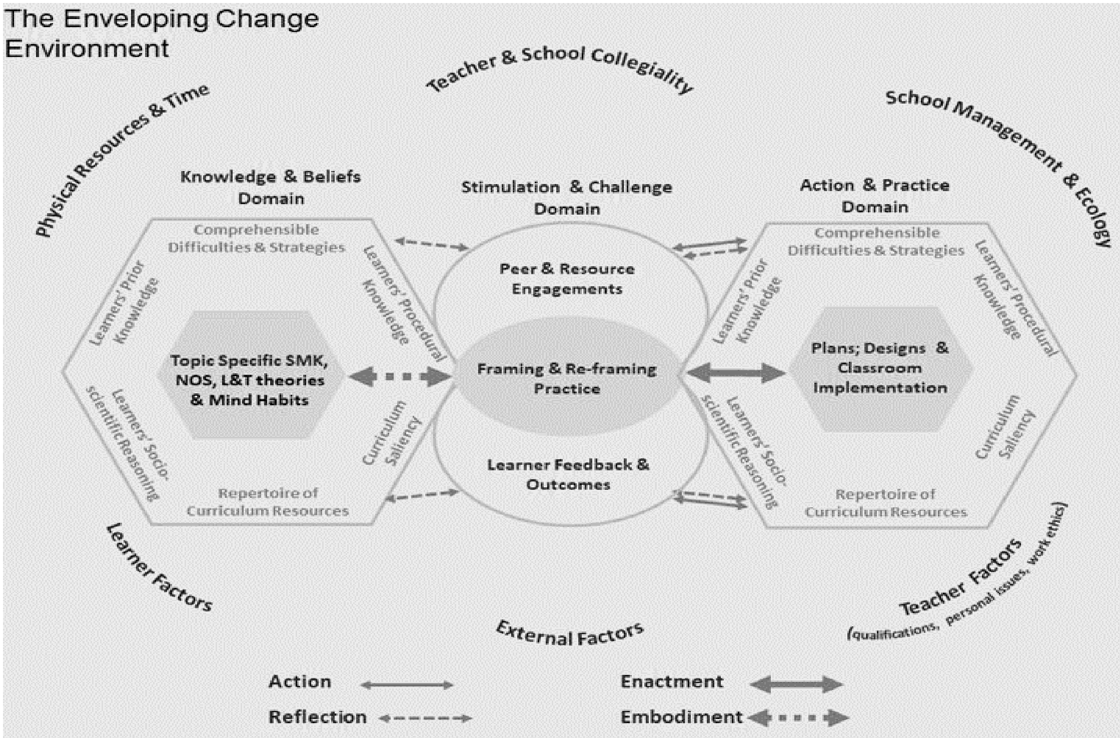



**Figure 2. 1: Conceptual framework of the study**

**Adapted from: Nakedi, M. (2014). Profiling chemistry teachers' changing PCK . In H. Venkat, M. Rollnick, M. Askew, & J. Loughran, *Exploring Mathematics and Science Teachers' Knowledge: Windows into teacher thinking* (pp. 84-95). Oxford: Routledge.**

### 2.4.1 Pedagogical Content Knowledge of Learners' Pre-Conceptions and Misconceptions (LPMCs)

Misconceptions among learners are incorrect ways of thinking about a specific concept that limit the learning of big ideas in a topic (Kind, 2015). Misconceptions among learners are conceptual models that lead to misunderstandings of a specific topic (Carr *et al.*, 1994). According to Duit (2003), misconceptions in science classrooms will impede conceptual change and limit learning of canonical constructs. Learners' beliefs, various texts, and teaching methods are all mentioned as sources of learners' misconceptions by Harrison and Treagust (2002). According to Davidowitz and Chittleborough (2009), teaching scientific models and symbols as discrete units of knowledge causes learners to misinterpret molecular, symbolic, and concrete depictions. For diagnosing learners' misconceptions, science teachers can use exercises, questionnaires, concept maps, interviews, demonstrations, graphics, and pre-tests (Schmidt, 1997). Case studies, according to Taber (2018), are effective classroom tools for exposing and challenging LPMCs of science concepts and NOS. Constructivist science teaching requires teachers to be aware of LPMCs in the classroom so that they can create experiences for students to develop correct scientific conceptual models (Duit, 2003). Pedagogy in science classrooms is determined by LPMCs in order to carry out the lesson in an understandable manner. Teachers use their knowledge of LPMCs to connect scientific concepts to the common sense of their students. When students have naive views of scientific concepts, it is critical to confront their misconceptions so that big ideas can be learned (Von Glasersfeld, 1991). Big ideas are a set of mental models that can be used to challenge misconceptions and make a topic teachable (Mitchell *et al.,* 2017). Teachers' knowledge of LPMCs is critical for identifying the big ideas that students struggle to grasp in a given topic. The teacher can use the learners' prior knowledge to guide the teaching of concepts in the classroom. Intuitive thinking models that contrast scientific concepts are central to learners' misconceptions. The role of teachers in the classroom is to instil in students the discourse of scientific thinking (Scott *et al.,* 1994). NOS teaching tenets assist students in understanding how scientists conduct research. The ability to incorporate NOS into science topics in classroom settings is one method of dealing with students' misconceptions and myths about science (Lederman & Lederman, 2017). Teaching NOS in science topics may help to dispel learners' misconceptions about how science works (Roberts *et al.,* 2011).

### 2.4.2 Pedagogical Content Knowledge of Learners' Socio-scientific Reasoning (LSSR)

Socio-scientific reasoning is a way of thinking that emphasizes science's genuine role in society (Roberts *et al.,* 2011). The LSSR teachers' PCK is knowledge of teaching the complexities of science, society, and ecology. Science topics combined with socio-scientific themes demonstrate how science and society are intertwined (O' Donoghue, 2013). Learning socio-scientific themes may help to develop LSSR because they provide authentic situations in which to examine contentious issues (Roberts *et al.,* 2011). Many science educators have criticized the disconnect between classroom science and learners' social contexts (Stanley & Brickhouse, 1994). Communities have also expressed concerns about the effects of technology on the environment (Mc Ginn & Roth, 1999). As a result, teachers' understanding of LSSR is critical in making classroom science an authentic experience for students. Activities with a socio-scientific theme, such as role plays and case studies, can be used to promote the LSSR (Roberts *et al.,* 2011). Understanding LSSR is important for teaching authentic socio-scientific topics such as climate change. Science teaching through contextual activities increases learners' knowledge and skills to solve community problems (O' Donoghue, 2013).

### 2.4.3 Pedagogical Content Knowledge of Curriculum Saliency (CS)

Curricular saliency refers to a teacher's understanding of major concepts in a topic (Geddis & Wood, 1997). A teacher's CS is the ability to organize concepts in order to make the topic understandable to students. A teacher's CS is their understanding of content concatenations in order to achieve specific teaching objectives (Mavhunga & Rollnick, 2013). The big ideas are the concepts that underpin a learner's understanding of a topic (Malcom, Mavhunga & Rollnick, 2018). Big ideas are scientific statements of a concept(s) with the goal of making a topic understandable to students. Teachers, on the other hand, find it difficult to construct big ideas in science topics (Kind, 2015).

Curricula saliency enables teachers to transform content from generic teaching plans into content tailored to their students' needs (Geddis & Wood, 1997). Teachers' CS is the ability to create lessons that are consistent with the big ideas in a topic (Mavhunga & Rollnick, 2014). This entails reshaping the curriculum to make content learning more understandable to students (Gess-Newsome, 2015). It is preferable for lesson content to reflect big ideas in a topic in order to make it more teachable. Curricular saliency also includes being aware of the contexts in which learners operate. It is critical to be aware of learners' everyday experiences in order to make classroom content relevant to learners' lives (Carr *et al.,* 1994). Because a socio-scientific topic crosses multiple disciplines, teachers' knowledge of CS is critical for making the concepts teachable (Mitchell *et al.,* 2017). As a result, big ideas must underpin classroom instruction. The goal of teaching a topic is for students to grasp the big ideas (Mitchell *et al.,* 2017). Teaching complex socio-scientific topics such as climate change necessitates teachers' ability to connect big ideas from various subjects in order to make the topic teachable. Curricula saliency entails using big ideas as conceptual tools to connect classroom content in ways that promote sound pedagogy (Malcom, Mavhunga & Rollnick, 2018).

### 2.4.4 Pedagogical Content Knowledge of Learners' Procedural Knowledge (LPK)

The use of classroom-talk to develop investigative knowledge and skills is an example of LPK teaching knowledge. Teachers' knowledge of LPK is limited to sharing scientific ideas on the subject (Hennessy, 2016). Dialogue, discussion, debate, and argumentation are common exchanges in the classroom. In this self-study, a dialogue is a conversation between a teacher and a learner, or between a teacher and a learner(s) (Hannan & Abdullah, 2018). A discussion is an interaction between a teacher and students that encourages the exchange of ideas and the achievement of a common goal (Erduran, Simon, & Osborn, 2004). Argumentation is the interaction of presenting simple arguments in the form of assertions backed up by evidence and rebuttals in the form of counter-claims (Larrain, Howe, & Cerda, 2014). These social connections mediate concept learning in the classroom.

The teachers' LPK is critical in teaching climate change because it exposes learners' thinking and causes conceptual change. Teaching the culture of science exposes students to scientific procedures. As a result, understanding how scientific investigations are conducted constitutes LPK in science. Science discourse is not intuitive; it is specialized knowledge for teaching. Teachers' knowledge of LPK entails coming up with big ideas on science concepts (Mitchell *et al.,* 2017). These big ideas make students aware of how scientific knowledge is constructed. One of the specific goals of teaching Physical Sciences in the South African CAPS curriculum is to help students develop their investigative skills in science (DoBE, 2011). While there is a continuum of skills, this study will concentrate on observing, measuring, identifying and controlling variables, interpreting, predicting, and identifying a problem, hypothesising methods of recording results, using scientific models, and drawing conclusions. LPK teaching teaches NOS tenets such as the role of creativity in science and the tentativeness of scientific constructs. The way these aspects of science appear in the teachers' lesson plans and execution is their exposé of LPK.

### 2.4.5 Pedagogical Content Knowledge of Representations, Models, Analogies and Resources (RMAR)

Teachers' knowledge of RMAR is knowledge of teaching with representations that help learners understand the content (Kind, 2015). The Representations, Models, Analogies, and Resources are tools for teaching abstract concepts, making difficult concepts easier to learn, and developing students' conceptual models (Davidowitz & Chittleborough, 2009). RMAR, according to researchers, consists of models, illustrations, explanations, demonstrations, graphics, diagrams, images, metaphors, and analogies (Kind, 2015; Daehler *et al.,* 2015; Gess-Newsome, 2015). Chemical diagrams are used in Chemistry classes to demonstrate molecular, symbolic, and macroscopic concepts (Davidowitz & Chittleborough, 2009). The simultaneous presentation of chemical diagrams aids in scaffolding learners' thinking in specific topics (Davidowitz & Chittleborough, 2009). Authentic content graphics embody unmistakable representations that assist teachers in developing correct scientific models and confronting learners' misconceptions (Kim & Axelrod, 2005). Graphics include graphs, pictures, and charts that help learners understand the teaching content (Locatteli *et al.*, 2010). Representations assist students in developing thinking models to explain concepts in a topic (Taber, 2018). The mapping of models in diagrams and analogies must be correct in order for learners to construct sensible scientific concepts and minimize misconceptions (Locatteli *et al.,* 2010).

### 2.4.6 Pedagogical Content Knowledge of Topic Comprehensible Difficulty (TCD)

Teachers' knowledge of TCD includes knowledge of learners' difficulties conceptualizing concepts as well as teachers' mediation to facilitate access to these concepts (Kind, 2015). TCD for teachers' entails noting concepts that perplex students, anomalies in content, scientific concepts that appear to contradict common experiences, the continuum of different contexts, and abstract concepts (Loughran, 2015). Difficult-to-learn concepts must be understandable in order for students to comprehend a topic. The use of big ideas connects concepts in a topic and makes difficult concepts more teachable (Kind, 2015). Difficult concepts may render the subject unteachable (Gess-Newsome, 2015). When difficult constructs are understood in the classroom, I believe that using teachers' TCD knowledge may lead to conceptual change in learners. TDC knowledge for teachers is about executing good teaching to resolve difficult concepts and make them understandable to students (Mitchell *et al.,* 2017).

## 2.5 Conclusion of Chapter 2

In Chapter 2, I described my study's theoretical foundations as situative cognition and cognitive constructivism. I researched the CK and PCK of climate change in the literature. The conceptual and analytical models for socio-scientific topics in the context of self-studies are based on an adopted Nakedi's LTtP 'spinning top' model of PCK. The methodology of the study is covered in Chapter 3.

**CHAPTER 3:**

## RESEARCH METHODOLOGY

### 3.1 Introduction

The methodology is the method used to collect and analyze data in order to provide solutions to the study's questions (Opie, 2004). Overall, this self-study employs a qualitative methodology. There are, however, sections that employ a quasi-quantitative approach. My research is based on the constructivist philosophy of new knowledge that is co-constructed through various forms of shared experiences. The methodology is summarized in Chapter 1 section 1.7. However, in this chapter, I will go over the sections of the research methodology that are I research design, (ii) study participants, (iii) research instruments, (iv) data analysis, (v) credibility, and (vi) ethics in greater detail.

### 3.2 Research design: Self-study

This study looks into my CK and PCK for teaching Grade 11 students the Chemistry of climate change. Qualitative methodologies can be used to investigate a teacher's CK and PCK (Hadiyanti *et al.*, 2015). My research methodology for building a case of my CK and PCK is self-study. Self-studies aim to be critical of current knowledge and to develop models of good practice based on self-investigation (Crowe, 2010). The argument is that teachers are qualified subjects to study their profession and classroom practices because they are specialists (Watson, 2013). According to research, self-study improves teachers' teaching and learning competencies by providing them with authentic knowledge and skills in their field (Samaras & Freese, 2006; Lunenberg *et al.,* 2010; Watson, 2013). Self-studies are useful in pedagogy because they allow teachers to capture and present their own PCK (Lunenberg *et al.*, 2010). When teachers examine their own teaching, they may improve their PCK in specific areas (Loughran, Berry, Mulhall, & Woolnough, 2006).

#### 3.2.1 The self-study as a research methodology

Self-study in pedagogy is based on the learning of various teaching experiences from one's own experiences (Watson, 2013). Self-study has been shown in studies to improve teachers' classroom skills in order to make content more understandable for students (Samaras & Fresse, 2006; Lunenberg *et al.,* 2010; Watson, 2013). This establishes self-study as a valuable pedagogical tool for developing teachers' CK and PCK (Lunenberg *et al.*, 2010).

Teachers are viewed as reflective practitioners in their classrooms, according to self-studies (Hamilton & Pinnegar, 2000). Critical reflection enables teachers to question common assumptions in their practice (Loughran, 2015). According to studies, self-study research in classroom teaching depicts specialized knowledge for teaching (Hamilton & Pinnegar, 2000; Lunenberg *et al.*, 2010; Watson, 2013). Teaching is a complex practice that combines PCK elements for effective classroom experiences. Teaching self-study is a tool for characterizing teachers' classroom practices (Hamilton & Pinnegar, 2000). When teachers reflect on bodies of knowledge that guide their teaching, authentic teaching knowledge and skills emerge in situ, within classrooms (Loughran, 2002). Continuous rethinking of one's classroom experiences is essential in teaching and validates self-studies as a useful pedagogical methodology.

**3.2.2 Characteristics of a self-study**

A pedagogical self-study can be divided into five processes: I the teacher objectively investigates their own practice; (ii) continuous reflection on classroom incidents; (iii) critical knowing of the thinking that underpins teaching; (iv) various classroom settings; and (v) confrontation of dogma in common practice (Samaras & Freese, 2006).

In more detail:

a. A pedagogical self-study involves a teacher examining their teaching experiences (Loughran, 2002). The goal of self-investigation is to use teaching experiences to create content that is more appropriate for specific classrooms (Loughran, 2002). This self-study investigates my efforts to translate climate change content into more understandable concepts for students.

b. A self-study is a series of reflections in which the teacher rethinks prior and current classroom experiences with the goal of developing knowledge and teaching skills (Loughran, 2002). The teacher is conscientious of viewing both the CK and PCK as long-lasting but tentative constructs that can be revised (Samaras & Freese, 2006). Teachers' knowledge of teaching may diverge from common practice knowledge (Loughran, 2002). In self-study, reflections aid in deciphering the intricate underpinnings of classroom pedagogy (Samaras & Fresse, 2006).

c. Self-studies entail the application of teaching knowledge and skills in a variety of classroom settings. A self-study attempts to depict the thinking that underpins teachers' classroom activities (Samaras & Fresse, 2006). The self-study represents a shift from an intuitive to a more critical approach to teaching (Lunenburg *et al.,* 2010). This will assist teachers in becoming more aware of their professional knowledge (Lunenberg *et al.*, 2010).

d. A self-study is a story about one's own teaching experiences in a specific situation. This self-study tells the story of how I taught the chemistry of climate change to Grade 11 students. A self-study methodology is one in which teachers investigate their specialized knowledge for teaching purposes (Watson, 2013). Self-studies assist teachers in conceptualizing their teaching experiences in a given topic (Watson, 2013). The gap between teaching concepts and authentic practice narrows in self-study because knowledge and skills are gained through practical experiences (Samaras & Fresse, 2006).

e. Self-study in pedagogy stimulates thinking that challenges teachers' prior knowledge and teaching skills. The teacher serves as both an instrument and an observer in order to portray their teaching experiences. A community of practice validates the observations and lends credibility to the self-study. 2010; Lunenburg et al. As a result, it is critical for other experts to check the teacher in the study. This is the function of collegiality in self-study (Samaras & Fresse, 2006). The study's activities are confirmed by teacher specialists in the community of practice.

### 3.2.3 My justification of self-study

I chose self-study because I believe it allows teachers, as pedagogical specialists, to study their own practice by reflecting on their own experiences as custodians of the profession. This point of view stems from the situative viewpoint, which emphasizes knowledge construction through authentic experiences and practices. Section 2.1.1 of Chapter 2 contains an earlier discussion of the situative viewpoint. As a result, it is prudent for teachers and educators to investigate their own classroom activities. Self-study is a method for acquiring specialized knowledge and practice skills. According to Ball (2000), a teacher develops authentic knowledge and skills of their profession through classroom experiences. I agree with this line of thought and believe that it is critical for teachers to be critical and systematic in their own teaching.

## 3.3 Study's participants

The teacher researcher is the main participant in the study. In this self-study the unit of analysis is the teacher-researcher's understanding of climate change constructs and teaching practice. My objective is to observe my pre- and post- CK and portray my specialized knowledge of teaching the topic of climate change. The study was conducted at Sandtonview School with Grade 11 learners doing Physical Sciences. My colleagues are my critical pals; they are scientific educators with more than two decades of expertise. Colleagues are chosen for participation based on their expertise in scientific education. The table 3.1 below summarizes my credentials and areas of competence, as well as the collegiality.

**Table 3.1: Summary of the teachers' details in the self-study**

| Code of participant | Qualifications/ Current studies | Teaching Subjects |
|---|---|---|
| Self | Honours Degree in Science Education/ Masters in Science Education | Physical Science, Mathematics and Natural Sciences |
| Teacher A | Science Education Honours Degree/ PhD | |
| Teacher B | Science Education Honours Degree | |

The Grade 11 class in the self-study is made up of students from a variety of social backgrounds and with a range of intellectual abilities. This variety of learners is crucial in the research because it enables me to comprehend the many socio-scientific perspectives on climate change held by members of various socioeconomic groups. The role of learners in this study is to serve as a point of reference for the teacher-researchers' comprehension and practice.

### 3.4 Research instruments

Pre and post concept maps were used to capture and represent my CK. Pre and post CoRes, PaP-eRs, teachers' reflective journals, and teaching artefacts capture and display my PCK. The transcripts for the lessons are taken from audio recordings. The recordings document my classroom teaching activities. Loughran et al. developed the CoRes and PaP-eRs as pedagogical tools (2004; 2006). Good teaching stories conceived from critical reflections in teachers' journals provide an account of PCK in a specific topic (Hiebert et. al., 2002). Various instruments triangulate the data to increase the study's trustworthiness (Henze & Van Driel., 2015).

#### 3.4.1 Concept maps

Concept mapping is an educational tool that depicts how teachers intertwine concepts to make them teachable to students (Primo & Shavelson, 1996). A concept map depicts the big ideas that make a topic meaningful (Roth & Bernhardt, 2016). The constructs are organized into conceptual units, which are made up of concepts and linking words (Haugwitz *et al.,* 2010). The teaching of big ideas makes a topic more understandable to students in the classroom (Primo & Shavelson, 1996). Concept maps depict the teachers' CK that may result in conceptual change in students (Novak, 2010). The self-study necessitates a critical examination of my CK for the purpose of teaching the topic of climate change. I looked at the CAPS document for Physical Sciences to help me develop my climate change content. My thinking is to build big ideas from the curriculum document's objectives.

Teachers can use concept mapping to confront students' misconceptions and develop scientific ways of thinking (Kwen, 2001). They connect concepts from a topic in a clear manner (Gess-Newsome, 2015). Concept maps display teachers' content knowledge in order to develop scientific models on a specific topic (Novak, 2010). The ability to grasp big ideas is an indicator of a teacher's CK. As a result, concept maps capture and depict the teachers' CK (Haugwitz *et al.,* 2010). In pedagogy, concept maps show the teachers' knowledge of a topic (Schwendimann & Linn, 2015). Concept maps reveal the conceptual knowledge of teachers on a specific topic (Haugwitz *et al.,* 2010). Concept mapping depicts what teachers consider to be sensible constructs when teaching about climate change (Mc Clure & Bell, 1990). Concept maps assist teachers in understanding critical concepts that students use to access content in a topic. The creation of pre and post concept maps is a tool for observing teachers' CK shifts in a specific topic (Haugwitz *et al.,* 2010). The teachers' changing conceptual knowledge is depicted by pre- and post-concept maps (Schwendimann & Linn, 2015). The pre- and post-concept maps capture and depict CK shifts in teaching Grade 11 students the Chemistry of climate change.

#### 3.4.2 Content Representation (CoRe)

Teachers' PCK is a difficult concept to capture and depict. However, CoRes and PaP-eRs are two of the tools that have been used in many pedagogical studies to capture the specialized CK for teaching (Loughran et al., 2006). The PCK construct is difficult to observe, and teachers find it difficult to express this tacit construct. This has resulted in the development of various instruments for capturing and displaying PCK in specific settings (Gunstone, 2015). Loughran and his colleagues created the CoRe to capture teachers' PCK (Loughran et al., 2006). CoRes documents and displays teaching experiences in a specific topic (Rollick et al., 2008). Teachers' specialized knowledge that underpins classroom practice is modelled by CoRes (Loughran et al., 2006). Pre and post CoRes demonstrate how teachers' PCK shifts when teaching (Hadiyanti et al., 2015). A look at the pre and post CoRes demonstrates how teachers develop skills to convert content into teachable forms (Demirdogen et al., 2015).

A CoRe is made up of rows and columns that intersect with a big idea prompt (Demirdogen et al., 2015). The answers to the question(s) in the eight prompts allow the teacher to express their teaching knowledge (Gess-Newsome, 2015). Figure 3.1 depicts the format of a CoRe in appendix-8. The CoRe is a useful template for portraying teachers' PCK on a topical level. The limitations of a CoRe are that it is a complex tool that requires teachers to have CK in order to construct it properly, and it is topic and context specific (Loughran, 2010). The CoRe depicts my specialized knowledge for teaching the topic of climate change in this study. A CoRe template is depicted in Figure 3.1.

| **The CoRe is for grade 11 learners** **Topic: Chemical Systems** **Subject: Physical Sciences/** **Prompts** | **IMPORTANT SCIENCE CONCEPTS** | | |
|---|---|---|---|
| | **A:** | **B:** | **C:** |
| 1. What you **intend** the students to learn about this idea | | | |
| 2. Why it is **important** for students to know this. | | | |
| 3. What **else** *you* know about this idea (that you do not students to know yet) | | | |
| 4. Difficulties/ limitations connected with teaching this idea. | | | |
| 5. Knowledge about students' thinking which influences your teaching of this idea | | | |
| 6. Other factors that influence your teaching of this idea | | | |
| 7. Teaching procedures (and particular reasons for using these to engage with this idea) | **Probes of students' understanding:** | **Prediction-Observe- Explain** | **Translation activities:** |
| 8. Specific ways of ascertaining students understanding or confusion around this idea (include likely range of responses) | | | |

**Figure 3. 1: A snapshot of the template of a Content Representation (CoRe)**

### 3.4.3 Professional and Pedagogical- experience Repertoires (PaP-eRs)

The PaP-eRs are narratives of critical parts of the lesson that depict a teacher's combination of PCK elements (Loughran *et al.*, 2006). A PaP-eR shows how PCK elements interact to alter learners' thinking models about specific concepts in a topic. They are critical points in the lesson where PCK elements become visible in order to make classroom content understandable to students. The PaP-eR is a story about the most important parts of the lesson where PCK elements help learners understand the content. The disadvantage of PaP-eRs is that they take a long time to build (Loughran, 2010). In this study, I created PaP-eRs from transcripts of the audio recordings of the lessons.

### 3.4.4 Reflective journal

In a self-study, teachers' reflections are an important source of data (Holt, 2003). The journal entries describe episodes of teachers' classroom activities with the objective of causing conceptual change in learners. The reflective journal of teachers documents conceptual change strategies, teaching methods, and the teachers' thinking while teaching (Cochran-Smith & Lytle, 2004). Teaching journals contain information that serves as the foundation for teachers' specialized knowledge when teaching a specific topic. Teachers' journals depict knowledge and skills in classroom executions in order to make content more appropriate for learners (Gess-Newsome, 2015). A teachers' journal can also be used by other teachers to reflect on specific teaching techniques. My journal in this study is an account of teaching about climate change. Appendix-11 contains excerpts from my reflective journal.

### 3.4.5 Teaching artefacts

Teaching artefacts are various teaching tools that assist the teacher in making the content understandable to students (Holt, 2003). The goal of the teaching tools is to assist learners in developing correct scientific models of thinking and minimizing misconceptions in topics (Garritz & Villa, 2012). A teaching tool can take many forms and help students develop critical and problem-solving skills, higher order thinking, and correct conceptual models in a positive way (Appamaraka *et al.*, 2009). Worksheets, class exercises, projects, and case studies were used in this study to make climate change a teachable topic.

## 3.5 Data analysis

Data analysis is the method(s) used to convert raw data into a useful form that can be used to answer study questions (Putton, 2004). Text descriptions may be used in self-studies to describe themes and concepts of specific concepts (Coia & Taylor, 2009). Text descriptors are data analysis tools that are organized into predefined categories (Creswell & Creswell, 2017). The story of my CK and PCK for teaching the Chemistry of climate change is told through text accounts of their experiences in this self-study.

### 3.5.1 Data analysis in concept mapping

My CK in the topic of climate change is depicted through the analysis of concept maps. To evaluate my pre and post concept maps, I used a concept map rubric in appendix-13 with five pre-set categories. A concept map rubric is a tool for scoring concept maps before and after they are created (Haugwitz *et al.*, 2010). Spider charts are used to plot the scores (Haugwitz *et al.*, 2010). The text descriptors of the rubric's five categories provide an in-depth analysis of my CK in the topic. I compared the scores of the pre and post concept maps to assess the change in my CK.

### 3.5.2 Data analysis in Content Representations (CoRes)

The pre and post CoRe analysis is done with comparative text descriptors to give meaning to the differences between the answers that I gave to the specific prompts. Prompts activate the teachers' thinking on specific big ideas and portray the teachers' professional knowledge. Table 3.2 displays the PCK that comes out of prompts on specific big ideas of my plans to make the content of climate change teachable.

**Table: 3.2 shows how my PCK elements manifest in the Content Representation (CoRe)**

| **Prompt** | **The PCK it captures and portrays** |
|---|---|
| 1. What you intend the learners to learn about this idea? | CS |
| 2. Why it is important for learners to know this? | CS |
| 3. What else *you* know about this idea (that you do not want learners to know yet)? | CS |
| 4. What are the difficulties/ limitations connected with teaching this idea? | TCD |
| 5. What is your knowledge about learners' thinking which influences your teaching of this idea? | LPMCs |
| 6. Are there any other factors that influence your teaching of these ideas? | RMARs, LSSR and NOS |
| 7. What are your teaching procedures (and particular reasons for using these to engage with this idea)? | RMARs, LSSR and LPK |
| 8. Specific ways of ascertaining learners' understanding or confusion around this idea (include likely range of responses) | LPMCs<br>RMARs |

The prompts excite answers on the specific big ideas thereby exposing my thinking and actions in the classroom. The differences in my pre and post CoRe will portray the shift of my PCK.

### 3.5.3 Data analysis in PaP-eRs, journals and teaching artefacts

Using text descriptors, I examine data from PaP-eRs, teachers' memoirs, and teaching artefacts to support any shifts in my CK and PCK. The LTtP model's pre-set categories of PCK serve to draw out specific PCK elements in this study. The data is decoded using the LTtP model's six pre-set categories of PCK elements. According to the LTtP model, PCK consists of teachers' knowledge of LPMCs, LSSR, CS, LPK, RMARs, and TCD (Nakedi, 2018). I will use PaP-eRs to identify specific points where various PCK elements overlap in order to analyze critical parts of teaching. My reflection journal contains my thoughts on these points in the PaP-eRs. My supporting evidence of classroom activities will be the various teaching artefacts in the lessons.

### 3.6 Credibility and trustworthiness

The triangulation of data sources and analysis in qualitative studies increases the research's credibility (Opie, 2010). The use of more than one tool in data collection on a specific topic is referred to as triangulation (Park & Suh, 2015). Various tools are used to capture and display the elicit PCK in a more credible manner (Kirschner, 2015). Data collected from concept maps, CoRes, teachers' journals, and teaching tools depict data triangulation and minimize instrument limitations. In self-studies, the use of multiple data collection tools to isolate and display the teachers' PCK is appropriate

(Carlson *et al.,* 2015). Multiple PCK measures provide a more comprehensive picture of teachers' professional knowledge in a specific topic (Park & Suh, 2015).

In self-studies, self-reflection and social connections with other specialists are essential (Lunenburg *et al.,* 2010). Collegiality serves as a critical friend and helps to consolidate the study's thinking and observations (Lunenburg *et al.,* 2010). A community of practice provides diverse perspectives and lends credibility to self-study (Watson, 2013). Other specialists may certify the self-study observations and findings (Samaras & Fresse, 2006). Social interactions where best practices can be learned are essential for self-study (Lunenburg *et al.,* 2010). In this study, my community of practice consists of my school colleagues and supervisors. The classroom associates can observe the teacher's experiences in the self-study, so the study is not limited to the teacher's dispositions. The collegiality aids in shaping the self-study in a credible manner (Coia & Taylor, 2009). When teachers discuss pedagogy, they share knowledge in order to improve their own classroom practice (Daehler *et al.,* 2015). Because I was vulnerable to the community of practice, the collegiality made the self-study objective. There is an individual and collective lens for viewing the self-study more authentically. Reflection of practice with other teacher specialists is ingrained in good teaching (Heller & Wong, 2015). This claim is based on the belief that through their collective experiences, teachers can gain knowledge and skills in teaching complex science topics (Bishop & Denley, 2007). Social exchanges in this self-study develop an awareness of the difficulties in teaching the topic of climate change.

The collegiality graded the concept maps and provided feedback on my previous classroom experiences. The collegiality in self-study provides a forum for critical reflection. The critical friends created their own reflective journals based on their observations of the lessons. When the collegiality is critical of the study's outcomes, group validity is realized (Kirschner *et al.,* 2015). Observations and results in self-studies are reliable when observers reproduce tolerable results relative to each other.

### 3.7 Compliance to ethics

The self-ethical study's standards are compatible with those established by the university's ethics committee. I obtained authorization to conduct the research from the Department of Education (see appendix-3). I was approved an ethical clearance certificate in appendix-2 authorizing the collection of data from participants. I have permission, anonymity, privacy, security, and confidentiality documentation to demonstrate that I respected the rights and dignity of instructors and students who participated in the study. When a research involves individuals of interest, they should not be exposed to unjust treatment, annoyance, fear, or loss (Cohen *et al.,* 2003). I performed the research with candour, honesty, and a strong moral compass. I addressed a letter to the Principal in appendix 4 requesting permission to do my study at Sandtonview School. Consent letters from parents in appendix 5 granted me permission to conduct my research with the learners.

### 3.8 Snapshot of the methodological process

The steps in figure 3.2 is a view of the critical stages of my methodology viz; data collection, a synopsis of the findings and the way to analyze to the data. Various tools for data collection and the data analysis are sorted in graphs, tables and text descriptions.

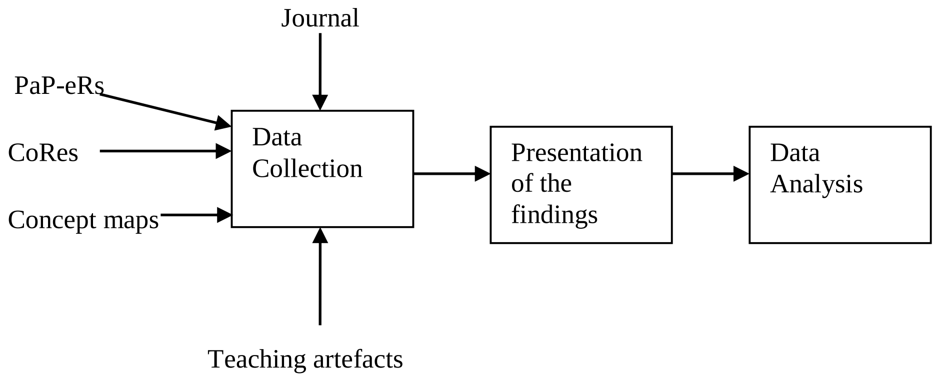



**Figure 3. 2: An overview of the methodology in the self-study**

### 3.9 Conclusion of Chapter 3

Chapter 3 has looked at how I validate the methodology of a self-study and in Chapter 4 will display the finding of the self-study and a critical look at the data to find answers to the 3 research questions in Chapter 1 section 1.6. The methodology of the self-study looked at the procedures and instruments for data collection and analysis as well as data triangulation and the ethics in the self-study.

**CHAPTER 4**

# THE RESULTS, ANALYSIS OF DATA AND DISCUSSION

## 4.1 Introduction

The objective of this chapter is to map out the data to the research questions in the study. The self-study chiefly makes use of text descriptions coupled with some quantitative calculations to analyze the data. Text description is a qualitative tool to describe and explain my specialized knowledge and skills in teaching. The pre and post concept maps capture my CK of climate change and the pre and post CoRes, PaP-eRs, journals and teaching tools capture and portray my PCK elements in pre-set categories of the LTtP model.

## 4.2 Results and analysis of my Content Knowledge in climate change

My first research question seeks to know how I portray my CK of the topic of climate change. The result from the pre and post concept mapping portrays my CK in the form of key concepts that I think make the topic of climate change teachable to Grade 11 learners. I will first look at my prior mapping, secondly the post concept mapping, and lastly the differences between the two maps. The differences in concept maps characterize my shifting CK in the self-study.

### 4.2.1 My prior Content Knowledge in climate change

I constructed the pre concept map from reading the CAPS curriculum document for Grade 11 Physical Sciences. The main concepts in the pre concept map that connect to the curriculum are the Greenhouse gases and global warming.

**My reflection:** My thinking at the beginning of the study, looking at the CAPS document was that the content for teaching climate change was taken at face value. What I mean by this is that the content is inadequate for learners to develop meaningful knowledge and skills in this critical topic. The expectation from the CAPS document is to cover the content in the prescribed time to prepare learners for the common provincial examinations with no consideration of the various contexts and in which teaching takes place in specific schools. The education district directors, subject facilitators and heads of departments expect good curriculum coverage which is always a difficult exercise to execute. This situation creates a mechanistic classroom and constructive pedagogy is minimized due to time and contextual constraints. I see myself as a teacher that promote rote learning, drilling concepts into learners to meet the coverage deadlines and minimum pass mark of 30% so that I can have a 100% pass rate. In this conundrum I wonder what content my learners would have understood in the classroom for life-long learning and what scientific knowledge and skills they have to solve problems in their communities. The topic of climate change is not explicit in the Physical Science CAPS document. I realized then it is critical to interpret the curriculum objectives and the topics for classroom purposes. The CAPS document is clear in its outcomes to develop learners with knowledge and skills of ecology and scientific literacy. On this basis climate change is a critical socio-scientific theme but its content on climate change is limited. This made me realize that there was a mismatch between the bigger outcomes in CAPS document and the objectives at the topic of Chemical Systems at Grade 11.

I constructed the pre concept map from the objectives in the CAPS document at a topical level. Below is my pre concept map that portrays my thinking of what concepts are critical when teaching the topic of climate change.

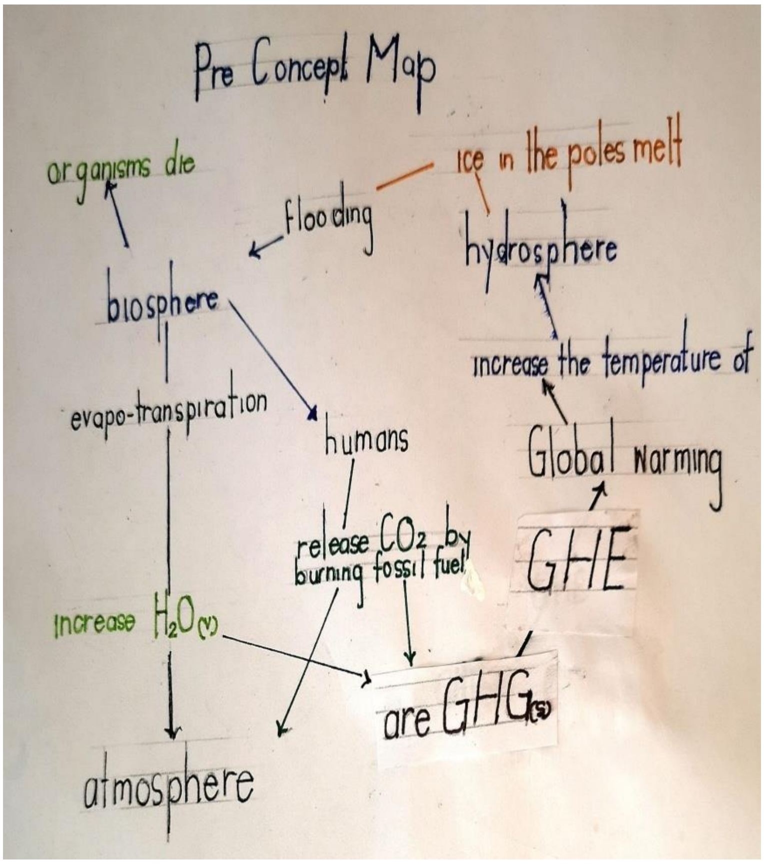



**Figure 4. 1: is my Pre Concept Map**

### 4.2.2 The Framing and Re-Framing of my Content Knowledge

The post concept mapping portrays my CK that constitutes more than the concepts in the CAPS document and includes key concepts that I think make the socio-scientific topic of climate change more teachable to learners. My thinking was underpinned by reading various texts and my own classroom experiences.

> **My reflection:** A further look at the other CAPS documents of related science subjects (Life Sciences and Geography) showed me that climate change is a cross-cutting theme. It was however, important for this self-study to include elements of Physical Science especially the Chemistry of climate change. From various readings I found that the curriculum may be reset so that specific teaching objectives are met in the classroom. This understanding is deep-rooted in my convictions of what I see as most suitable CK for teaching to develop knowledge and skills in learners for them to understand a topic.

The CAPS curriculum for Physical Sciences in Grade 11 has states that it seeks to develop learners' thinking of the world as a community that may solve problems as a collective, and care for the global ecosystem. While the curriculum's principles and objectives are clear in terms of the ecological state, I observed a lacuna in the content and concepts at the topical level with regards to ecological concepts. A critical socio-scientific theme of climate change was vague at the topic level in the section of Chemical Systems. The concepts are burning fossil fuels without a look at how the science, society and ecology interconnect in anthropogenic climate change. This was a problem for me. The content of climate change is limited to the burning of fossil fuels without conceptual models of the intricacies in the history of anthropogenic climate change. I contend that this conceptual space leads to rote learning of the impacts of burning carbon fuels without an understanding of the key concepts that underpin the topic. This incongruity is evident in the general objectives of the curriculum that show the inconsistencies of CAPS curriculum document. The objectives are minimized in the classroom content.

> In sub-section (d) it states that the National Curriculum Statement from Grade R-12 sets out to produce learners that are able to "use science and technology effectively and critically showing responsibility towards the ecology and health of others" (DoBE, 2011)

The content set out in Physical Sciences for term 4 in Grade 11 is Chemistry (Chemical Change). The topic where content of climate change is disclosed is "Exploiting the lithosphere" and says that learners must be able to:

> "Describe the consequences of the current large scale burning of fossil fuels; and why many scientists and climatologists are predicting global warming" (DoBE, 2011).

This reflects a retraction of climate change content in the science classroom relative to the curriculum objectives. However, from the readings on the CK of climate change at secondary school various scholars viz; Anyanwu *et al.,* 2015; Branch *et al.,* 2016; Veron *et al.,* 2016; O'Donoghue, 2013 and Wise, 2010, I discovered that the topic of climate change demanded three critical topic objectives to match the CAPS curricula objectives. These objectives led me to develop my own content for the Grade 11 learners. My lesson objectives are that; learners must be able to describe the causes of anthropogenic climate change, explain the chemistry of climate change in terms of the GHE model and discuss the impacts of climate change. These three objectives shaped the concepts in my post concept mapping. My thinking was to produce big ideas to make the intricate socio-scientific topic of climate change more teachable. Table 4.1 display the main concepts derived from my topic objectives.

**Table 4.1: Shows my key concepts for teaching the topic of climate change**

| **Topic teaching objective;** | **Key concepts for teaching anthropogenic climate change** |
|---|---|
| (i) describe the causes of anthropogenic climate change; | • carbon fuels are an economic driver for many communities<br>• anthropogenic $CO_2$ as product of combustion reactions of fossil fuels |
| (ii) explain the chemistry of the enhanced GHE model | • Greenhouse gases are released from human activities<br>• Enhanced GHE is a model to explain current climate change<br>• Scientific claims are tentative and may change in light of new evidence |
| and (iii) discuss the impacts of climate change | • Global warming decrease the global biodiversity<br>• Climate change has negative impacts on the livelihoods of people in various communities |

In the literature there is mention of main concepts that are critical in teaching and learning of climate change. I decided to use the key concept to frame my topic because I thought that my learners would need this type of knowledge so that the topic of climate change is more sensible for them. The use of key concepts is stressed as a more constructive way to sort out content to make a specific topic more teachable to learners. If key concepts are comprehensible to learners, they will find the topic more understandable. I used the key concepts as templates to construct my post concept map. This conceptual teaching tool was a driver in shifting the way I understood content in a topic. My understanding of climate change content is portrayed in figure 4.2.

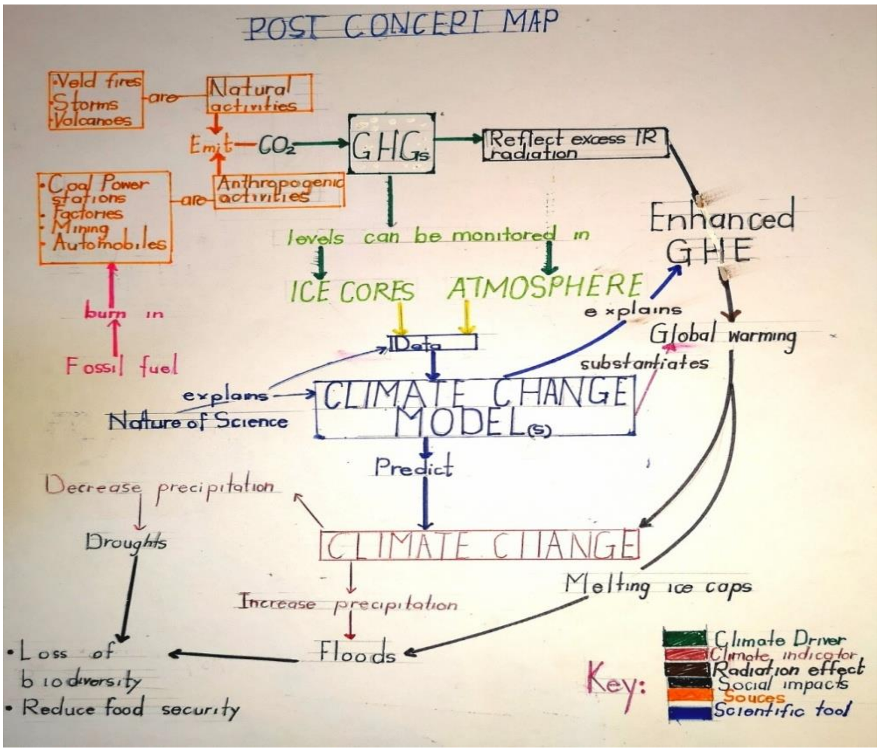



**Figure 4. 2: is my Post Concept Map**

**Reflection on my concept mapping:** The construction of concept maps was not without its own difficulties. My prior understanding of concept mapping was synonymous to a mind map whose function is to portray important concepts in the topic directly from the curriculum document. This was the way I portrayed my CK in the pre concept map. It is my observation that this prior understanding of concept mapping and the concepts of climate change was naïve. My prior thinking was just to use climate change concepts in the CAPS document. When I started to read various literature on concept mapping and climate change my knowledge of the role of concept mapping in teaching and learning and my understanding of the intricate concepts in a socio-scientific topic of climate change shifted. I realized that my prior concept map portrays limited CK of climate change. My learning experience from pre and post construction of concept maps was that the teaching profession demands continuous studying to develop new knowledge and skills that suite specific contexts to make classroom content teachable to learners. It is critical to shape shift the content to suit specific classroom settings and teaching objectives. As a Physical Science teacher with a decade of teaching experience a teacher must still be open to learning to add to what I would term experiential CK gained in the profession over time. The experiential CK came from the CAPS training workshop, studying the Grade 11 textbooks and past examination papers and memorandums, examination reports and teaching different learners. The research however, demanded the study of science educational texts that include journal articles and textbooks on pedagogy and climate change. The literature in these texts was a source of CK with detailed descriptions of teaching and learning climate change in diverse contexts. This was critical to develop my CK of climate change.

### 4.2.3 My Content Knowledge shifts observed in concept maps

My post concept mapping is more sophisticated compared to my prior concept map. This reflects that there are specific things that lead to my shifting CK in climate change that is portrayed from pre to post concept mapping. I constructed pre and post concept maps to observe the CK that constitutes my thinking of key concepts to make the topic of climate change teachable to Grade 11 learners. To quantify my observation, I used a concept map rubric in appendix-13 to score the pre and post concept maps. This would give me a measure of the CK in the concept maps. To substantiate my scores, my colleagues also scored the concept maps. Teacher A and B scored the concept maps and the average scores were tabulated and the plotted into a graph. The concept map rubric was a tool that I used to assess my CK of climate change portrayed in the concept maps and the collegiality to validate the scores. This exercise was part of my own personal growth in CK of climate change. The rubric to assess the concept maps has pre-set categories of CK that constitute concepts, groupings, hierarchy, branches, and propositions. Figure 4.3 show a summary of the pre-set categories in the concept rubric.

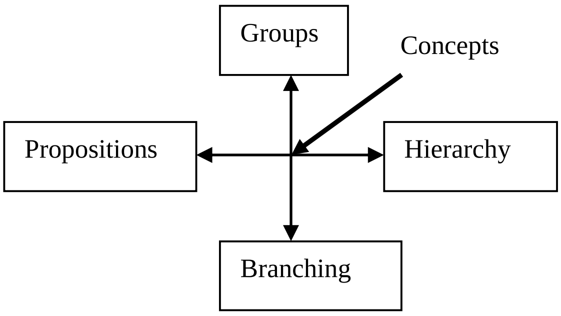



**Figure 4. 3: A diagram of the main concepts in the concept map rubric.**

The scores measure my CK in climate change concepts in the four criteria set in the rubric. The final scores are from me and the colleagues on pre and post concept maps. From the multiple score the average was calculated to give a more reliable score of my CK. Thus, my colleagues were involved to authenticate my observations in concept mapping. The average score sheet of the pre and post-concept maps are shown in table 4.2.

**Table 4.2: Show the average scores of pre and post concept mapping.**

| **Concept map** | **Category** | | | | |
|---|---|---|---|---|---|
| | Concepts | Grouping | Hierarchy | Branching | Proposition |
| Pre-Concept Map | 4 | 7 | 3 | 4 | 17 |
| Post-Concept Map | 10 | 17 | 8 | 9 | 30 |

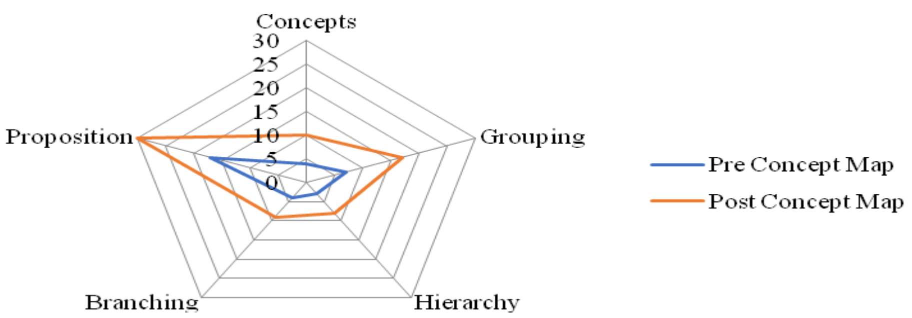
The average scores in the pre and post concept maps are different. Comparing the pre and post averages it may be seen that the post concept map average is higher than the pre-concept scores. The large standard deviation of the pre and post concept map shows the variance of pre to post concept mapping. The data in the table 4.3 indicate that there is an increase in my CK due to the average difference of ~ 8 between the pair of scores in each category. This means that the difference in the mean values of the pre- and post-concept maps cannot be due to random statistical chance. The difference of my concept mapping scores from pre to post mapping construe that at the end of the self-study there is an increase in my CK for teaching the Chemistry of climate change to Grade 11 learners. The post concept map portrays gains in average knowledge of my CK. The consistent increases in the scores of post concept maps show a more compact model of my CK for teaching the topic of climate change. Table 4.3 depicts the various statistical parameters in the pre and post concept maps.

**Table 4.3: A table of comparison of the statistical analysis between the pre and post concept maps**

| | **Pre** | **Post** |
|---|---|---|
| **Mean** | 7.0 | 14.8 |
| **SD** | 5.79 | 9.20 |
| **SEM** | 2.59 | 4.12 |
| **95% CI of mean** | (-.19)- (14.19) | (3.37)- (26.23) |

$\overline{d}$ = 7.8; SEM= 1.53; *n*= 5; *d. f*= 4; and $t_0$= 4.89; critical t= 2.78

The results from the average scores of the concept maps are summarized in a spider plot shown in graph 4.1.




**Graph 4.1: A spider plot of pre and post concept maps**

**4.2.4 Reframing my Content Knowledge**

The variance in the scores of each category was a tolerable ± 3. Discussions then ensued to come up with a consensus in the form of average scores. This reflection with critical friends was done in two steps. One, the prior meeting to discuss the exercise to assess the concept maps with teacher A and B. This was recorded in my journal as the meeting to pre-evaluate concept mapping in appendix-14. Two, the post meeting to consolidate the pre and post concept mapping scores with teacher A and B. This was recorded in my journal as the meeting to post evaluate concept mapping in appendix-15.

**Reflection:** The reflection with the collegiality was a process to first validate my observations and secondly to signpost my personal growth in the way I think of content and concepts when teaching the topic of climate change. The deviation between my concept map scores and my colleagues was tolerable. My thinking was that to teacher A and B were professional and would fit well into the self-study because they are post graduates students with more than a decade of teaching experience with what I believed to be excellent subject and pedagogic content from their current studies and classroom experience. In the pre-evaluation meeting, teacher A stressed that the topic was very important in Physical Sciences and pointed out that learners may connect classroom science to their communities in socio-scientific topics such as climate change. In the post evaluation meeting all teachers had to validate their scores of concept mapping in line with the concept map rubric. Content discussions also ensued after the scoring of concept maps on how to best teach the energy changes in climate change. More detail is in appendix-15

Spider plots display that the pre concept map had a lower number of climate change concepts relative to the post concept map. The constructs in the pre concept map were isolated in knowledge partitions with poor interconnections. The concepts of climate change are not interwoven to portray the intricacies of climate change as a socio scientific topic. The pre concept map is limited to two concepts which are the GHE and global warming. The post concept map had a wider continuum of concepts that include the causes of anthropogenic climate change, sources of greenhouse gases, enhanced GHE model and the impacts of global warming. The shift in the number and connections of the teachers' concepts portrays more CK of climate change in post concept mapping. My groups of concepts for teaching climate change also portray increased CK connections from pre- to post-concept mapping. The pre concept map show concept groups limited to what the rubric identifies as open groups and are named point and chains. No loop groupings were present in the pre concept mapping. Post concept mapping displays more intricate concept grouping that include looping of concepts. The number of hierarchical concepts in the concept maps shifted from few to more in the pre to post concept maps. The pre concept map is concealed to two statement lines while post concept maps had substantial multiple statement lines with cross-linking concepts. The constructs in post concept mapping portray critical and key concepts that make the content of climate change more teachable. Concepts in the pre concept map have a linear hierarchy and the constructs in the post concept map interconnect with each other at various levels. The branching in the post concept map had more common concepts linked to specific constructs in line with the rubric criteria in appendix-12.

In the rubric propositions are two canonical concepts connected by a linking word. Individual propositions were pinned down by a two-point scale as in the concept mapping rubric. Post concept mapping portrayed more propositions relative to the pre concept map. The propositions in the pre concept map have limited descriptions in consecutive concepts. The discourse in the post concept map display more word variations to integrate critical and key concepts in climate change.

There is a shift in concept mapping that show more conceptual ideas of canonical knowledge propositions in climate change in the post concept map. More propositions portray more content that is of use when teaching climate change.

To make the content more teachable learners need to make sense of the electromagnetic continuum shifts in terms of frequencies in energy transfers so that they may see how the enhanced GHE leads to global warming. While teaching in the FET phase I must have knowledge of what learners have been experienced to in the later GET phase and make sufficient conceptual connections for more sensible teaching of specific science concepts this for me may be a good point to start my lessons so that learners may see the big ideas in the topic. One of the big ideas I was able to generate is that the enhanced GHE involves energy transfers. This will make teaching of new concepts easier and is part of my own personal growth in teaching such an intricate socio-scientific topic of climate change to the Grade 11 learners doing Physical Sciences.

#### 4.2.5 Discussion of my Content Knowledge on climate change

The construction of concept maps is an essential conceptual tool to portray and develop my CK of climate change. Concept maps scores may infer teachers' conceptual models of a topic (Yin *et al.,* 2005). Therefore, my CK of climate change is portrayed in my pre and post concept mapping. My CK of climate change shifted in post concept mapping exceeding pre concept maps in all categories of the concept rubric. My CK develops more key concepts in climate change portrayed in post concept mapping. Concept mapping is an intellectual tool used to develop and display a teachers' CK for a specific topic (Novak, 1998). The concept maps portrayed my critical concepts to make the topic of climate change teachable. The Spider plots indicate substantial increases in climate change knowledge as shown by the higher scores in the concept map rubric.

The pre-concept map scores are low in all areas, indicating a lack of conceptual understanding about teaching climate change before the start of the self-study. Esa (2010) supports this by stating that instructors have limited abilities to rethink their CK in ways that learners can grasp. If instructors' conceptual knowledge of a subject is lacking, the subject becomes unteachable in the classroom. A teacher's cognitive ability is crucial to teaching (Anyanwu *et al.,*2015). In contrast to post-concept maps, which have more cohesive content structures, pre-concept maps contain inadequate idea links. Post-concept mapping of climate science ideas becomes more entwined, resulting in CK formats for teaching. The conceptual adjustments in teachers' understanding about climate change demonstrate that CK can be built in practice. Additional essential ideas in the post concept mapping demonstrate my curricula saliency in preparing to make the subject clear. From these fundamental assumptions, I was able to develop more robust constructs of climate change.

Concept mapping captured how my CK of climate change shifted in terms of hierarchy and number of concepts. Results for the concepts and hierarchy categories show the most sizable gains in the teachers' CK of climate change. This displays a more unified teachers' CK of climate change in post concept mapping. The pre concept mapping had less content knowledge of climate change. At the end of the study I was more conscious of what key concepts to rethink to make climate change teachable. Post concept mapping portray a shift in content knowledge to more correct scientific models that may make the topic more understandable for learners. The concept map rubric also uses the category of concept branches. The increase in branching of concepts in the post concept map discloses a more sophisticated teachers' CK that suite a socio-scientific theme. The concept groups account for more than just more content but display intricate content connections. Loops of concepts on the concept map capture an authentic intertwine of science, technology and society. Concept grouping is critical in climate change because the loops portray the impacts of society on ecology. A more authentic display of anthropogenic climate change in post concept mapping epitomize classroom science that connect to learners' everyday experiences. This I feel is a more desirable way of teaching a socio-scientific topic. The loops order the concepts in ways that explore the intricacies of climate change in learners' lived experiences.

### 4.3 Portrayal of shifts in my Pedagogical Content Knowledge in pre and post Content Representations (CoRes)

The observations of my pre and post CoRes in the self-study portray my shift in PCK of climate change. I used text descriptions to analyze my pre and post CoRes to see how my knowledge and skills were shifting at the beginning and end of the self-study when teaching climate change to Grade 11 learners. The prompt(s) in the CoRe describe a category of my PCK relative to a specific big idea. The link of the prompt to a category of PCK was looked at in Chapter 3, sub-section 3.5.2.

#### 4.3.1 Shifts in my knowledge of Curricula Saliency and big ideas

Big ideas are critical in making a topic teachable. Big ideas are an important part of my PCK of CS of climate change. This has been looked at in Chapter 2 sub-section 2.4.3. In the analysis of the CoRes my CS is portrayed in terms of the prompts 1, 2 and 3. My CS is portrayed in the pre and post CoRe's big ideas. Big ideas isolate the content in the topic to make the topic of climate change more sensible. Big ideas constitute conceptual statements with powerful knowledge to make the topic teachable. The key concepts in a topic gravitate on big ideas and shape classroom content and learning experiences. The way big ideas draw out concepts in the classroom confronts learners' misconceptions and also makes learning of difficult concepts easier.

In the analysis of my PCK of CS and big ideas I noted that my pre CoRe was pinned down by content from my prior thinking of what content learners had covered in their previous Grades from Grades 8-10. This indicates that in coming up with my big ideas I did not include learners' prior conceptions in my plan of teaching. The source of my prior knowledge was from my teaching experiences of Sciences at Grade 8 and 9. My prior knowledge of big ideas and the use of a CoRe were naïve. The content of big ideas was intricate and difficult for me to construct. It was more study on the concept of big ideas in teaching that I was now able to come up with big ideas in a topic. Prior to this experience I had made my pre CoRe for teaching climate change as shown in the snapshot.

| **The CoRe is for grade 11**<br>**Topic: Climate change**<br><br>**Prompt** | **Important Science Ideas**<br>1: Models are constructs used to understand the structure of the globe | 2: Burning of fossil fuels causes global warming | 3: Humans cause climate change |
|---|---|---|---|
| What you intend the students to learn about this idea? | The Earth has specific regions that are interconnected with each other called spheres by various cycles of substances. There are models that scientists have come up with to represent the structure of the globe. | The spheres are in a state of natural balance maintained by the various cycles of substances e.g. $H_2O$ and C-cycle. | The biosphere is the location of organisms on the globe. Humans as part of this location can impact the other regions by their activities. |

**Figure 4. 4: A screenshot of my prior big ideas portraying my PCK of CS**

In the analysis of my PCK of CS and big ideas, the post CoRe portrays more coherent big ideas relative to the pre-CoRe. The pre and post CoRes in appendix-9 and 10 display a shift in the teachers' thinking and construction of big ideas. The big ideas in the lessons form a cue in the post CoRe that portrays an advanced teachers' PCK of CS. The string of big ideas in the post CoRe challenge learners' misconceptions by coming up with teaching tenets of NOS to make learners construe the enhanced GHE model. The teachers' big ideas make classroom science connect with learners' everyday experiences of climate change to make the lessons more authentic. These big ideas are shown in the post CoRe. I decided to teach the NOS before some concepts of climate change to close learners' knowledge gaps in terms of their knowledge in NOS and LPK and to confront some common learners' misconceptions. This knowledge of my PCK of CS is underpinned by the thinking that an understanding of how science works is elemental for learners to conceptualize anthropogenic climate change and the enhanced GHE model.

| **The post CoRe is for grade 11**<br>**Topic: Climate change**<br><br>**Prompt** | **Important Science Ideas**<br>1: Science is a human construct. | 2: Changes in climate are continuous. | 3: Levels of greenhouse gases change the global temperatures. | 4: The GHE involves the transfer of energy. | 5: Anthropogenic climate change is a consequence of human activity. |
|---|---|---|---|---|---|

**Figure 4. 5: Screenshot of my post CoRe's big ideas portraying PCK of CS**

The post CoRe was a more integral display of my PCK of CS and my big ideas. The big ideas focused on the anthropogenic impact of the GHE in causing climate change due to global warming. The forth big idea in the post CoRe will ensure learners understand the normal and enhanced GHE as different but critical ecological processes in a world with anthropogenic climate change. My classroom content in the post CoRe is pinned down by the NOS. So I introduced the GHE to learners as an important concept and shifted their thinking from the normal to the enhanced GHE model. It is my contention that learners at this stage understand that scientific models are tentative and change in light of contrasting evidence. My thinking is that if learners appreciate the role of data and evidence, creativity in science and the interconnections of science with society the content of anthropogenic climate change will be teachable. Therefore, in my post CoRe there is a shift to a more compact and connected bodies of knowledge in the teachers' CS and big ideas. This is shown in appendix-10 that depicts PCK of CS and my big ideas.

### 4.3.2 Shifts in my knowledge of Topic Comprehensibility Difficulty

My observation is that concepts that are difficult to teach are also a challenge for learners to understand. These difficulties come from various sources and may limit learners' understanding of the big ideas in a topic. Therefore, it is my PCK of TCD that I will use to make these concepts easier for learners as I teach the topic of climate change. A look at the PCK of TCD was done in Chapter 2, section 2.4.6.

In the analysis of my PCK of TCD in the pre CoRe I realized that my knowledge of difficult concepts was limited to the intricacies of misconceptions in greenhouse gases and the abstract nature of how greenhouse gases impact the global climate. This is seen in the snapshot in figure 4.6.

| | | | |
|---|---|---|---|
| What are the difficulties/ limitations connected with teaching this idea? | Numerous misconceptions that distorts the way scientific knowledge is generated. | The abstract nature of the way greenhouse gases impacts the environment. Increasing greenhouse gases is clear in scientific data and may not be visible in communities. | Learners may use global warming as synonymous with anthropogenic climate change and this creates a conceptual gap in understanding the impact of climate on other global ecosystems. |

**Figure 4. 6: A snapshot of my PCK of TCD in the pre-CoRe**

In the analysis of my PCK of TCD in the post CoRe I listed more difficult concepts in my planning to teach anthropogenic climate change. The enhanced GHE and the idea of anthropogenic causes and solutions to climate change are abstract concepts for Grade 11 learners. The conception of greenhouse gases in the context of contemporary climate change is a problem for learners because my thinking is that it demands learners to understand the common global warming that is critical for life on the globe. The GHE model underpins the enhanced GHE due to anthropogenic activities. If I structure the concepts with that order these abstract constructs are teachable. I may say that this knowledge to teach the GHE then the enhanced GHE is part of my CS and TCD. I observed a shift in my knowledge of TCD from the pre to the post CoRe as I could think of more conceptual experiences learners find difficult to make sense of in the topic. This is portrayed in the snapshot in figure 4.7 that has more difficult concepts I plan to see when teaching climate change. These difficult concepts are diverse from the NOS to climate change concepts. In my plan to teaching climate change most of my knowledge of TCD came from the questionnaires. I made use of the Views about Scientific Inquiry (VASI) and Views of Climate Change (VoCC) questionnaires to check learners' levels of competencies in specific concepts of the topic. This was valuable knowledge of their prior thinking and difficult questions they got incorrect.

| | | | | | |
|---|---|---|---|---|---|
| 4. What are the **difficulties/ limitations** connected with teaching this idea? | The difference between data and evidence, hypothesis and theories are seldom difficult for learners to understand. These constructs take time to be understood in a meaningful way. Learners are not clear on the definitions of the terms and struggle to contrast them and categorize the terms in contexts. | It is elaborate to believe that global climate can be changed at a communal level. | The idea that greenhouse gases refer to $CO_2$ is a common misconception. Gases that are able emit IR-radiation might be a better way to explain greenhouse gases because $H_20_{(v)}$ is an important greenhouse gases. | In the GHE model misunderstandings often come up when learners do not remember that the globe absorbs high energy radiation (uv and visible light) from the Sun and intern emits low energy radiation in the form of IR radiation. It is IR- radiation that warms up the globe. Learners instead conflate global warming and ozone depletion. | Learners find it difficult to understand the importance of anthropogenic activities in causing global warming. Learners have difficulties scaling the levels of $CO_2$ in their communities. Their C footprint is an abstract concept. |

**Figure 4. 7: A snapshot of my PCK of TCD in the post CoRe**

### 4.3.3 Shifts in my knowledge of Learners' Prior Conceptions and Misconceptions

The knowledge that learners come with to the classroom is their prior conceptions. This knowledge may contradict the content in the classroom in which case it will be a misconception or the knowledge may be a template to construct new knowledge. The later class of prior conceptions may connect what learners know and the canonical concepts in the classroom. However, misconceptions will make the classroom content unteachable. I have looked at the PCK of LPMCs in Chapter 2, section 2.4.1.

In the pre CoRe I used my own experience to find the LPMCs. I did not use a specific teaching tool to do a diagnosis of the learners' prior conceptions to find out the specific knowledge they came with into the classroom. The use of my past experiences is limited to the learners I have been exposed to only. Learners' common misconceptions are critical in pedagogy. It is more sensible to do a synopsis of your own learners' ideas to pin point the knowledge that learners have prior to teaching. If teachers' knowledge of learners' prior conceptions is limited then the teaching will not confront specific misconceptions. My initial thinking of learners' prior conceptions was limited because in the post CoRe I realized that learners found it difficult to understand anthropogenic climate change, the enhanced GHE and impacts of climate change on the global ecosystem. My assumption that learners know global warming was naïve. This is displayed in figure 4.8 that shows a snapshot of my pre CoRe in relation to learners' prior misconceptions.

| | | | |
|---|---|---|---|
| What is your knowledge about students' thinking which influences your teaching of this idea? | Learners understand that the globe is an ecosystem. | Learners understand the energy flow from the sun to the global ecosystem | Learners understand that climate change impacts communities and ecosystems |

**Figure 4. 8: A snapshot of my PCK of LPMCs in the pre CoRe**

In the analysis of my PCK of LPMCs in the post CoRe to find learners' prior and misconceptions I gave learners a VASI questionnaire in appendix-6 to sort their prior knowledge on the NOS and a VoCC questionnaire in appendix-7 to see their understanding of concepts in climate change. While the questionnaires have a continuum of constructs, I identified the concepts that were important for the scope of this self-study. I had to streamline the learners' answers to suite my study. To consider learners' prior conceptions before my teaching is important to make conceptual connections of learners' prior thinking so that the content in the classroom connects with learners' prior conceptions. This knowledge is also part of the teachers' CS and is more visible in the post CoRe. In the post CoRe the teacher portrays a deep knowledge of LPMCs.

| | | | | | |
|---|---|---|---|---|---|
| 5. What is your knowledge about learners' thinking which influences your teaching of this idea? | Learners think that scientific concepts are a version of truth instead of viewing it as a form of knowledge. In everyday life experiences and often in scientific contexts the words hypothesis; laws and theories and; data and evidence are synonymous. | Learners do not appreciate the notion of a changing climate despite having some forms of experiences of consequences of climate change such as recurring heat waves, flooding, droughts and changes in seasonal patterns. I am convinced that where climate evidence is apparent e.g. melting ice caps on mountains , learners will accept this as proofs. | Learners are eager to decide that greenhouse gases are undesirable gases. Greenhouse gases make the globe warmer | Learners often suppose that the incoming radiation from the sun leads to global warming. Therefore, they view solar radiation as bad rather than useful energy in the global ecosystem. Learners conflate global warming and ozone depletion. | A submission to anthropogenic climate change may lead some learners to believe that the natural geo-atmospheric processes are now inactive and do not influence the state of the current global climate. |

**Figure 4. 9: A snapshot of my PCK of LPMCs as portrayed in the post CoRe**

My contention is that prior checking of learners' thinking in the post-CoRe gave me more opportunities and time to reframe my CK in line with learners' incorrect conceptions and concepts that are difficult to understand with minimal constraints of learner participation. It is more sensible to give all learners a chance to express their prior concepts. This was done in my planning in the post CoRe. Planning to probe for LPMCs in both the NOS and the content of climate change prior to teaching in classroom is critical to find out what the learners know so that these bodies of knowledge may be templates the teacher and the learners may construct knowledge. One of the ways to confront LPMCs is the use of case studies that embed the teachers' PCK of learners' SSR because they contain social concepts of climate change, teachers' PCK of LPK because they contain NOS and teachers' TCD because the big idea of science as a construct that we model is intricate. I see that concepts for teaching are coherent once I scaffold classroom content on learners' prior knowing.

### 4.3.4 Shifts in my knowledge of Representations, Models, Analogies, and Resources

My shifting PCK of RMARs constitute changes in my knowledge of how I display the content to make it more understandable for learners. While there is a continuum of this knowledge I have made use of a specific representations that I think are useful when teaching the socio-scientific topic of climate change. These have been looked at in Chapter 2, section 2.4.5. The role of my PCK of RMARs is to make concepts that are difficult more teachable. I observed that my prior PCK of RMARs in the pre CoRe was limited to the presentation of concepts and not directed at making the content easier for learning. My prior knowledge of representations was to use technology and present content to learners with the use of graphics. This is shown in the snapshot in figure 4.10. I planned to use various ICTs to concretize the concepts but this was not mapped to teaching specific difficult constructs.

| | |
|---|---|
| Are there any other factors that influence your teaching of these ideas? | Teaching resources: ITs to create/ download learning medias such as pictures, videos and power-point presentations |

**Figure 4. 10: A snapshot of my portrayal of my prior PCK of RMARs**

My post PCK of RMARs as planned in the post CoRe and executed in the lesson was more objective. My PCK of RMARs was mapped out concepts that I had found were difficult for learners to understand or had specific misconceptions. The use of an analogy to make the enhanced GHE more teachable and minimize the misconception that ozone depletion leads to global warming. The representations gave me the opportunity to explain the concepts in ways that learners could understand. The differences in my thinking of RMARs changed from simple content displays to target conceptual tools for teaching. The screenshot in figure 4.11 portrays my PCK of RMARs at the end of the study.

| | | | | |
|---|---|---|---|---|
| 7. What are your **teaching procedures** (and particular reasons for using these to engage with this idea)? | **Probe learners for understanding:** Engage learners in **question and answer** ask learners why some scientific constructs are no longer accepted as part of science. Allow learners to ponder on these questions and respond. Use models of the geocentric model of the solar system to evoke their thinking on the role of data and evidence in science. **Deal with learners' misconceptions:** Give learners a **case study** on the History of Science that explains how $CO_2$ levels lead to the GHE, use graphs, pictures and diagrams. | | **Modeling of ice cores:** The teacher gave learners an activity to design an ice core that shows the trend in the trend of greenhouse gases $CO_2$. Ask the learners to think about the time period when there was a sudden rise in $CO_2$ and what was the cause? | **Analogy**: Use an analogy of the common greenhouse to explain the enhanced GHE. Map out the components of the greenhouse with corresponding explanation to curb the build-up of misconceptions so that learners can understand the changes in radiation and how the enhanced GHE leads to current global warming. Show the analogy with diagrams to teach this difficult concept. So that learners do not conflate ozone depletion with global warming. |

**Figure 4. 11: Portrays my PCK of RMARs in the post CoRe**

### 4.3.5 Shifts in my knowledge of Learners' Procedural Knowledge

My PCK of LPK constitutes the teachers' knowledge to develop learners' scientific skills. These skills include a variety of competencies and in this study I have looked at what I think are the critical scientific skills to develop in learners when teaching anthropogenic climate change. The details of these scientific skills are in Chapter 2, section 2.4.4.

My prior knowledge of teaching LPK was set in the discourse of discussions. Prior to the study my thinking of teaching climate change was to make sure that learners may observe that the concepts in the topics are linear where greenhouse gases will lead to the GHE which then cause climate change. My teaching of climate change could be identified as linear. This is shown in the snapshot of my pre CoRe in figure 4.12.

| | | | |
|---|---|---|---|
| 7. What are your teaching procedures (and particular reasons for using these to engage with this idea)? | **Probes of students' understanding:** Learners engage in discussions and explanations | **Prediction- Observe-Explain:** Learners participate in role play, discussion and explanations | **Translation activities:** Learners engage in debates on specific socio-scientific concepts issues. |

**Figure 4. 12: Portrays my PCK of LPK in the pre CoRe**

My post knowledge of LPK shifted to more diverse knowledge forms of learners' procedural skills and I now understood that the topic of climate change has intricate concepts and these conundrums and interconnections of concepts are critical in teaching the topic current climate change so that learners understand the scientific discourse of socio-scientific topics. This is shown in the post CoRe in figure 4.13. The skills are more than just discussions in the class but take the form of argumentation, drawing scientific models and categorize variables in both climate change concepts and NOS to show how scientists come up with specific concepts.

| | | | | |
|---|---|---|---|---|
| 8. Specific **ways** of ascertaining learners' understanding or confusion around this idea (include likely range of responses) | **Note the discourse that learners use:** the use of the word theory to mean a possible explanation of phenomenon that can be supported by evidence indicates that learners have understood the idea that the word theory does not refer to some form of thinking process. Learners understand that models are used to explain concepts in science. **Learners articulate their views**: Allow learners to give their own understanding of the meanings of the words 'theory', 'law', 'data' and 'evidence', ask them to justify their responses with examples. | The teacher facilitates learners into **argumentation** which can deepen their levels of understandings of specific socio-scientific issues. | **Models of ice cores** are checked with **a rubric.** The rubric checks learners' understandings of the rise of $CO_2$ levels and chemical covalent bonding **models of Lewis structures**. **Probing:** Probe learners to check if the issues they have raised are intertwined with the ecology. Ask learners, 'is the global ecosystem is in a state of stasis. | **Note the discourse that learners use:** e.g. the absence of uv radiation and IR radiation when learners explain the GHE may show that their understanding of the electromagnetic spectrum is inadequate. The teacher needs to use the terms incoming radiation, high frequency or energy radiation so that learners' conceptual understanding is scaffolded |

**Figure 4. 13: Portrays my PCK of LPK in the post CoRe**

### 4.3.6 Shifts in my knowledge of Learners' Socio-Scientific Reasoning

My PCK of LSSR constitutes the teachers' knowledge to develop learners' knowledge of science in society. These skills include a variety of competencies and in this study I have looked at what I think are the critical skills for learners to make sense of anthropogenic climate change. The details of these scientific skills that develop LSSR are in Chapter 2, section 2.4.2. My prior knowledge of LSSR was fixed on case studies that show the impacts of climate change on communities. This is shown in figure 4.14 that portrays my PCK of LSSR in my prior thinking.

| | |
|---|---|
| 8. Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses) | • Case study on how humans activities impact ecosystems |

**Figure 4. 14: Showing my prior thinking that portrays my knowledge of LSSR**

My post knowledge of LSSR is portrayed in various activities such as a quiz, case studies on the history of $CO_2$ levels in relation to global temperatures and role play. What surprised me was that I had knowledge of LSSR but was not conscious of specific skills I was teaching. In the course of the study I realized that this critical knowledge involves more than just making learners active in class. The activities with socio-scientific themes are mapped out to confront specific misconceptions or make difficult concepts more teachable. This knowledge was more pronounced in the post CoRe.

## 4.4 Portrayal of my post Pedagogical Content Knowledge

My second research question is about how I portray my PCK when teaching climate change to Grade 11 learners doing Physical Sciences. The text descriptions I came up with from my lesson transcripts have critical sections of specific PCK elements I use for teaching. These elements of PCK are portrayed in the form of PaP-eRs. The text descriptions are set on six pre-determined categories of PCK in the LTtP model. While a division is made in my PCK of climate change it is the mix of PCK elements that in practice make the content more teachable to learners. As stated in the section 3.3.3, the PaP-eRs will show a specific situation of PCK mix in my lessons. There are many situations that portray my PCK however in this study my PaP-eRs will be limited to one episode.

### 4.4.1 Portrayal of my Pedagogical Content Knowledge of Representations and Topic Comprehensible Difficulty

In teaching the enhanced GHE I made use of an analogy, a graph and an ice core model. The enhanced GHE is a difficult construct for learners to understand. Analogies may be draw from learners' common knowledge to make sense of intricate and abstract concepts in the classroom. I made use of an analogy to concretize the concept of the enhanced GHE. The use of learners' everyday experiences of how a greenhouse works to explain the enhanced GHE in the topic of climate change made the concept teachable in the classroom. A mix of my knowledge of TCD and the use of an analogy in teaching the enhanced GHE is an amalgamate of my PCK of climate change. Figure 4.15 portray my analogy of the enhanced GHE.

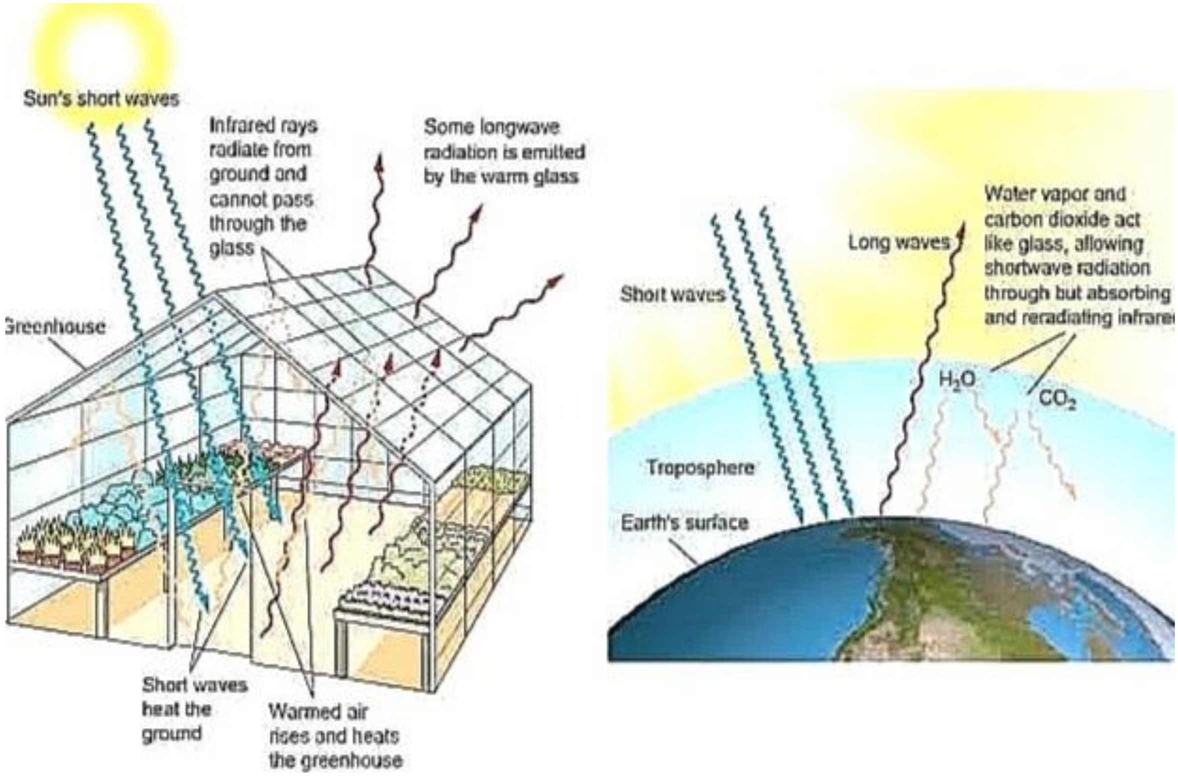



**Figure 4. 15: A diagram of an analogy to explain the enhanced GHE**

**Adapted from: IPCC. Climate Change (2013). The Physical Science basis. Contribution of working group 1 to the fifth assessment report of the intergovernmental panel on climate change. Stocker. T.F., *et al.* (Eds.). Cambridge: Cambridge University Press.**

The analogy made the enhanced GHE easy to teach. However, I was cautious to use this analogy in such a way to make learners construct correct scientific conceptual models and minimize misconceptions. I did this by mapping specific parts of the greenhouse to the way the enhanced GHE impacts the globe. A snapshot of my PaP-eR shows my PCK of RMARs and TDC and how I mapped the analogy to the enhanced GHE.

| | |
|---|---|
| Mr. Chigura: | Yes the average global temperatures have been increasing. Its all due to the enhanced GHE due to an increase in GHGs. infra-red (IR) radiation is released by the surface when the uv-radiation bounces off the ground. …the excess IR that is released by the globe is trapped by… GHGs e.g. carbon dioxide are able to absorb IR and emit it in the atmosphere. So, if you have a high concentration of carbon dioxide levels here the excess IR is absorbed, here and, the reflected radiation from the ground. … will lead to … global warming…so in the same way that is how the greenhouse works … Our greenhouse operates like our globe. Like our atmosphere, the plastics around the greenhouse are the atmosphere...they have the ability to trap the heat within the house itself, so GHGs have the ability to trap the heat... The surface of the greenhouse match the earths' surface that emits excess IR radiation, there is no problem with uv/ visible radiation that passes through the plastics or atmosphere because GHGs do not absorb the high frequency or high energy radiation. It can only absorb IR which is on the lower end of the electromagnetic spectrum with low frequency. So …the GHGs can absorb IR and reflect it back to the ground<br>… Learners what have you understood from this explanation? |
| Dineo: | What I understood… is that uv rays are radiated into the atmosphere and they go back as IR from the ground. |
| Mr Chigura: | Very good. |
| Thapelo: | …GHGs can trap IR into the atmosphere. They absorb low frequency low frequency IR radiation. |
| Mr. Chigura: | What is that going to result in? |
| Precious: | Global warming. |
| Mr. Chigura: | … What traps the heat here? (Teacher points to the plastic cover of the greenhouse) |
| Class: | Plastic |
| Mr. Chigura: | It is the plastic which represents the atmosphere here. We have GHGs that are acting as a trap…a radiation trap in the atmosphere to cause the globe to warm up. |

**Figure 4. 16: A snapshot of the lesson text showing how I made use of an analogy to explain the enhanced GHE.**

I also depicted the average global temperatures as a dependent variable and anthropogenic levels of $CO_2$ as an independent variable with a graph. In this case my thinking is that a graph may help concretize the intricacies of the enhanced GHE from an increase in $CO_2$ to cause current climate change. From my climate change questionnaire and my own experience of teaching, learners find it difficult to explain scientific variables. To make the content teachable I portrayed the historical shift from the common GHE to the enhanced GHE. The increase in $CO_2$ from the combustion of coal and crude oil are the main sources of anthropogenic $CO_2$. The graph helps me confront one of the learners' misconceptions exposed in the climate change questionnaire is that some learners think that scientific models do not change. The enhanced GHE model is a new conceptual model to explain current climate change.

The complex mix of learners' misconceptions on the tentativeness of scientific models and a graph of $CO_2$ levels and global temperatures make up my PCK of RMAR, NOS and TCD to make the enhanced GHE teachable. The graph is shown in representation is shown in figure 4.17.

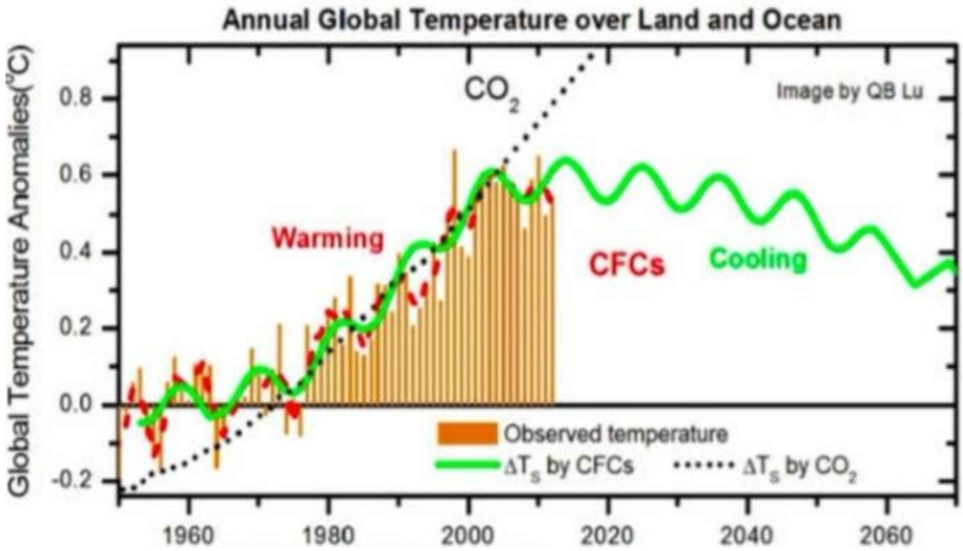



**Figure 4. 17: Showing the trends of global temperature with carbon dioxide concentration from 1960 -2020 Adapted from: Ward, P. L. (2016). Ozone Depletion Explains Global Warming. *Current Physical Chemistry*, 1-21.**

The thinking in my pre CoRe of how to represent content was confined to symbols in chemical equations. In the study I found that my teaching of chemical diagrams with equations is algorithmic and promote rote learning. My post CoRe and classroom teaching portray the molecular and symbolic levels in chemical diagrams which indicate a shift in my PCK of RMAR. The ice core activity is a mix of chemical bonding and climate change. To make chemical equations more teachable the learners had to connect the chemical symbols with molecular diagrams in the activity. This order of chemical representations minimizes misconceptions because it intertwines the molecular and symbolic levels (Treagust *et al.*, 2018). The various representations to explain the difficult concepts of chemical equations and the GHE portray my PCK of RMAR and TCD. The is shown in one of the learners' written responses to the ice core activity. Figure 4.18 shows a learners' ice core models with molecular and symbolic depiction of anthropogenic levels of $CO_2$ that cause the enhanced GHE.

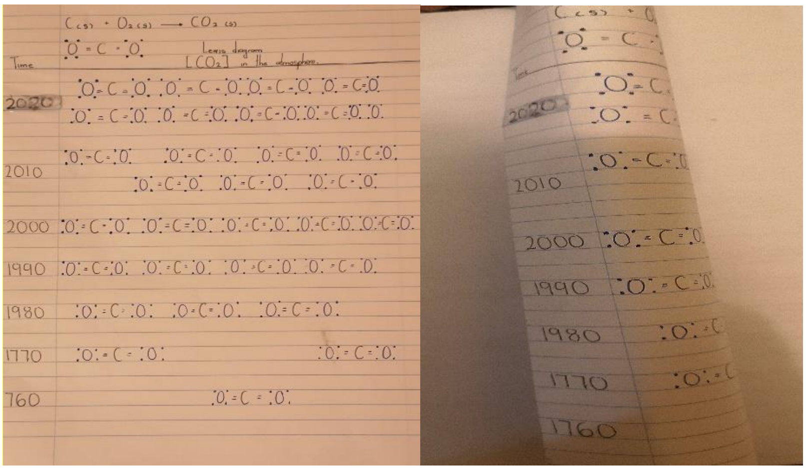



**Figure 4. 18: Shows the ice core model of a learner showing the concentrations of $CO_2$ from 1960-2020.**

**My reflection**

From my past experiences of teaching the enhanced GHE, it is clear that this concept is difficult. I came to this conclusion as most learners had difficulties with the concept of the enhanced GHE in the climate change questionnaire. To come up with meaningful teaching content I decided to use an analogy of the how the greenhouse works to make learners understand the enhanced GHE. To me this portrayed my PCK of RMAR however, critical to the use of an analogical model is to explain the analogy with clarity to minimize the build-up of misconceptions in learners' conceptual models. I linked the plastic covering on the greenhouse to the atmosphere with high levels of greenhouse gases as a trap of IR radiation that increase the temperature of the greenhouse as the enhanced GHE will lead to global warming. The change in solar energy from UV and visible light to IR is a big idea in the topic of climate change that enable learners to understand the energy changes that lead to global warming.

The model of ice core activity is important to my teaching of the NOS. I contend that if my learners know how the levels of $CO_2$ are obtained by scientists it is an authentic way of learning science. The way I set the questions in the activity demanded learners to construe the information in a similar way that scientists do it in the real world when they come up with data of $CO_2$ levels from ice cores. Scientists observe and measure the levels of $CO_2$ in various layers of ice. In the exercise learners must represent the levels of $CO_2$ in various ice layers. My intention with the ice core model activity was to expose learners to one of the ways scientists get data on historical levels of global $CO_2$ levels in specific timelines when air is trapped in ice. My thinking was to connect learners' thinking to the way scientists obtain scientific data and to portray Lewis structures for the covalent molecules relooking the topic of chemical bonding.

The use of the graph was necessary to show the learners how the levels of $CO_2$ increase the global temperatures and connect the variables on the graph. However, I did not use this graph to identify and see how the anthropogenic activities impact each of the variables. Most of the concepts in the lesson was on the enhanced GHE model and I did not explain the anthropogenic impacts on the enhanced GHE.

### 4.4.2 Portrayal of my Pedagogical Content Knowledge of Learners' Socio-Scientific Reasoning and Topic Comprehensible Difficulty in the lesson

The concept of the C-footprint is also difficult to explain when teaching the chemistry of climate change. The idea to connect an individual to the global enhanced GHE due to their activities that increase $CO_2$ is an abstract concept for learners. The teacher's use of an activity in appendix-16 on the C-footprint to teach this difficult concept portrays the teachers' PCK of TCD. The use of everyday experiences draws learners into discussions of how their taken for granted human activities constitute the C-footprint. In the post CoRe I made use of an authentic activity to show the intersect of science with society and technology. This specialized knowledge in teaching make up my PCK of LSSR and involve the use of learners' daily experiences to portray how science impacts society. The learner's C- footprints are calculated from specific prompts which are scored in line to their daily activities. The extract in figure 4.19 portrays my PCK of TCD and LSSR to make learners understand how daily activities contribute to the C-footprint which increase $CO_2$ levels.

| | |
|---|---|
| Mr. Chigura: | …You don't have a thermal power station you don't have an automobile but still as an individual you can contribute to the GHGs in the atmosphere…today you have contributed to the GHE, from this morning by carrying out your daily activities. |
| Learner: | When you were bathing sir? |
| Mr. Chigura: | …anthropogenic sources...Mulisa … when you woke up? Let's go through his morning activities, morning until you got here. You can start. |
| Mulisa: | …I woke I went to the bathroom sir. |
| Mr. Chigura: | Did you use hot water? |
| Alexina | …hot water today |
| Mulisa: | After bathing I went to put on my uniform… |
| Mr Chigura: | Ok alright let's pause there. There depending on the time you woke up there was a form of lighting isn't it? |
| Mulisa: | …yes sir I did switch on the lights. |
| Mr Chigura: | What type of geyser do you have? |
| Mulisa: | …it was not solar. |
| Mr. Chigura: | …that's fine then it was electrical and then breakfast… it had to be cooked. So, depending on the gadgets did you warm milk for breakfast? |
| Mulisa: | No. |
| Mr Chigura: | But it is refrigerated there is another electrical appliance. You see…So, … you got here what did you use? |
| Alexina: | Transport |
| Mr. Chigura: | Transport, specify. |
| Alexina | A Putco bus. |
| Mr. Chigura | Do you have an idea of how many of how many passengers were in the bus? |
| Alexina | Many, sir. |
| Mr Chigura | …So your daily activities contribute to carbon release in various forms per unit time and we call this the carbon footprint. The measure of your C output due to daily activities for an individual or a collective per unit time /month. Give me more examples of everyday activities that contribute to your personal C- footprint and tell the class of the source of C that will . |
| Ayanda | Watching TV. |
| Mr. Chigura | …. please explain |
| Ayanda | TVs use electricity which is generated …from thermal power stations |
| Mr. Chigura | So coal is a compound made up of CHs undergoing combustion to releases $CO_2$ and $H_2O$ as GHGs. |
| Leaner | When they burn coal they produce $CO_2$ in coal stations to make electricity. |

**Figure 4. 19: Shows snapshot of my teaching knowledge of LSSR in teaching a difficult concept**

**My reflection**

I used a C-footprint worksheet in appendix-16 to draw out the learners' C-footprints from their daily activities. The teaching of the C- footprint from learners' experiences connects their C- footprints to the global enhanced GHE and portray my PCK of TCD and LSSR. The teaching of the C-footprint concept from learners' individual experiences made this abstract concept understandable for learners. The C- footprint activity was a conceptual tool to link human activities to $CO_2$ emissions and global climate change. The expert above portrays how I interact with learners prior to the activity on the C- footprint to give them some base knowledge of how anthropogenic activities lead to the enhanced GHE. My thinking in this activity was to display how the C-footprint is intertwined in everyday life and the impact on ecology. The combination of my PCK and of LSSR and TCD portray the specialized knowledge of teaching the intricate concept of the C-footprint.

### 4.4.3 Portrayal of my Pedagogical Content Knowledge of Learners' Procedural Knowledge

My PCK of LPK is portrayed in my teaching of NOS and use of argumentation in the classroom. The difference between data and evidence is one of the tenents in NOS that learners found difficult in the VASI question. Teaching science concepts with argumentation develop learners' skills to use scientific discourse and come to sensible conclusions.

The data of $CO_2$ concentration and global temperature is key to make sense of the anthropogenic climatic model. The extract below shows my pedagogy to access gate keeping concepts of climate change to make learning of the variables of time, global temperatures and $CO_2$ concentration understandable. The combination to use data from $CO_2$ concentration and global temperatures as evidence of current climate change in a graph depict PCK of LPK. The historical concentration of $CO_2$ demands learners to explain the relationship of the variables. My skills to teach learners variables by making them account for the shifts in $CO_2$ levels portray my PCK of LPK. This is portrayed in figure 4.20.

| | |
|---|---|
| Mr. Chigura: | …$CO_2$ is important in affecting global temperatures…so when scientists gather data about $CO_2$ concentrations and global temperature …they can come up with a graph that looks like this. What is on the x-axis; which variable is it the independent or dependent variable? |
| Learners: | The independent variable |
| Mr. Chigura: | Independent and which variable is this? It is period, it's the time. So, from way back here …the 1700s. How many years is that Shaun? |
| Learner: | 2019. |
| Mr. Chigura: | About three hundred years ago? What is the average temperature value of the global temperature? |
| Learner: | ~ 13 ºC …. |
| Mr. Chigura: | Ok and you see from 1700 to 1800 any major fluctuation in temperature? |
| Learners: | mixed responses. |
| Mr. Chigura: | It's the same isn't around that figure of $13^0$ so, temperature variation was stable according to this graph. Right but from 1800 something … started to happening to the levels of carbon dioxide in the atmosphere, Karabo |
| Karabo: | increasing |
| Mr. Chigura: | It's increasing very good and that trend continues and its continuing up until today. Right, now as the levels of $CO_2$ increase what happened to the temperature Mulisa? |
| Mulisa: | The temperature started to increase |
| Mr. Chigura: | It was also increasing. Right and you can explain this using what effect? |
| Learner: | The GHE. |
| Mr. Chigura: | The GHE. And you can see that there is a relationship between the concentration of $CO_2$ in the atmosphere and the temperature and the fact that both are increasing at the same rate what relationship is that? What type of relationship exists between $CO_2$ concentration in the atmosphere and temperature? … Mosa. |
| Mosa: | As the $CO_2$ increases so are the temperatures. |
| Learner: | Direct proportional |
| Mr. Chigura: | Meaning that as one increases i.e. $CO_2$ then the other one global temperatures are… increasing. |

**Figure 4. 20: A snapshot that portray my knowledge of LPK**

The $CO_2$ levels that scientists have measured from ice cores constitute the data and the evidence of anthropogenic climate change is the increase in global temperatures. This classroom episode depicts my PCK of LPK in line with teaching NOS. The thinking in this episode was to stress the intertwine the variables of anthropogenic climate change, high $CO_2$ levels and global temperatures.

The teachers' PCK to involves learners in various forms of classroom talk constitute the teachers' PCK of LPK. Argumentation is a form of classroom talk that demands learners to support their claims with evidence or rebuttal opportunities from learners with counter-claims. Argumentation is a form of classroom discourse that develops learners' critical thinking on anthropogenic climate science because it demands learners to give reasons that supports their worldviews. The class argumentation on the causes of current climate change due to greenhouse gases in the form of $CO_2$ portray the teachers' PCK of LPK by probing learners to connect anthropogenic activities to climate change. An extract from an episode where the class was locked in argumentation is portrayed in an expert in figure 4.21.

Mr. Chigura: …what is the cause of the current changes in the global climate? Let's hear some inputs…

claim

Mahlatse: It's a result of human activities, sir.

Mr. Chigura: It's a result of human activities. Why? Let's hear your reasons.

Mahlatse: Burning of fossil fuels.

Mr. Chigura: That's good, what are other human activity?

Mahlatse: Air pollution.

Mr. Chigura: Air pollution, …in what ways.

Ayanda: The increase of $CO_2$..

support evidence

Mr. Chigura: Alright.

Lee-Ann: …she said the releasing of $CO_2$ into the atmosphere. The first one was the burning of fossil fuels.

Learner: We said that because of human activities

Mr. Chigura: Because

Learner: The manufacturing… releases gases …

Learner: …the fumes that come from the manufacturing of products causes air pollution by releasing greenhouse gases…

rebuttal

Mosa: … but is it a natural process as the population increases they use consume more $O_2$ and release $CO_2$.

rebuttal-support evidence

Mr. Chigura: …more humans or aerobic species on the globe, they release more $CO_2$ during respiration processes… So, it's a natural process we have… photosynthesis…. looking at the chemical equations there is an equilibrium of $O_2$ and $CO_2$ in the life processes.

$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$: respiration

$CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$: photosynthesis

Therefore, the levels of $CO_2$ will not lead to the enhanced GHE

Counter-claim

Learner: The problem is…excess $CO_2$ in the atmosphere … because of cutting down trees.

Mr. Chigura: …so you are saying that it's human activities that leading to cutting down trees. Class what do we call this random cutting down of trees?

counter-support evidence

Class Deforestation….

Mr. Chigura ….so greenhouse gases mainly $CO_2$ come from burning fossil fuels, industries and deforestation minimize the uptake of $CO_2$ from the atmosphere, all of which are human activities leading to an increase in $CO_2$ and climate change.

**Figure 4. 21: Shows an expert portraying argumentation in the classroom**

The use of argumentation helped learners to co-construct correct thinking models of anthropogenic activities that are a source of greenhouse gases. This is shown when the teacher co-ordinates learners' arguments to link specific activities to an increase in $CO_2$ levels. The use of argumentation causes a conceptual change in learners and portrays how modern day society impacts the global ecology. Claims were put forward by learners and sustained with evidence. The role of the teacher was to step in and confront learners' misconceptions on the causes of anthropogenic climate change to develop scientific conceptual models. The way the teacher executes scientific argumentation in the classroom in relation to their learners' misconceptions portrays teachers' PCK of LPK and LPMCs.

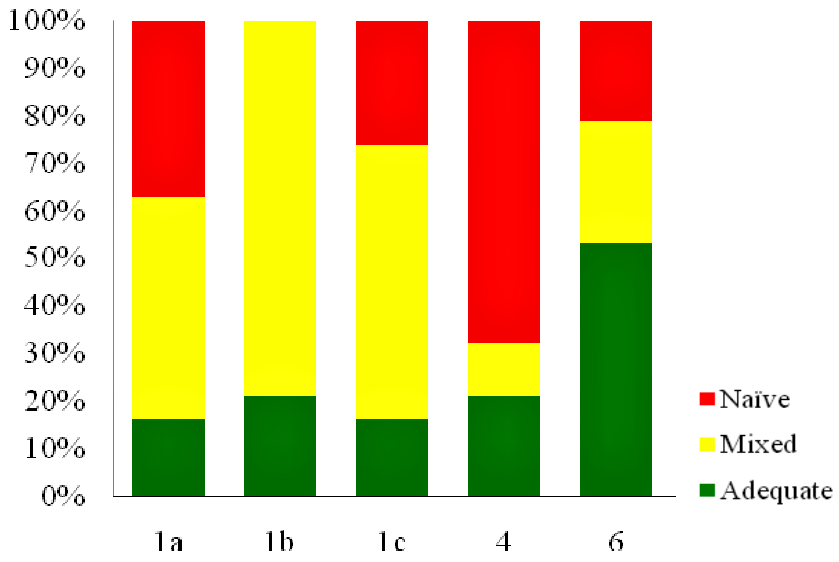
#### 4.4.4 Portrayal of my Pedagogical Content Knowledge of Learners' Prior Conceptions and Misconceptions

The teachers' knowledge of LPMCs constitutes ways to elucidate learners' prior knowledge when teaching the topic of climate change. The objective to determine LPMC is to access learners' thinking and construct teaching methodologies to challenge and overcome learners' incorrect scientific constructs. The views of scientific investigations and climate change questionnaires are the diagnostic tools I made use to unearth learners' prior and misconceptions.

##### 4.4.4.1 Portrayal of my knowledge of learners' prior views and misconceptions about the Nature of Science

The scientific inquiry questionnaire evaluated learners' knowledge of how scientific custodians construct knowledge. The questions exposed learners' misconceptions of both declarative and procedural scientific knowledge. My thinking of learners' prior conceptions of scientific investigations impacts my planning and teaching of climate change. I made use of LPMCs to queue concepts as part of my PCK of CS in ways that effect conceptual change in learners' thinking models. In this way LPMCs are conceptual pointers to set up big ideas to challenge learners' thinking and make the topic understandable.

The learners' views on the scientific inquiry questionnaire adopted from Gaigher *et al.*, 2014 were catalogued into 3 sections which are sufficient, mixed and naïve. The category of learners' view was analyzed per question for each learner and summarized in a bar graph showing the learners' % responses to the questions on how science works. The totals of responses to the questionnaire show that learners' have a lot of naïve and mixed views of how canonical knowledge is made by scientists. A small number of learners had sufficient and correct understandings of the nature of scientific inquiry. In reaction to this outcome I decided to embed critical principles of scientific processes into the topic of climate to make the topic of climate change more teachable. The use of the questionnaire to unearth learners' prior conceptions portrays my PCK of LPMCs of NOS.




**Graph 4.2: A bar graph indicating the percentage of learners' responses on selected nature of scientific inquiry questions**

The bar graph enabled me to see how learners conceptualize the way scientific investigations are carried out by mapping out their views of specific NOS tenets. Question 1(a) had a continuum of responses with 50 % of learners having mixed views of what constitutes an investigation because they could not justify their correct responses indicating conceptual gaps in reasoning skills of how scientific studies are carried out and 40% of the learners had naïve views indicating deep misconceptions of NOS. One of the learners' misconceptions was that valid science is limited to laboratory work by doing experiments. This is shown by the learner (L) who wrote:

> L: No (it is not a scientific investigation), it is not scientific because he did not test anything. He just concluded his investigation…

A few learners' answers were sufficient. 10% of the learners gave correct answers supported by a scientific reason. One of the correct views of science stated by a learner is shown below:

> L: Yes (It is a scientific investigation), because science is when you observe and study … things that occur in nature.

Question 1(b) tests learners' understanding of the role of data in experiments. Almost 80% of the learners have mixed views on what constitute an experiment. Many learners found it difficult to state the function of data in experiments. While learners are able to identify the scenario as an experiment, many learners had no evidence to support their answers. The naïve view was that all experiments include practical activities. One learner wrote;

> L: why should it be an experiment ... he won't be doing any practical work…

Only 20% of learners had sufficient knowledge that it was an experiment. A learner wrote;

L: Yes (it is an experiment) because there is data collection.

Question 1(c) tested learners' views on the scientific method. 26% of learners had naïve views as shown by the learner who wrote;

L: No (it is not a scientific method) … it can be wrong to try out different methods…

The learners with sufficient views were able to give a reason for their answers with a correct example constituted 16% and characterized by the learner who wrote;

L: Yes (it is a scientific method), An investigation to see if boys are really smarter than girls. We can carry out a survey…, An experiment to see if a double-star super-nova exists, different methods will be used.

Learners with mixed views gave the correct response but failed to rationalize their thinking. A learner with mixed views of the scientific method wrote;

L: Yes. There are different ways to see cells… hand-lens microscope and light microscope. Their view of scientific methods is limited to the steps in experiments when doing science.

In question 4 learners are asked to give the differences between data and evidence. The learners' responses are poor with 68% of learners having naive views of what data and evidence is in scientific discourse. Learners conflate data and evidence and see them as synonyms. Most learners lacked knowledge to separate data and evidence as shown by the learner who wrote;

L: No, they are not different from one another in any way because your data is the evidence…

The learners' responses that gave mixed views was 11% indicating that a small number of learners had a fair level of understanding data and evidence in scientific settings. A learner with this view wrote;

L: Yes (data and evidence are different). Data is information captured. Evidence is data that proves a certain statement so, the difference is small.

The learners that possessed a correct conceptual model of data and evidence was 21% of the class for example one learner stated;

L: Data is information that you collected while evidence is data…to support your claim…

In question 6 learners were asked to relate data collection to scientific conclusions. Half of learners making up 53% gave adequate responses such as a learner who wrote;

L: Plants grow taller with less sunlight according to the data as there is less sunlight the more the plant grows….

26 % of learners had mixed views showing that they had a limited understanding of how data collected leads to conclusions when doing scientific experiments.

L: Option c- it receives sunlight but does not grow.

The learners with naïve views were 21% indicating that they have difficulties with the data which was in conflict with their general everyday discourse as evident in a learner who wrote;

L: Option c, there was no sunlight at all…the plant grew from no sunlight.

This indicate that learners' come to science classrooms with prior conceptions that may contradict scientific constructs.

#### 4.4.4.2 My knowledge to challenge learners' Misconceptions in the Nature Of Science

My use of big ideas in NOS to confront learners' misconceptions displays my PCK of CS. The teaching of NOS confronts learners' misconceptions and made the topic of climate change teachable. The questionnaire exposed learners' views on the use of the scientific method in coming up with scientific models, differences between data and evidence and the use of data in coming up with scientific conclusions. Most of the learners' prior thinking of these principles of NOS was incorrect. The teaching of some tenets of NOS prior to teaching the climate change was to interrogate learners' misconceptions in what counts as science and expose their incorrect views of NOS. My thinking was to use case studies to give learners situations of how scientists carry out investigations and the history of scientific models. I had a class discussion with learners to share ideas on a case study appendix-17. My objective of this classroom talk was to make learners understand that scientists use of data and evidence to come up with specific conclusions and explanatory models. This is portrayed in the snapshot in figure 4.22.

| | |
|---|---|
| Mr. Chigura: | What did Nicholas do in the case study? |
| Katlego: | …sir Nicolas Copernicus developed a new model from the motion of the planets that stated the position of the Sun in the Solar system. |
| Tebogo: | Explain what data and evidence is ... |
| Mr. Chigura: | Mulisa … |
| Mulisa: | The data is the evidence made in the information and the evidence is the data that is used to support a clear hypothesis... |
| Mr. Chigura: | So far, his definitions are correct … now can you mention examples in the passage. |
| Mr. Chigura: | Karabo... |
| Karabo: | Observe the investigation that was made by Kepler which was taken into consideration by Copernicus who used it to prove that planets moved in perfect circles. |
| Mr. Chigura: | …so is that falling under data or evidence? |
| Learners: | Evidence. |
| Mr. Chigura: | Evidence …you are saying that when Kepler analysed, … that is only when those numbers started making sense then they …become something meaningful hence they are his evidence … |
| Learners: | Yes |
| Mr. Chigura: | Otherwise numbers by themselves are meaningless…Yes |
| Mahlatse: | Johannes Kepler analysed the orbit of each planet and found that it was an ellipse. |
| Mr. Chigura: | Alright. |
| Mahlatse: | To show that planets did not move in circles. |

**Figure 4. 22: A snapshot portraying my knowledge to challenge learners' misconceptions in NOS**

The case study provides an authentic setting to cement the way learners understand the difference of data and evidence and how they are used in scientific studies. Case studies confront learners' incorrect scientific conceptions and point out that scientific knowledge is underpinned by evidence. The relook of scientific knowledge in the shape of planetary orbits from concentric to elliptical is in line with the new data that give different conclusions. Case studies give a historical setting of the tensions of how new evidence is canonized into scientific discourse. The use of the case study challenge learners' misconception that data is the same as evidence. My thinking at this point is that the concept of tentative scientific models will become a big idea in teaching the shift from the common GHE to the enhanced GHE based on data from $CO_2$ levels and evidence of increase in global temperatures.

#### 4.4.4.3 Portrayal of my knowledge of learners' prior views and misconceptions in climate change

My knowledge of LPMCs is sourced from giving learners an adopted VoCC questionnaire in appendix-7 prior to teaching climate change. The different questions unearthed a continuum of learners' prior knowledge and incorrect conceptions. The results of their prior conceptions are summarized in table 4.4. The learners' prior knowledge shows conceptual gaps in the way they conceive climate constructs and this helped me to see the constructs they find difficult to understand. The class had a mean score of 4 out of a maximum of 12. Most of the learners had correct understanding that greenhouse gases and CFCs impact the global ecosystem. More than 70% of learners had incorrect conceptions of the GHE, C-footprint and ozone depletion. These findings shed light on which concepts learners find difficult in the topic.

**Table 4.4: Show results of learners' knowledge in climate change concepts**

| Concept | Correct (%) |
|---|---|
| Greenhouse Effect | 27 |
| Ozone depletion | 30 |
| Carbon footprint | 28 |
| Greenhouse gases | 64 |
| CFCs | 66 |

Most learners could categorize greenhouse gases and CFCs. However, this did not translate into knowing the impacts of these gases on the global ecology in terms of the GHE. Hence learners had low correct scores on questions that demanded an understanding of global warming and ozone depletion. From the results I predicted that the concepts learners are going to find difficult are the GHE, enhanced GHE and the C- footprint. This knowledge made my post CoRe compatible to my Grade 11 learners' thinking models.

### 4.5 Discussion on my teaching knowledge

The reflections and discussion on my teaching experiences portray the thinking that pin down my PCK of climate change and reframing of my PCK shifts in the self-study when teaching the Chemistry of climate change to Grade 11 learners.

#### 4.5.1 My knowledge of Learners' prior conceptions and misconceptions

My expertise of how to investigate learners' misconceptions enables me to conceptually discover learners' alternative conceptions that contradict canonical knowledge. My PCK of LPMCs is a vital component of specialized knowledge because it challenges learners' thinking. Previous to teaching, I examined learners' prior ideas to get insight into the contradictions, tensions, and content inconsistencies they bring to class. Learners have naive and varied understandings of competing notions of climate change and the nature of scientific inquiries. This was a signal to the instructor to build visible constructions demonstrating how scientists generate constructs. This background necessitated the teaching of certain NOS concepts in the case study in order to address LPMCs and alter learners' perceptions of how science works. There is minimal planning to teach the NOS in my pre-CoRe. As a result, the history of climate change is obscure. I do teach the GHE over the course of the study by providing a graphical picture of how CO2 levels have risen before to and during the industrial revolution. Wise (2010) emphasizes the historical background of climate change. Mc Ginnis

(2016) emphasizes the need of confronting learners' misunderstandings about climate change while teaching the history of climate change.

My ability to elicit learners' assumptions grew as a result of deliberately exposing their thinking prior to introducing the questionnaire ideas. Prior to doing the self-study, my understanding of learners' preconceived notions was limited. The reason for this is because I lacked preceding teaching activities that would have allowed learners to discover their pre-instructional understandings. This finding is congruent with Hadiyanti, Widodo, and Rochintaniawati (2015), who discovered that science teachers seldom address students' misunderstandings. However, throughout the research, my preparation and instruction reflected understanding of LPMCs in that I used the VoCC and VASI to extract previous knowledge from learners.

The methodology and reframing of my teaching in the course of the self-study introduced this critical thinking of constructive teaching. The conscious decision to detect learners' misconceptions is a situation of my active learning in practice. The knowledge of LPMCs is more than a display of learners' conceptual gaps. This knowledge constitutes conceptual templates to construct big ideas in the topic The teachers' knowledge of learners' prior conceptions is the conceptual point to commence teaching in a more constructive way that create conceptual links for learners to easily understand classroom content.

### 4.5.2 My knowledge of Curricula Saliency

This knowledge expresses my value of specific gate keeping concepts to make the topic understandable for learners in the self-study. The pre and post CoRes indicate that in the course of the self-study I had developed more CS. This was induced by critical reflection of at my prior conceptions and a study of teaching experiences. The LTtP model was a tool that helped me to relook at my CS in the pre CoRes. The pre CoRe was my point of reference to reframe my CS that is portrayed in the post CoRe and my classroom experience. Reflections in the journal also give acumens into my specialized knowledge of CS. The use of my CS in coming up with specific big ideas is coherent in the post CoRe. In the extracts from the lessons my CS manifests in the classroom in the teaching of big ideas in NOS prior to climate change.

### 4.5.3 My knowledge of Representations

I made use of specific representations to make learning of difficult concepts easy in the classroom. These constitute diagrams, graphs, models of ice cores and analogies. The analogy of the greenhouse as the global atmosphere concretized the abstract concept of the enhanced GHE which the learners find difficult to understand. The use of an analogy considers learners' own preconceptions from their everyday experiences. Representations of this form are more intelligible conceptual tools that connect learners' prior knowledge with the classroom content and develops learners' conceptual models. The objective of the ice core modelling activity was to develop the big idea of anthropogenic climate change from an increase in carbon dioxide levels due to human activities. The ice core model activity was a conceptual tool to portray how scientists use models to support anthropogenic climate change. The data of $CO_2$ levels in ice cores is consistent with the climatic model of the enhanced GHE. The ice core model also includes the concept of chemical equations which are represented at symbolic and molecular levels as Lewis structures to make the concept more intelligible for learners. This sophisticated account of visual representations in the post CoRe to make the content teachable portrays my PCK of RMARs.

### 4.5.4 My knowledge of learners' socio-scientific reasoning

My knowledge of LSSR is portrayed in classroom activities that created opportunities for learners to construct knowledge on the intertwines of science and society. The C- footprint worksheet drew from learners daily lives activities that increase the C-footprint. This social tool mediated the learning of that difficult concept. The use of case studies on the history of $CO_2$ levels in the ice cores and the graph that show $CO_2$ levels and global temperatures portray the interconnectedness of science, society, technology and the ecology. The teaching of science concepts with specific authentic contexts portray my PCK of LSSR to show learners that specific social and technological activities impacts the ecology.

### 4.5.5 My knowledge of Topic Comprehensibility Difficulty

My PCK of TDC is specialized knowledge to pinpoint concepts that are difficult for learners to understand and come up with ways to make teachable in the classroom. The dual questionnaires as investigative tools achieved the objective to detect constructs that learners find problematic in both the NOS and climate change. The thinking and executions to make concepts simple ensued the prognosis of a difficult concept such as in the case of the non-intuitive concept of the enhanced GHE. Learners found it difficult to learn because they cannot generate conceptual models from common sense. For learners to develop correct scientific models the I used an analogical model to concretize the enhanced GHE. Once a difficult concept was detected prior to teaching I developed ways to make it teachable in the classroom.

### 4.5.6 My knowledge of Learners' Procedural Knowledge

The PCK of LPK that I portray in teaching the topic of climate change was confined to learners' procedural skills that comprise scientific variables in investigations, data and evidence, and the tentative nature of constructs that I see as critical to develop competencies in science literacy. I made use of socio-historical activities in the worksheets as a context in which the NOS tenets play out and embed climate change concepts. Case studies and ice core models were the conceptual tools in teaching the LPK. The VASI questionnaire was a tool to carry out a prognosis on learners prior and misconceptions on how scientists come up with scientific knowledge.

**4.6 Conclusion of Chapter 4**

In chapter four I have displayed the findings from the data analysis of pre and post concept maps, pre and post CoRe, PaP-eRs, journal and what I have defined as my teaching tools. I have also indicated what I have come to know on how to develop content knowledge in the topic of climate change and teaching this intricate topic. In chapter five I will give the reflections, recommendations and implications of the self-study.

# CHAPTER 5

## REFLECTIONS, LIMITATIONS, IMPLICATIONS AND RECOMMENDATIONS

### 5.1 Introduction

In this chapter, I look at the experiences drawn from the self-study in terms of my intentions to develop, observe and portray my CK and PCK for teaching secondary school climate change. This chapter gives the reflections, limitations, implications and recommendations that came from the self-study.

### 5.2 Reflections

This self-study sought to identify changes in my CK and PCK when teaching climate change to Grade 11 students in my class. The study's goal was to model my knowledge for planning and teaching using various tools and to observe any changes in my CK and PCK. The tools that captured and portrayed my CK and PCK were concept maps, CoRes, PaP-eRs, a reflective journal, and other teaching artefacts. The findings show how I came up with my knowledge of climate change content and pedagogy, as well as the shifts from prior to post CK and PCK. The self-study provided experiences and opportunities to gain knowledge and experience in planning and teaching a socio-scientific topic. Personal research and the exchange of ideas with other colleagues and mentors raised my awareness of teaching. The study aided my CK and PCK in teaching Physical Science topics at the high school level.

### 5.3 Research question 1

What are my conceptions of Content Knowledge and how are they shifting when teaching the Chemistry of climate change to Grade 11 learners doing Physical Sciences?

#### 5.3.1 Findings

In this study, I discovered that reflecting on my CK as part of my preparation to teach about climate change increased my teaching knowledge. The concept maps I created for this self-study depict CK of climate change. This finding confirms that I have CK for teaching climate change as a Physical Sciences teacher. This is consistent with the findings of Ball et al. (2008), who state that a teacher's CK can be seen in the way constructs are reconceptualized to meet the objectives of the lesson. My CK was depicted and observed in concept maps in this study. Identified as a teaching tool that demonstrates a teacher's knowledge of a subject (Novak, 2010).

The prior and post concept mapping, on the other hand, show a shift in my CK of climate change at the beginning and end of the study. The differences between pre- and post-concept mapping indicate shifts in my climate change knowledge. I had developed a more sophisticated CK of climate change by the end of the study. I discovered that at the start of the self-study, I had few big ideas about climate change. My post concept map included enough concepts such as greenhouse gases, GHE, and C-footprint. According to Anyanwu et al. (2015), for effective climate change education, teachers must be able to identify greenhouse gases, explain the GHE, and describe the C-footprint. However, as I framed and reframed my CK in the self-study, my CK shifted in concept mapping. The findings indicate that my CK is essential for developing expert knowledge and big ideas for teaching Physical Science topics.

### 5.3.2 Recommendations

Teaching is a profession that requires teachers to have solid and up-to-date knowledge of major concepts in their subject areas. The development of teachers' CK is a critical component of their good practice. Teachers must be critical of their CK in order to shift their understandings of big ideas in topics. This can be done with the help of other teachers in professional learning communities. Teachers' specialized knowledge is becoming more solid as they reconsider their CK and PCK in specific topics. A shift in teaching methods that incorporates CK reflections may make the concepts more teachable in science classrooms. Other teachers may benefit from such reflection on their teaching planning as well.

## 5.4 Research question 2

How is the portrayal of my Pedagogical Content Knowledge when teaching the Chemistry of climate change to Grade 11 learners?

### 5.4.1 Findings

I discovered that my PCK could be portrayed in certain pedagogical techniques to demonstrate my understanding of teaching a specific topic. This research demonstrates that teachers' knowledge on how to teach climate change may also be expressed via CoRes, PaP-eRs, teachers' notebooks, and teaching artefacts. The usage of pre- and post-CoRes prompted me to consider my PCK. An activity that has the potential to alter a teacher's PCK. This is confirmed by Loughran (2010), who asserts that when instructors rethink their instruction in order to make material teachable, their PCK may improve. The above results demonstrate that I effectively recorded and represented my PCK on climate change, which contributes to my body of knowledge in scientific teaching. Gess-Newsome (2015) argues that instructors may examine their teaching critically in order to improve their practice. The research established that the complexities of teaching knowledge from expert instructors may be decoded into canonical knowledge forms that can be used to create knowledge and skills for teaching in communities of practice. This is congruent with research undertaken by Mavhunga in 2018 to capture and depict PCK for major secondary school Chemistry topics such as Chemical Bonding and Chemical Equilibrium. This study shows that the teachers' knowledge of teaching climate change can also be concretized in CoRes, PaPeRs, teachers' journals and teaching artefacts.

### 5.4.2 Recommendations

This self-study could be used as a case study for future studies to model PCK in secondary school science topics. Looking at the research question in the self-study, I can say that I developed and presented my PCK for teaching in the most professional way possible. Science education is now a critical tool for developing knowledge and skills that will transform students into global citizens who understand the relationship between science and society in their communities. Self-study may be used to improve pedagogy for teaching socio-scientific topics. Uncovering pedagogy is a body of knowledge from which teachers can draw to inform their own practice and contexts. This research could help and contribute to the portrayal of teachers' knowledge and practices.

## 5.5 Research question 3

How is my Pedagogical Content Knowledge shifting throughout the self-study when teaching the Chemistry of climate change to Grade 11 learners?

### 5.5.1 Findings

The findings show that my PCK is critical to come up with my own specialized knowledge and big ideas for teaching Physical Science topics to make the content more teachable. The process to come up with big ideas is from reframing my content knowledge for teaching to make learners easily understand the concepts. This is portrayed in the differences of pre- and post CoRes and PaPeRs that indicate a more sensible PCK at the end of the self-study. The findings show that my PCK is critical to come up with my own expert knowledge and big ideas for teaching Physical Science topics to make the content more teachable.

Anyanwu *et al*. (2015) found that some science teachers possess misconceptions in the topic of Climate change. However, the finding of the current study does not support this observation. I did not conflate ozone depletion with global warming. In my post concept mapping the GHE leads to global warming. Furthermore, Anyanwu *et al*. (2015) points out that teachers' misconceptions filter down to learners therefore, assume that my correct CK of the GHE are transmissible to learners in classrooms. The self-study has shown that a teachers' PCK can shift by caring out specific practices which in this case are set in the context of the study.

### 5.5.2 Recommendations

The self-study has shown that a teachers' knowledge of teaching may shift by doing specific practices which in this case are set in the context of the study. The core of self-studies drew from the contention that knowledge come from participation and a relook at the thinking in authentic situations. If teachers are proxies of their profession, then PCK must come from their daily classroom experiences. Teachers are practitioner within the knowledge setting and have specialized knowledge to derive meaning of pedagogies as they shift their knowledge of practice. Self-studies describe how I as a skilful teacher develop knowledge and skills in the context of their practice. This self-study has raised critical questions open for further interrogation. Self-studies in pedagogy allow the teacher to say their story when looking at their own teaching practice as they are experts in their own disciplines and have direct experiences to teaching and learning activities. When teachers are involved in critical reflection of their own practice their pedagogy will experience shifts.

### 5.6 The limitations of the self-study

The limitation of this self-study is that teachers' PCK is not easily seen in teachers practice and it is time consuming to capture and portray. The self-study was constrained by the inherent nature of PCK as an intricate and tacit concept. The use of CoRes and PaP-eRs to explicate the teachers' PCK for climate change consume a lot of time because they require elaborate treatment in their construction and analysis. This activity is possible within the borders of a well-grounded research as in ordinary classroom teaching practice teachers would find it problematic to articulate their big ideas and unpack these conceptual tools sufficiently. The PCK for socio-scientific topics is a contemporary area of pedagogy research that fits in with current goals of science education. This self-study seeks to contribute CK for teaching climate change.

### 5.7 Implications of the self-study

It is advised that stakeholders in teaching and learning at secondary schools look at the possibilities of mixing the concepts in cross-cutting topics such as climate change. This will enable the teaching of specific concepts with more depth and minimal repetitions and misconceptions. Self-studies are a source of big ideas teachers come up with in their own subjects. Curriculum practitioners may use these cases to construct an integrated science curriculum.

#### 5.7.1 Implications on teachers' content knowledge

Concept maps improve curriculum saliency by providing cognitive tools to restructure the concepts in ways that interconnects the big ideas in cogent ways that integrate constructs to make meaningful bodies of knowledge and skills. Therefore, concept maps may be part of lesson preparation in the planning section of teaching to facilitate teaching of the big ideas. The big ideas are made explicit in the concept maps and this helped to develop my knowledge base of content knowledge to know how it impacted on my teaching methodologies.

#### 5.7.2 Implications on teachers' pedagogical content knowledge

The adopted pre- and post-CoRes may be tools to personalize teachers' classroom practice. CoRes are constructed as a means to observe and develop the thinking that underpins the complexities embedded in the act of teaching climate change to Grade 11 learners. The analysis of CoRes and PaP-eRs show evidence of evolution in my specialized knowledge for teaching with the objective to increase the way classroom content is made more teachable. It is critical to include socio-scientific topics across in the science curriculum so that the objective of teaching science for scientific literacy is realized. When learners understand the big ideas it will propel them to learning experiences that are worthwhile. An implication of this is that teachers may own their own pedagogy as specialists with professional knowledge germane in their science classrooms. The CoRes showed that I could develop knowledge and skills of teaching climate change in the course of the study.

### 5.7.3 Implications for future research

The pedagogical routes of future research grounded by issues that have come out of the self-study have various connotations. This study has made me to be critical of the philosophies of teaching socio-science topics in terms of planning and teaching methodologies. The current South African curriculum has limited socio-scientific topics in the CAPS. To contextualize classroom science, the teacher has to connect scientific constructs and everyday experiences for scientific literacy The self-study made me develop my CK and PCK in ways to make me comprehend more of the conceptual processes as I framed and reframed my specialized knowledge. The implications for further study that emanate from this self-study are that teachers have professional growth opportunities when they research their own profession in their capacity as science teacher specialists. The impact of the investigation on various elements of classroom practice still needs more examination. The ways in which learners may benefit from self-studies by their teachers is an interesting area of concern as learner performance is a critical indicator of pedagogy. The impact of socio-scientific themes on learners' gains of scientific literacy is an extension of such self-studies. Communities of practice make teachers share ideas with the objective to improve their teaching of specific science topics. Future studies may look at the impact of self-studies on learners' performance in specific topics.

## 5.8 Conclusion

This self-study stress how I as the pedagogue may develop my CK and PCK from critical methodologies of doing a self-study. If teachers have tendencies to replicate their own classroom experiences, then an interposition to develop their pedagogy could be through self-studies. A self-study is an alternative research method in pedagogy where the pedagogue constructs his/her own concoction of specialized content knowledge of teaching by looking at their practice. This self-study embodies a case where I was not conjuring general teaching methodologies but critically looking at the intricate knowledge elements in my practice when teaching Climate change. The concept maps, CoRes, journal and teaching artefacts are the study tools that portray my thinking and class activities of how to make learning of climate change more understandable. This study is a case that other science teachers may look at as my experience of teaching climate change and may draw out specific knowledge and skills.

This study is my story of portrayal and evolution of my competencies in CK and PCK. My study embraces individual and collective solidarity with the objective to develop CK and PCK in the context of teaching climate change. The self-study was a worthwhile journey to develop and deepen my CK and PCK of climate change and I hope the knowledge and skills I have gained can be of use in other science topics and to other teachers.

**REFERENCES**


Abd-El-Khalick, F. (2005). Developing deeper understandings of nature of scienceThe impact of a philosophy of science course on pre-service science teachers' views and instructional planning. *International Journal of Science Education*, *1*, 15.

Abd-El-Khalick, F., & Zeidler, D. L. (2015). New Horizons for the Journal of Research in Science Teacher. *Journal of Research in Science Teaching, 52*(3), 263-267.

Aho, L. (1984). A Theoretical Framework for Research into Environmental Education. *International Research of Education, 30*(2), 183-191.

Aikenhead, G. (1994). What is STS Science Teaching. In J. Solomon, & G. Aikenhead, *STS Education: International perspectives on reform* (pp. 47-49). New York: College Press.

Akin, N. F., & Kondakci, E. (2018). The Nature of the Interplay amoung components of Pedagogical Content Knowledge in Reaction Rate and Chemical equilibrium topics of novice and experienced Chemistry teachers. *International Journal of Science Education, 19*(1), 80-105.

Anyanwu, R., Grange, L., & Beets, P. (2015). Climate change science: The literacy of Geography teachers in the Western Cape Province, South Africa. *South African Journal of Education, 35*(3), 1-9.

Appamaraka, S., Suksringarm, P., & Singseewo, A. (2009). Effects of Learning Environmental Education Using the 5Es- Learning Cycle Approach with theMetacognitive Moves and theTeachers' Handbook Approach on Learning Achievement, Integration Science Process Skills and Critical Thinking of High School students. *Pakistan Journal of Social Sciences, 6*(5), 287-291.

Bartos, S. A., & Lederman, N. G. (2014). Teachers' Knowledge Structures for Nature of Science and Scientific Inquiry: Conceptions and Classroom Practice. *Journal of Research in Science Teaching, 51*(9), 1150-1184. doi:10.1002

Bayir, E., Cakici, Y., & Etas, O. (2014). Exploring Natural and Social Scientists' Views of Nature of Science. *International Journal of Science Education*, 1286-1312.

Bektas, O., Ekiz, B., Tuysuz, M., Kutuka, S. E., T, A., & Kondakci, E. U. (2013). Pre-service chemistry teachers' pedagogical content knowledge of the nature of science in the particle nature of matter. *Chemistry Education Research and Practice, 14*, 201-213.

Bell, J. (2010). *Doing your research* (6 ed.). London: McGraw Hill.

Berry, A., & Loughran, J. (2010). *What do we know about effective.* York.

Bishop, K., & Denley, P. (2007). *Learning Science Teaching: Developing a Professional Knowledge Base.* New York: Open University Press.

Booi, K., & Khuzwayo, E. M. (2019). Difficulities in developing curriculum for preservice science teachers. *South African Journal, 39*(3), 13.

Boon, H. J. (2010). Climate change? Who knows? A comparison of secondary students and pre-service teachers. *Australian Journal of Teacher Education*, 104-120.

Bowen, E. (2003). Student Engagements and Its Relation to Quality Work Design: A Review of the Literature. *Action Research Exchange, 2*(1), 1-13.

Branch, G., Rosenau, J., & Berbeco, M. (2016). Climate education in the classrooms: cloudy with a chance of confusion. *Bulletin Of The Atomic Scientists, 72*(2), 89-96.

Brodie, K., & Pournara, C. (2005). Towards a framework for developing and researching group work in mathematics classrooms. In R. Vinthal, J. Adler, & C. Keitel, *Mathematics and educationresearch in South Africa: perspective, practices and possibilities.* Cape Town: Human Sciences Research Council.

Brown, G. (2010). Service Learning in the Scholarship of Teaching and Learning: Effective Practices. *International Journal for the Scholarship of Teaching and Learning, 4*(2), 1-17.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher*, 32-40.

Budprom, W., Suksringam, P., & Singsriwo, A. (2010). Effects of learning environmental education using the 5E learning cycle with multiple intelligences and teachers' handbook approaches on learning achievement, basic science processes skills and critical thinking of grade 9 students. *Pakistan Journal of Social Sciences, 7*(3), 200-204.

Burg, E. V. (2012). A Physics Teacher's Lifetime Search for PCK and Physics Representations across Contexts and Cultures. *Proceedings of the World Conference on Physics Education*, 23-37.

Carlson, J., Stokes, L., Helms, J., Gess-Newsome, J., & Gardner, A. (2015). The PCK Summit: A process and structure for challenging current ideas, provoking future work, and considering new directions. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 3-14). New York: Routledge.

Carr, M., Barker, M., Bell, B., & Biddulph, F. (1994). The constructivist paradigm and some implications for science content and pedagogy. *The content of science : a a constructivist approach to its teaching and learning*, 147-158.

Cochran, K., DeRuiter, J., & King, R. (1993). Pedagogical content knowing: an integrative model for teacher prepartion. *Journal of Teacher Education, 44*(4), 263-272.

Cohen, L., Manion, L., & Morrison, K. (2003). *Research Methods in Education.* London: Routledge.

Coia, L., & Taylor, M. (2009). "Co/autoethnography: Exploring our teaching selves collaborately". *Research methodsfor the self-study of practice*, 3-16.

Cooper, R., & Loughran, J. (2015). Science Teachers' PCK. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 60-74). London: Routledge.

Crowe, A. R. (2010). *Advancing social studies education through self study methodology: The power, promise, and use of self-study in social studies education* (Vol. 10). Kent: Springer.

Daehler, K., Heller, J. I., & Wong, N. (2015). Supporting growth of pedagogical content knowledge in science. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 45-49). London: Routledge.

Davidowitz, B., & Chittleborough, G. (2009). Linking the Macroscopic and Sub-microscopic Levels: Diagrams. In J. K. Gilbert, & D. Treagust, *Multiple representations in chemical education* (pp. 169-191). Dordrecht: Springer.

Dawson, C. (2002). *Practical Research Methods.* New Delhi: USB.

Demirdogen, B., Ayadin, S., & Tarkin, A. (2015). Looking at the Mirror: A Self-Study of Science Teacher Educators' PCK for Teaching Teachers. *Eurasia Journal of Mathematics, Science and Technology, 11*(2), 189-205.

Dhindsa, H. T., & Treagust, F. D. (2014). Prospective Pedagogy of Teaching Chemical Bonding for Smart and Sustainable Learning. *Chemistry Education Research and Practice*, 1-20.

DoBE. (2011, 2/4/12, 4 20). *Curriculum and Assessment Policy Statement (CAPS) Physical Sciences grades 10, 11, 12.* Pretoria: Government Printing Works. Retrieved 2017, from http.

DoBE. (2011, 4/2/12). *Curriculum and Assessment Policy Statement (CAPS) Natural Sciences Grade 7, 8, 9.* Pretoria: Government Printing Works.

Driver. (1994). Constructing Scientific Knowledge in the classroom. *American Research Association*, 5-11.

Driver, R., Squires, A., Rusworth, P., & Robinson-Wood, V. (1994). Constructing Scientific knowledge in the Classroom 23 (6). *American Educational Research Association*, 5-11.

Duit, R. (2003). Conceptual change: a powerful framework for improving science teaching and learning. *International Journal of Science Education, 25*(6), 671-688.

Erduran, S., Simon, S., & Osborn. (2004). TAPping into argumentation: Developments in the Application of Toulmin's Argument Pattern for Studying Science Discourse. *Wiley InterScience*, 916-033.

Esa, N. (2010). Environmental knowledge, attitudes and practices of student teachers. *International Research in Geography and Environmental Education, 19*(1), 39-50.

Esme, H. (2014). How In Service Teachers Integrate History and Nature of Science in Elementary Science Courses. *Educational Sciences: Theory and Practice, 14*(1), 353-372. doi:10.12738

Evens, M., Elen, J., & Depaepe, F. (2015). Developing Pedagogical Content Knowledge: Lessons Learned from Intervention Studies. *Educational Research International*, 1-23.

Felipe, E. G., Cezar, F., Moloni, A., & Simarori, M. C. (2017). Analysis of a New Teaching Approach to teach Chemical bonding to High School Spanish Students . *Da investigato as Practicas,* 1-26.

Furio, C., Azcona, R., & Guisasola. (2002). The learning and teaching of the concepts ' Amount of Substance' and ' mole': A review of the literature. *Chemistry Education* , 277-292.

Furio, C., Azcona, R., Guisasola, G., & Ratcliff, M. (2000). Difficulties in teaching the concepts of amount of substances' and 'mole'. *International Journal of Science Education,* 1285-1304.

Fussel, M. H. (2007). Adaptation planning for climate change: concepts, assessments, and key lessons. *Sustainability science, 2*(2), 265-275.

Gaigher, E., Lederman, N., & Lederman, J. (2014). Knowledge about Inquiry: A study in South African high school. *International Journal of Science Education, 36*(18), 3125-3147.

Garritz, A., & Villa, O. N. (2012). Interviews and Content Representations for Teaching Condensed Matter Bonding. An Effective Component of Affective Component of PCK. *NARST conference* Indianapolis.

Geddis, A. N., & Wood, E. (1997). Transforming Subject Matter and Managing Dilemmas: A Case Study in Teacher Education. *Teaching and Teacher Education, 13,* 611-626.

Geddis, A., Onslow, B., Beynon, C., & Oesch, J. (1993). Transformimg contentknowledge: Learning to teach about isotopes. *Science Education,* 579-591.

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK Summit. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 28-40). New York Routledge.

Gijlers, H., & De Jong, T. (2005). The relation between prior knowledge and students' collaborative discovery learning processes. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 42*(3), 264-282.

Green, W., & Naidoo, D. (2006). Knowledge contents reflected in post-Apartheid South Africa physical science curriculum documents. *African Journal of Research in Maths, Science, Technology Education, 10*(1).

Gunstone, R. F. (2015). Re-examining PCK: A personal commentary. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 245-255). New York: Routledge.

Gupta, R. K., & Awasthy, R. (2015). *Qualitative Research in Management: Methods and Experiences.* London: Sage

.

Hackling, M. W., & Fairbrother, R. W. (1996). Helping students to do open investigations in science. *Australian Science Teachers Journal*, 26-33.

Hadiyanti, N. L., Widodo, A., & Rochintaniawati, D. (2015). Biology Teachers Content Representations (CoRes) in Concept of Human and the Environment. *International Conference on Mathematics, Science, and Education*, 1-5.

Hamilton, M. L., & Pinnegar, S. (2000). On the threshold of a new century: Trustworthiness, integrity, and self study in teacher education. *Journal of teacher education, 51*(3), 234-240.

Hanusein, D. L., Lee, M., & Akerson, V. (2010). Elementary Teachers' Pedagogical Content Knowledge for teaching Nature of Science. *Science Teacher Education*, 145-167.

Haugwitz, M., Nesbit, J., & Sandman, A. (2010). Cognitive Ability and the Instructional Efficiency of Collaborative Concept Mapping. *Learning and Individual Differences, 20*(5), 536-543.

Hedge, D. S. (2015). *Essay on Research Methodology.* London: Springer.

Hennessy, S. (2016). Developing s coding scheme for analysing classroom dialogue across contexts. *Learning, Culture and Social Interaction*, 1-8.

Henzle, I., & Van Driel, J. H. (2015). Toward a more comprehensive way to capture PCK in its complexity: A more comprehensive way to capture PCK. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining Pedagogical Content Knowledge in ScienceEducation* (pp. 120-134). New York: Routledge.

Herman, B. C., Feldman, A., & Hernandes, V. V. (2017). Florida and Puerto Rico Secondary Science Teachers' Knowledge and Teaching of Climate Science. *International Journal of Science and Math Education, 15*, 451-471.

Herman, B. C., Feldman, A., & Vernaza, V. (2013). Secondary Science Teachers' and Students' Climate Change Conceptions and Teachers' Climate Change Practices. *NARST.* Puerto Rico.

Herman, B., & Clough, M. P. (2017). The Role of History and Nature of Science in Climate Change Teaching and Learning. *Teaching and Learning about Climate Change*, 31-44.

Hiebert, J., Gallimore, R., & Stigler, J. (2002). A Knowledge Base for the Teaching Profession: What Would It Look Like and How Can We Get One. *Educational Researcher, 31*(5), 3-15.

Hobson, A. (2003). Physics literacy, energy and the environment. *Physics education, 38*(2), 109-114.

Homer, M. (2016). *The future of quantitative educational research methods: bigger, better and perhaps, Bayesian.* (3, Ed.) Leeds: Hillary Place Papers.

Howie, E. (2003). Language and other background factors affecting secondary pupils' performance in Mathematics in South Africa. *African Journal of Research in SMT Education, 27*(1), 1-20.

IPCC. (2014). *Climate change.* Paris: IPOC.

Jing-Jing, H. U. (2014). A critical review of Pedagogical Content Knowledge' components: nature, principles and trend. *International Journal of Education Research, 2*(4), 411424.

Khishfe, R. (2014). Explicit Nature of Science abd Argumentation Instruction in the Context of Socioscientific Issues: An effect on student learning and transfer. *International Journal of Science Education*, 974-1016.

Khishfe, R., & Abd-El-Khalick, F. (2002). The influence of explicit and reflective versus implicit-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching, 39*(7), 551-578.

Kilia, M., & Cakmak, M. (2013). Concept Maps as a tool for Meaningful Learning and Teaching in Chemistry Education. *International Journal on New Trends in Education and Their Implications, 4*(4), 1-14.

Kim, B. S., Ko, K. E., Lederman, N. G., & Lederman, J. S. (2005). A Developmental Continuum of Pedagogical Content Knowledge for Nature of Science Instruction. *Annual meeting of the National Association for Research in Science Teaching* (pp. 1-36). Dallas: Department of Mathematics and Science Education.

Kim, T., & Axelrod, S. (2005). Direct Instruction: An Educators' Guide and a Plea for Action. *The Behaviour Analyst Today, 6*(2), 11.

Kind, V. (2015). On the beauty of knowing then not knowing: Pinning down the elusive qualities of PCK. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 178-195). New York: Routledge.

Kirschner, S., Taylor, J., Rollnick, M., Borowski, A., & Mavhunga, E. (2015). Gathering evidence for the validity of PCK measures: Connecting ideas to analytic approaches. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining pedagogical content knowledge in science education* (pp. 229-234). London: Routledge.

Kolsto, S. D. (2001). Scientific literacy for citizenship: tools for dealing with the science dimension of controversial socio-scientific issues. *Science Education, 85*(3), 291-310.

Krippendorff, K. (2018). *Content Analysis: An Introduction to its Methodology.* Pennsylvania: SAGE.

Larrain, A., Howe, C., & Cerda, J. (2014). Argumentation in Whole-Class Teaching and Learning. *International Educational of Science Research, 23*(2), 1-45.

Lavaniegos, B. E. (2018). Consequences of Climate Change on the Oceans: Widening the Scope of Environmental Policies in North America. 95-110.

Lave, J. (1996). Teaching, as learning, in practice. *Mind Culture and Activity, 3*(3), 149-163.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate Peripheral Participation.* Cambridge: Cambridge University Press.

Lave, J., & Wenger, E. (1996). Practice, person, social world. In H. Daniels, *An Introduction to Vygotsky* (pp. 143-150). London: Routledge.

Leach, J., & Scott, P. (2003). Individual and sociocultural views of learning in science education. *Science and education, 12*(1), 91-113.

Lederman, G. (2006). Research on Nature of Science:Reflections on the Past, Anticipation of theFuture. *Asian-Pacific Forum on Science Learning and Teaching*, 1-12.

Lederman, N. G., & Lederman, J. S. (2017). The Future of Peer Review. *Journal of Science Teacher Education, 28*(3), 219-221.

Linder, C., Ostman, L., Roberts, D. A., Wickman, P., Erickson, G., & MacKinnon, A. (2011). Overview of Scientific Litercacy and the state of art in School Science Education. In C. Linder, L. Ostman, D. A. Roberts, P. Wickman, G. Erickson, & A. MacKinnon, *Exploring the Landscape of Scientific Literacy* (pp. 1-7). NewYork and London: Routledge.

Loughran, J. (2010). *What expert teachers do: Teachers' professional knowledge of classroom practice*. Sidney: Allen & Unwin.

Loughran, J. J. (2002). Effective Reflective Practice: In Search of Meaning in Learning about Teaching. *Journal of Teacher Education, 53,* 33-43.

Loughran, J. J. (2015). "Critical think pieces": Thinking about teaching as sophisticated business. In D. Garbett, & A. Ovens, *Teaching for tommorow today* (pp. 3-10). Auckland: Edify.

Loughran, J. J., Berry, A., Mulhall, P., & Woolnough, J. (2006). *Understanding and valuing the development of pedagogical content knowledge in science teacher education.* Rotterdam: Sense Publishers.

Loughran, J., Mulhall, P., & Berry, A. (2004). *Understanding and developing science teachers pedagogical content knowledge.* Rotterdam: Sense publishers.

Lubben, F., & Bennett, J. (2008). From novel approach to mainstream policy? The impact of context-based approaches on chemistry teaching. *Chemistry educartion*, 252.

Lunenberg, M., Zwart, R., & Korthagen, F. (2010). Critical issues in supporting self-study. *Teaching and Teacher Education*, 1280-1289.

Malcom, S. A., Mavhunga, E., & Rollnick, M. (2018). A lesson on teaching the mole concept conceptually: A learning study. *26th conference of the Southern African association for research in mathematics, science and technology education* (pp. 179-168). Gaborone: SAARMSTE.

Matthews, K., Cook, A., & Acia, A. (2019). Towards theories of partnership praxis: an analysis of interpretive framing in literature on students as partners in teaching and learning. *Higher Education Research and Development, 38*(2), 280-293.

Mavhunga, E. (2018). Revealing the Structural Complexity of Component Interactions of Topic-Specific PCK when Planning to Teach. *Research Science Education*, 1-22.

Mavhunga, E., & Rollnick, E. (2014). PCK of teaching electrochemistry in chemistry teachers: A case in Johannesburg, Gauteng Province, South Africa. *Chemistry Education, 25*(3), 354-362.

Mavhunga, E., & Rollnick, M. (2012). Development and pilotting a tool for measuring topic-specific PCK in chemical equilibrium. *European Science Education Research Association.* Science education and citizenship.

Mavhunga, E., & Rollnick, M. (2013). Improving PCK of chemical equilibrium in pre-service teachers. *African Journal of Research in Mathematics, Science and Technology Education, 17*(1-2), 113-125.

Mavhunga, E., Ibrahim, B., Qhobela, M., & Rollnick, M. (2016). Students teachers' competence to transfer strategies for developing PCK for electric circuits to another Physical Sciences topic. *African Journal of Research in Mathematics, Science and Technology Education*, 1-15.

Mc Ginn, M. K., & Roth, W. M. (1999). Preparing students for competent scientific practice: Implications of recent research in science and technology studies. *Educatiotional researcher, 28*(3), 14-24.

Mc Ginn, M., & Roth, W. (1999). Preparing students for competent scientific practice: Implications of recent research in science and technology studies. *Educational Researcher, 28*(3), 14-24.

Mc Ginnis, R. J., Mc Donald, C., Hestness, E., & Breslyn, W. (2016). An Investigation of Science Educator' Views of Roles and Responsibilities for Climate Change Education. *Science Education International, 27*(2), 179-193.

McComas, W. (1996). Ten Mtyths of Science: Reexamining what we think we know. *School Science and Mathematics, Vol. 96*, 1-10.

McComas, W. (1996). Ten myths of science: Re-examining what we think we know. *School Science and Mathematics, 96*, 10.

Michael, P. C. (2007). Teaching the Nature of Science to Secondary and Post -Secondary Students: Questions Rather Than Tenets. *Centre for Excellence in Science and Mathematics Education*(25), 1-5.

Michell, I., Keast, S., Panizzon, D., & Mitchell, J. (2017). Using 'big ideas' to enhance teaching and student learning. *Teachers and Teaching, 23*(5), 596-610.

Mifsud, M. (2011). An Investigation on the Environmental Knowledge, Attitudes and Behavior of Maltese Youth. *US-China Education Review B*, 413-422.

Mihladiz, G., & Dogan, A. (2011). Pre- service science teachers' subject matter knowledge of the nature of science. *Western Anatolia Journal of Educational science*, 311-316.

Miles, M. B., & Huberman, A. (1994). *Qualitative data analysis: A sourcebook.* Beverly Hills: Sage Publication.

Nakedi, M. (2014). Profiling chemistry teachers' changing PCK . In H. Venkat, M. Rollnick, M. Askew, & J. Loughran, *Exploring Mathematics and Science Teachers' Knowledge: Windows into teacher thinking* (pp. 84-95). Oxford: Routledge.

Nakedi, M., & Rollnick, M. (2012). Planned Actions, Reflective Practice and the Shifting Knowledge Base- the Journey of one Science FET Teacher. *The 30th Annual Meeting of the Southern African Association for Research in Mathematics, Science and Technology Education. 1*, pp. 381-394. Blantyre: SAARMSTE.

Novak, D. J. (2010). Learning, Creating, and Using Knowledge: Concept maps as facilitative tools in schools and corporations. *Journal of e-Learning and Knowledge Society, 6*(3), 21-30.

O'Donoghue, R. (2013). *Introductory Core Text.* Rhodes University, Environmental Learning Research Centre, Grahamstown.

Park, S., & Suh, K. J. (2015). From Potraying towards Assessing PCK: Drivers, dilemmas, and directions for future research. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 104-118). London: Routledge.

Patton, M. Q. (2001). *Qualitative Research and Evaluation Methods.* (3, Ed.) Thousands Oaks: Sage Publications.

Primo, M. A., & Shavelson, R. J. (1996). Problems and Issues in the Use of Concept Maps in Science Assessment. *Journal of Research in Science Teaching, 33*(6).

Roberts, D. A. (2011). Competing visions of scientific literacy. In C. J. Linder, L. Ostman, D. A. Roberts, P. O. Wickman, G. Erickson, & A. MacKinnon, *Exploring the landscape of scientific literacy* (pp. 11–27). New York: Routledge.

Rollnick, M., & Mavhunga, E. (2014). PCK of teaching electrochemistry in chemistry teachers: A case in Johannesburg, Gauteng Province, South Africa. *Educacion quimica, 25*(3), 354-362.

Rollnick, M., & Mavhunga, E. (2014). The relationship of PCK knowledge to Practice: a case study of two Pre-service teachers teaching Chemical Equilibrium.

Rollnick, M., & Mavhunga, E. (2015). The PCK summit and its effects on the work in South Africa. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 135-145). Johannesburg: Marang Centre for Mathematics and Science education.

Rollnick, M., Bennett, J., Rhemtula, M., Dharsey, N., & Ndlovu, T. (2008). The Place of Subject Matter Knowledge in Pedagogical Content Knowledge: A case study of South African

Roth, C. E. (1992). *Environmental Literacy: Its Roots, Evolution and Directions in the 1990s.* Ohio: ERIC for Science, Mathematics, and Environmental Education.

Roth, M., & Bernhardt, K. L. (2016). Using Concept Maps for Assessment and Improvement of a Multi-Section Introduction to Engineering Course. *ASEE's Annual Conference and Exposition* (pp. 1-14). New Orleans: American Society for Engineering Education.

Roth, W. M., & Lee, S. (2002). Scientific literacy as collective praxis. *Institute of Physics Publishing, 11*, 33-56.

Sadler, T. D., Amirshokoohi, A., & Kazempour, M. (2006). Socioscience and ethics in Scienceclassrooms: Teacher perspectives and strategies. *Journal of Research in Science Teaching*, 353-376.

Samaras, A. P., & Freese, A. R. (2006). *Self-study of teaching practices.* New York: Peter Lang Publishing.

Schwartz, R., Lederman, N. G., & Khalick, F. (2012). A series of misrepresentations: A response to Allchin's whole approach to assessing nature of science understanding. *Science Education, 96*(4), 685-692.

Schwendimann, B. A., & Linn, M. C. (2015). Comparing two forms of concept map critique activities to facilitate knowledge integration processes in evolution education. *Journal of Research in Science Teaching*, 1-28.

Scott, P., Asoko, H., Driver, R., & Emberton, J. (1994 ). Working from children's ideas : Planning and teaching a chemistry topic from a constructivist perspective . *The content of science : a constructive approach to its teaching and learning* , 201-220.

Sharma, A. (2012). Global climate change: What has science education got to do with it? *Science & Education*, *21*(1), 33-53.

Shulman, L. (2015). PCK Its genesis and exodus. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 3-14). New York: Routledge.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Shulman, L. S. (1987). "Knowledge and Teaching: Foundations of the new reform". *Havard Educational Review, 57*, 1-22.

Shulman, L. S. (2015). Introducing PCK: Issues, ideas, and development. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 3-13). New York: Routledge.

Sjostrom, J., & Eilks, I. (2018). *Reconsidering different visions of scientific lteracy and science education based on the concept of Bildung.* Cham: Springer.

Sullivan, S. M., Ledley, T. S., Lynds, S. E., & Gold, A. U. (2014). Navigating climate science in the classroom: Teacher preparation, perceptions and practices. *Journal of Geoscience Education 62*(4), 550-559.

Taber, K. (2008). Towards a Currucular Model of the Nature of Science. *Science & Education, 17*(2) 179-218.

Taber, K. S. (2018). Alternative Conceptions and the Learning of Chemistry. *Israel Journal o Chemisrty, 58,* 1-21.

Treagust, D. F., Won, M., & Mc Lure, F. (2018). Multiple Representation and Students Conceptua Change in Science. In T. G. Amin, & O. Levrini, *Converging Perspectives on Conceptua Change: Mapping an Emerging Paradigm in the Learning Sciences* (pp. 20-30). New York Routledge.

Tullberg, A., Stromdahl, H., & Lybeck, L. (1994). Students' conceptions of 1 mol and educators conceptions of how they teach ' the mole'. *International Journal of Science Education*, 145-156

Uwe, F. (2007). *Designing Qualitative Research.* London: Cronwell Press.

Veron, D. E., Marbach-Ad, G., Wolfson, J., & Ozbay, G. (2016). Assessing Climate Literacy Conten in Higher Education Science Courses: Distribution, Challanges. and Needs. *Journal of Colleg Science Teaching, 45*(6), 43-50.

Vogel, C. (2004). Living with environmental risks and change in Alexandra Township. *South Africa Geographic Journal, 86*(1), 30-38.

Von Glasersfeld, E. (1991). A constructivist's view of learning and teaching . *Research in physic learning : Theoretical issues and empirical studies* , 29-39 .

Ward, P. L. (2016). Ozone Depletion Explains Global Warming. *Current Physical Chemistry*, 1-21.

Watson, G. C. (2013). *Part- Time University Teaching in Ontario: A Self- Study.* Ontario: Broc University.

Wertsch, J. V. (1985). The social origins of higher mental functions. In J. V. Wertsch, & L. S. Vygosky *The social formation of mind* (pp. 58-76). Cambridge: Havard University Press.

Wise, S. B. (2010). Climate Change in the Classroom: Patterns, Motivations, and Barriers to Instructio Amoung Colorado Science Teachers. *Journal of Geosciences Education, 58*(5), 297-309.

Woodley, E. (2009). Practical Work in Science- Why science is important. *SSR*, 49-51.

Yin, R. K. (2013). *Case study research: Design and methods.* Sage publication.

**APPENDICES**

**Appendix 1- A letter to the Department of Basic Education asking for permission to conduct my study**

GAUTENG PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

**For admin. use only:**

Ref. no.: D2017 / 121

Enquiries: 011 3550775
Gumani Mukatuni

---

GDE RESEARCH APPROVAL LETTER

| | |
|---|---|
| **Date** | **30 June 2017** |
| **First Name/s:** | **TERRENCE** |
| **Validity of Research Approval** | **30 June 2017 to 30 November 2017** |
| **Name of Researcher** | **Chigura T.T** |
| **Address of researcher** | **35 Richard Str; Homestead; Germiston; 1014** |
| **Telephone / Fax Number/s** | **0837059327** |
| **Email address** | **chiguratt@gmail.com** |
| **Research Topic** | **A self-study to develop Pedagogical Content Knowledge in Physical Sciences using Climate change as a context to teach grade 11 learners Scientific literacy** |
| **Number and types of schools:** | **One Secondary School** |
| **District/ s/ HO** | **Johannesburg East** |

| ***1.2*** | **Private Contact Details** |
|---|---|
| ***Home Address*** | ***Postal Address (if different)*** |
| 35 RICHARD STREET | |

## Appendix 2- Ethical clearance certificate

**Wits School of Education**

WITS UNIVERSITY

27 St Andrews Road, Parktown, Johannesburg, 2193 Private Bag 3, Wits 2050, South Africa. Tel: +27 11 717-3064 Fax: +27 11 717-3100 E-mail: enquiries@educ.wits.ac.za Website: www.wits.ac.za

10 October 2017

Student Number: 748794

Protocol Number: 2017ECE030M

Dear Terrence Tafadzwa Chigura

**Application for Ethics Clearance: Master of Science**

Thank you very much for your ethics application. The Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate, has considered your application for ethics clearance for your proposal entitled:

**A Self Study to develop my Pedagogical Content Knowledge using Climate Change as a Context to Promote Scientific Literacy in the Teaching of Natural and Physical Sciences Concepts to my Grade 10 Learners.**

The committee recently met and I am pleased to inform you that **clearance was granted**.

Please use the above protocol number in all correspondence to the relevant research parties (schools, parents, learners etc.) and include it in your research report or project on the title page.

The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

All the best with your research project.

Yours sincerely,

Wits School of Education

011 717-3416

cc Supervisor -Dr Mpunki Nakedi

**Appendix 3- A letter from the Department of Education granting permission to conduct the study**

**For administrative use only:**
**Reference no.: D2017 / 121**
Enquiries: Gumani Mukatuni 011 355 0775

GAUTENG PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

## GDE RESEARCH APPROVAL LETTER

| | |
|---|---|
| **Date** | **30 June 2017** |
| **First Name/s:** | **TERRENCE** |
| **Validity of Research Approval** | **30 June 2017 to 30 November 2017** |
| **Name of Researcher** | **Chigura T.T** |
| **Address of researcher** | **35 Richard Str; Homestead; Germiston; 1014** |
| **Telephone / Fax Number/s** | **0837059327** |
| **Email address** | **chiguratt@gmail.com** |
| **Research Topic** | **A self-study to develop Pedagogical Content Knowledge in Physical Sciences using Climate change as a context to teach grade 11 learners Scientific literacy** |
| **Number and types of schools:** | **One Secondary School** |
| **District/ s/ HO** | **Johannesburg East** |

***Re: Approval in Respect of Request to Conduct Research***

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school /s and / or offices involved. A separate copy of this letter must be presented to the Principal, SGB and the relevant District/ Head Office Senior manager confirming that permission has been granted for the research to be conducted. However, participation is VOLUNTARY

The following conditions apply to GDE research. The researcher has agreed to and may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below are flouted.

***CONDITIONS FOR CONDUCTING RESEARCH IN GDE***

*1. The District/Head Office Senior Manager/s concerned, the Principal/s and the chairperson/s of the School Governing Body (SGB.) must be presented with a copy of this letter.*

*2. The Researcher will make every effort to obtain the goodwill and co-operation of the GDE District officials, principals, SGBs, teachers, parents and learners involved. Participation is voluntary and additional remuneration will not be paid;*

Mukatuni 2017. 7. 1

Making education a societal priority

**Office of the Director: Education Research and Knowledge Management (ER & KM)**
9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710 Johannesburg, 2000 Tel (011) 355 0506

**Appendix 4- A letter to the Principal asking for permission to conduct the study**

**Letter to the Principal**

20/10/2017

The Principal

Sandtonview School

10 Maree street

Bramley

2090

Dear Mr H. Loff

**Re: Request for permission to do a short-term research in your school.**

My name is Terrence T Chigura. I am a second-year Masters in Science (Science Education) student in the School of Education at the University of the Witwatersrand. I am doing research on the Teaching of Climate Change to Physical science learners.

My research involves the following: I would need to prepare for my lessons, teach five lessons in a week to a selected FET Physical Sciences class. Whilst the main focus is on my teaching, I would also like to briefly assess them, to gauge their understanding and the effect of my pedagogy prior and post the study. I would also like to engage with at least two of your teachers, for purposes of evaluating my preparation and the quality of my lessons. They will be required to complete an observation journal for my lessons and take part in panel discussions for this study. Completion of observation schedules may be done during or after the lessons are conducted. The latter option serves to reduce disruptions that may arise if the teachers are to physically observe the lessons. The intended research will take place in the fourth term.

The reason why I have chosen your school is because it is where, I, the research teacher will be working. It is a convenient location for me to carry out the intended research. It helps me to collect data in a more natural setting.

I am kindly inviting your school, Sandtonview School, to participate in this research. The research participants will not be advantaged or disadvantaged in any way. They will be reassured that they can withdraw their permission at any time during this project without any penalty. There are no foreseeable risks in participating in this study. The participants will not be paid for this study. The names of the research participants and identity of the school will be kept confidential at all times and in all academic writing about the study.

Your individual privacy will also be maintained in all published and written data resulting from the study. You are also rest assured that all research data will be destroyed between 3-5 years after completion of the project.

Please let me know if you require any further information. I look forward to your response as soon as is convenient.

Yours sincerely,

Mr. TT Chigura

**Appendix 5- Consent letters from parents**

**Parents' Consent Form**

Please fill in and return the reply slip below indicating your willingness to allow your child to participate in the research project called:

**Developing Pedagogical Content Knowledge using Climate Change as a theme to teach Physical Sciences Concepts to Grade 11 learners a Self-study**

I, ______________________ the parent of __________________**give my consent for the following:**

| **Permission to:** | **Circle one** |
|---|---|
| 1. **Permission to observe my child in class** | |
| I agree that my child may be observed in class. | YES/NO |
| **2. Permission to be audiotaped** | |
| I agree that my child may be audiotaped during interview or observations. | YES/NO |
| I know that the audiotapes will be used for this project only | YES/NO |
| **3. Permission for questionnaire/test** | |
| I agree that my child may fill in a question and answer sheet or write a test | |
| For this study. | YES/NO |
| **4. Permission to be videotaped** | |
| I agree my child may be videotaped in class. | YES/NO |
| I know that the videotapes will be used for this project only. | YES/NO |

**Informed Consent**

I understand that:

- My child's name and information will be kept confidential and safe and that my name and the name of his/her school will not be revealed.
- He/she does not have to answer every question and can withdraw from the study at any time.
- he/she can ask not to be audiotaped, photographed and/or videotaped
- All the data collected during this study will be destroyed within 3-5 years after completion of the project.

Sign_____________________________ Date___________________________

**Appendix 6- Adopted Views About Scientific Inquiry (VASI) questionnaire for quantitative data**

**Adapted Views About Scientific Inquiry (VASI) questionnaire**

Name: ____________________

Class: _____________________

Date: _____________________

The following questions are asking your views related to science and scientific investigations. There are no right or wrong answers.

Please answer each of the following questions. You can use all the space provided to answer the questions.

A person interested in birds looked at hundreds of different types of birds who eat different types of food. He noticed that birds that eat similar types of food tend to have similar shaped beaks. For example, birds that eat hard-shelled nuts have short, strong beaks and birds that eat insects have long, slim beaks. He wondered if the shape of the birds' beak was related to the type of the bird eats and he began to collect data to answer that question. He concluded that there is a relationship between beak shape and the type of food the bird eats.

1. Do you consider this persons' investigation to be scientific? Please explain why or why not.

2. Do you consider this investigation to be an experiment? Please explain why or why not.

3. Do you think that scientific investigations can follow more than one method?

4. If no, please explain why there is only one way to conduct a scientific investigation.

If yes, please describe two investigations that follow different methods, and explain how the methods differ and how they can still be considered scientific.

If yes, please describe two investigations that follow different methods, and explain how the methods differ and how they can still be considered scientific.

4. Please explain if “data” and “evidence” are different from one another.

5. The data below shows the relationship between plant growth in a week and the number of minutes of light received each day.

| Minutes of light each day | Plant growth-height (cm per week) |
|---|---|
| 0 | 25 |
| 5 | 20 |
| 10 | 15 |
| 15 | 5 |
| 20 | 10 |
| 25 | 0 |

Given this data, explain which of the following conclusions you agree with and why.

Please circle one:

a) Plants grow taller with **more** sunlight.

b) Plants grow taller with **less** sunlight.

c) The growth of plants is **unrelated** to sunlight.

Please explain your choice of a, b, and c below:

**Adapted from**; Gaigher, E., Lederman, N., & Lederman, J. (2014). Knowledge about Inquiry: A study in South African high school. *International Journal of Science Education* , *36* (18), 3125-3147.

## Appendix 7- Students Views of Climate Change (VoCC)questionnaire

**Students Views of Climate Change (VoCC) questionnaire**

This questionnaire is part of a study of the environmental knowledge of young people. The aim of this questionnaire is to capture the environmental knowledge of secondary school learners. Before you answer the questionnaire, please read the instructions carefully.

The survey consists of two parts which are Part A: Background information; Part B: Your knowledge.

Please be as honest as you can and answer every question to the best of your ability. It is important that everyone answers all the questions, so that we get a proper picture of learners' knowledge that will be useful for teaching and learning processes.

**Part A: Background Information**

**Could you please give us the following information about yourself?** (Please tick √ one box only for each question).

| | | | | |
|---|---|---|---|---|
| **A. Grade** | | | | |
| **B. Age** | Below 16 | 17 | 18 | Above 18 |
| **C. Gender** | Female | Male | | |

**D. Name of School ______________________**

**E. What is your favourite school subject? ______________**

**Part B: Knowledge about Environmental Issues**

**For question 1 to 12: Please tick √ on only one of the box next to the statement that you agree with.**

1. Which of the following statements accurately describe the relationship between the greenhouse effect and the ozone hole?

| | |
|---|---|
| ☐ | The hole in the ozone layer triggers greenhouse warming |
| ☐ | Global warming due to the greenhouse effect results in ozone destruction |
| ☐ | Both the ozone hole and the greenhouse effect are caused by automobiles |
| ☐ | The greenhouse effect ant the ozone hole are separate atmospheric phenomenon that have different primary causes |
| ☐ | Global warming and the ozone hole are natural processes that have been occurring for millions of years |

2. Which of the following is NOT an effect that may result from global warming?

- [ ] A rise in sea level
- [ ] An increase in global temperatures
- [ ] An increase in levels of harmful ultraviolet (UV) radiation reaching earth's surface
- [ ] A change in global precipitation patterns

3. The 'hole' in the ozone layer leads to which of the following:

- [ ] Increased surface temperatures
- [ ] Increased rates of cancer
- [ ] Changing weather patterns
- [ ] Melting polar ice

4. Which of the following does not contribute to smog formation

- [ ] Motor vehicles
- [ ] Industrial processes
- [ ] Electricity production
- [ ] Use of CFCs

5. Which of the following statements accurately describes the environmental effects of ozone?

- [ ] Ozone is an environmental toxin that is hazardous to human
- [ ] Ozone is an essential component of the upper atmosphere
- [ ] Ozone prevents the effects of harmful radiation (e.g. skin cancer, cataracts, etc.)
- [ ] Ozone may be harmful or beneficial depending on its distribution in the atmosphere
- [ ] Ozone levels vary greatly depending on meteorological and anthropological variables

6. Which of the following is NOT a greenhouse gas?

- [ ] $CO_2$
- [ ] CFC
- [ ] Oxygen
- [ ] Methane
- [ ] Nitrous oxide

7. Chlorofluorocarbons (CFCs) are the most closely associated with which of the following?

- [ ] Urban smog
- [ ] Ozone hole
- [ ] Greenhouse effect
- [ ] Acid rain
- [ ] None of the above

8. Nitrous oxides ($NO_x$) are most closely associated with which of the following?

- [ ] Urban smog
- [ ] Ozone hole
- [ ] Greenhouse effect
- [ ] Acid rain
- [ ] None of the above

9. The major human impact on the carbon cycle is:

- [ ] Planting crops that take up $CO_2$ from the air
- [ ] Burning carbon containing fossil fuels and destroying forests
- [ ] Increasing the run-off of nutrients from farmland
- [ ] Increasing the population and breathing out more $CO_2$
- [ ] Not sure

10. The term Greenhouse Effect is best described as:

- [ ] Excess energy from the sun causing changes in weather patterns
- [ ] The destruction of the ozone layer by CFCs and halogens
- [ ] The warming of the Earth's atmosphere by a build-up of gases in the atmosphere
- [ ] Not sure

11.Intergenerational equity (fairness) means that:

- [ ] The needs of children and grandchildren are catered for
- [ ] The rights of future generations are considered to be as important as the rights of the present generation
- [ ] Parents treat children as equals
- [ ] Not sure

12. Indicate which of the following resources is renewable:

- [ ] Coal
- [ ] Copper
- [ ] Forests
- [ ] Oil
- [ ] Not sure

**Adopted from**; Mifsud, M. (2011). An Investigation on the Environmental Knowledge, Attitudes and Behavior of Maltese Youth. *US-China Education Review B* , 413-422.

**Appendix 8- A template of a Content Representation (CoRe)**

| The CoRe is for grade 11 learners<br>Topic: Chemical Systems<br>Subject: Physical Sciences/<br>**Prompts** | IMPORTANT SCIENCE CONCEPTS | | |
|---|---|---|---|
| | **A:** | **B:** | **C:** |
| 1. What you intend the students to learn about this idea | | | |
| 2. Why it is important for students to know this. | | | |
| 3. What else *you* know about this idea (that you do not students to know yet) | | | |
| 4. Difficulties/ limitations connected with teaching this idea. | | | |
| 5. Knowledge about students' thinking which influences your teaching of this idea | | | |
| 6. Other factors that influence your teaching of this idea | | | |
| 7. Teaching procedures (and particular reasons for using these to engage with this idea) | **Probes of students' understanding:** | **Prediction- Observe- Explain** | **Translation activities:** |
| 8. Specific ways of ascertaining students understanding or confusion around this idea (include likely range of responses) | | | |

## Appendix 9- The Pre-CoRe

| The CoRe is for grade 11<br>Topic: Climate change<br><br>**Prompt** | **Important Science Ideas** | | |
|---|---|---|---|
| | 1: Models are constructs used to understand the structure of the globe | 2: Burning of fossil fuels causes global warming | 3: Humans cause climate change |
| 1. What you intend the students to learn about this idea? | The Earth has specific regions that are interconnected with each other called spheres by various cycles of substances. There are models that scientists have come up with to represent the structure of the globe. | The spheres are in a state of natural balance maintained by the various cycles of substances e.g. $H_2O$ and C- cycle. | The biosphere is the location of organisms on the globe. Humans as part of this location can impact the other regions by their activities. |
| 2. Why it is important for students to know this? | Students can understand how the various global systems are structured and interconnected to support life located in the hydrosphere | Students can comprehend that humans activities have an impact on the balance of the natural cycles e.g. water and carbon cycles | Students can make sense of the gravity of human activities in changing the ecological equilibrium of certain locations by building dams and what they can do to mitigate these activities and to raise learners' awareness. |
| 3. What else *you* know about this idea (that you do not want students to know yet)? | Humans are the main agents of the current climate change experienced on the planet however, other natural phenomenon and geological events e.g. asteroid impact, volcanic and seismic activities can greatly affect the state of the climate. | | |
| 4. What are the difficulties/ limitations connected with teaching this idea? | Numerous misconceptions that distorts the way scientific knowledge is generated. | The abstract nature of the way greenhouse gases impacts the environment. Increasing greenhouse gases is clear in scientific data and may not be visible in communities. | Learners may use global warming as synonymous with anthropogenic climate change and this creates a conceptual gap in understanding the impact of climate on other global ecosystems. |
| 5. What is your knowledge about students' thinking which influences your teaching of this idea? | Learners understand that the globe is an ecosystem. | Learners understand the energy flow from the sun to the global ecosystem | Learners understand that climate change impacts communities and ecosystem |
| 6. Are there any other factors that influence your teaching of these ideas? | The curriculum structure: the teaching plans: that guide the volume of content the teacher needs to cover at a specific time.<br>Learners' socio-cultural backgrounds: learners' beliefs, preconceptions and convictions.<br>Teaching resources: ITs to create/ download learning medias such as pictures, videos and power-point presentations | | |
| 7. What are your teaching procedures (and particular reasons for using these to engage with this idea)? | **Probes of students' understanding:**<br>Learners engage in discussions and explanations | **Prediction- Observe- Explain:**<br>Learners participate in role play, discussion and explanations | **Translation activities:**<br>Learners engage in debates on specific socio-scientific concepts issues. |
| 8. Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses) | • Question and answer sessions to reveal their pre-conceptions.<br>• Probe learners to give a summary of concepts learned<br>• Exercises and tests to determine their understanding of concepts.<br>• Case study on how humans activities impact ecosystems | | |

## Appendix-10 Post CoRe

**Post CoRe**

| **The post CoRe is for grade 11 Topic: Climate change** | **Important Science Ideas** | | | | |
|---|---|---|---|---|---|
| **Prompt** | 1: Science is a human construct. | 2: Changes in climate are continuous. | 3: Levels of greenhouse gases change the global temperatures. | 4: The GHE involves the transfer of energy. | 5: Anthropogenic climate change is a consequence of human activity. |
| 1. What you **intend** the learners to learn about this idea? | Science is formulated by human beings.<br>The natural world exists independent of scientific concepts. Scientists use various tools and models to make sense of climate science. | Geo-atmospheric processes change average weather patterns. | An increase in the greenhouse gases increases the mean temperatures of the globe. | Greenhouse gases cause the GHE when they trap excess IR radiation released by the globe to cause global warming. | Current changes in climate are attributed to human actions as they advance their societies. |
| 2. Why it is **important** for learners to know this? | The teacher needs to initiate this or the learners will generate alternative conceptions of climate science i.e. the NOSI sets up a common understanding of how scientific knowledge is built.<br>It aids learners to comprehend that scientific concepts are tentative and identify the differences between data and evidence | The natural geo-atmospheric events explain the causes of historical climatic experiences of the Earth otherwise anthropogenic climate change will seem to be a false construct. | There is need to ascertain the relations of the concentration of greenhouse gases to Earthly temperatures, in order to explicate the correlation between the concentration of greenhouse gases and mean global temperature measurements. | This is important to comprehend that the globe absorbs high frequency radiation (uv and visible light) and emits low frequency IR which is reflected back to the earths' crust by a layer of greenhouse gases in the atmosphere. The idea of IR emission is useful in explaining why the incoming solar radiation has no potency on global temperatures. The concept of "greenhouses" in horticulture is drawn from learners' daily experiences. | This is important for understanding that current climate phenomenon is induced by human activities that results from their increasing demand for energy mainly sourced from fossil fuels. |

| | | | | | |
|---|---|---|---|---|---|
| 3. What else *you* **know** about this idea (that you do not want learners to know yet)? | The NOSI is broad. It involves processes of how scientific knowledge is generated and the products of the knowledge. However, that would be a poor way to start explicating the NOS. At grade 10 the tenets of NOS need to be introduced drawing from the grade 7, 8 and 9 constructs which learners can easily comprehend e.g. the demotion of Pluto from the Solar System to show the robust but tentative nature of scientific constructs. From the onset this is the structure I follow. These ideas are gradually embedded in the context of climate change to make them more explicit in teaching Chemical Systems. | The idea of an ever-changing state of climate is adequate: there is no need to draw out extra- terrestrial occurrences e.g. solar flares because this is not useful to develop the idea of the globe as an ecological organism that is affected by human doings. | Early on avoid other variables that give the impression to cause an increase in global temperatures. Pointing how variables may correlate and not be in a causal relationship. It is important not to allocate a lot of time on cause and effect and prove certain relationships and refute others. Limit all discussions to a consideration of Greenhouse gases so that learners' understandings are not cluttered. | The ability of Greenhouse gases to emit IR-radiation is due to its structural in terms of degrees of freedom and symmetry of vibrations that produce permanent dipole moments and an electric field. The more complex the GHG the more active it is in terms of its heat capacity. The way I will present the emission of IR radiation is using the conventional diagrams of incident and reflected rays of radiation. Changes in pH are critical for the survival of organisms because on a molecular level enzyme action is dependent on pH values. | It is difficult to comprehend how humans can distress the ecological state of the globe yet they are part and parcel of the bios. |
| 4. What are the **difficulties/ limitations** connected with teaching this idea? | The difference between data and evidence, hypothesis and theories are seldom difficult for learners to understand. These constructs take time to be understood in a meaningful way. Learners are not clear on the definitions of the terms and struggle to contrast them and categorize the terms in contexts. | It is elaborate to believe that global climate can be changed at a communal level. | The idea that greenhouse gases refer to $CO_2$ is a common misconception. Gases that are able emit IR-radiation might be a better way to explain greenhouse gases because $H_20_{(v)}$ is an important greenhouse gases. | In the GHE model misunderstandings often come up when learners do not remember that the globe absorbs high energy radiation (uv and visible light) from the Sun and intern emits low energy radiation in the form of IR radiation. It is IR- radiation that warms up the globe. Learners instead conflate global warming and ozone depletion. | Learners find it difficult to understand the importance of anthropogenic activities in causing global warming. Learners have difficulties scaling the levels of $CO_2$ in their communities. Their C-footprint is an abstract concept. |

| | | | | | |
|---|---|---|---|---|---|
| 5. What is your knowledge about learners' thinking which influences your teaching of this idea? | Learners think that scientific concepts are a version of truth instead of viewing it as a form of knowledge. In everyday life experiences and often in scientific contexts the words hypothesis; laws and theories and; data and evidence are synonymous. | Learners do not appreciate the notion of a changing climate despite having some forms of experiences of consequences of climate change such as recurring heat waves, flooding, droughts and changes in seasonal patterns. I am convinced that where climate evidence is apparent e.g. melting ice caps on mountains , learners will accept this as proofs. | Learners are eager to decide that greenhouse gases are undesirable gases.<br>Greenhouse gases make the globe warmer | Learners often suppose that the incoming radiation from the sun leads to global warming. Therefore, they view solar radiation as bad rather than useful energy in the global ecosystem.<br>Learners conflate global warming and ozone depletion. | A submission to anthropogenic climate change may lead some learners to believe that the natural geo-atmospheric processes are now inactive and do not influence the state of the current global climate. |
| 6. Are there any other factors that influence your teaching of these ideas? | Interpretive deliberations guided by the teacher are very important as it connects learners' prior understanding and experiences to the concept of NOS. Learners are able to debate and convince each other.<br>At grade 10 level learners are hesitant to commit and present their thinking to others so the teacher needs to develop their confidence levels in terms of their scientific writing and presentation skills. | It is often simple to teach this idea as a fact. However, this does not develop learners' conceptual understanding. Learners have a diverse interpretations informed by their unique experiences which they hold on to and are willing to defend. This section needs lots of discussions about situations involving evidence of climate change. It is critical that the teacher withholds judgments and conclusions on incorrect answers while learners engage with each other. | Learners do not have real world experiences on the impact of Greenhouse gases on global temperatures that the teacher can use to scaffold learners' comprehension. | The teacher needs to withhold the scientific explanation of the greenhouse effect to encourage learners to construct meaningful knowledge structures on the construct. This helps learners to develop higher order scientific thinking skills. | The idea is explored earlier that identify humans as the main cause of current climatic change but at the end of the topic their agency is considered as problem solvers in averting the crisis. |

| | | | | | |
|---|---|---|---|---|---|
| 7. What are your **teaching procedures** (and particular reasons for using these to engage with this idea)? | **Probe misconceptions: Open ended questions of the VASI questionnaire:**<br>Ask learners to respond by giving reasons for their answers to find out their thinking on specific content of NOS in terms of: the differences between hypothesis, laws and theories, differences between data and evidence, and the tentativeness of scientific constructs<br>**Probe learners for understanding:** Engage learners in **question and answer** ask learners why some scientific constructs are no longer accepted as part of science. Allow learners to ponder on these questions and respond. Use models of the geocentric model of the solar system to evoke their thinking on the role of data and evidence in science.<br>**Deal with learners' misconceptions:**<br>Give learners a **case study** on the History of Science that explains how $CO_2$ levels lead to the GHE, use graphs, pictures and diagrams. Allow **group discussions** so that learners can share and debate ideas in the case study.<br>**Defining the boundaries:** Draw out the alternative everyday meanings of the words 'theory', 'law', 'data' and 'evidence', this is useful to differentiate between scientific and common uses. | **Probe misconceptions:** Get learners to fill a questionnaire on their understanding of climate change concepts<br>**Role play:** To determine that climate change is an issue in society ask learners to role play and give a presentation on the issues that affect their community and how they intend to solve them.<br>An understanding of learners' socio-scientific backgrounds allows the teacher to present scientific situations that **connect to learners' everyday lives**. To accommodate learners' backgrounds some common issues were discussed in the class. Including some that are related to climate change e.g. recurring flooding.<br>This made learners rethink about their own ecological spaces at home in relation to climate.<br>The embedding of learners experiences to scientific constructs has more meaning to learners | **Multiple choice activity from questionnaire:**<br>Use multiple choice questions with distracters that complement learners' misconceptions and to probe their prior conceptions of Greenhouse gases.<br>**Modeling of ice cores:** The teacher gave learners an activity to design an ice core that shows the trend in the trend of greenhouse gases $CO_2$. Ask the learners to think about the time period when there was a sudden rise in $CO_2$ and what was the cause?<br>**Set up a common form of communication:** Get learners to start using these terms correctly in other sections of the topic. The constructs will be embedded in the subject matter and will be presented in a more explicit way. | **Analogy**: Use an analogy of the common greenhouse to explain the enhanced GHE. Map out the components of the greenhouse with corresponding explanation to curb the build-up of misconceptions so that learners can understand the changes in radiation and how the enhanced GHE leads to current global warming. Show the analogy with diagrams to teach this difficult concept. So that learners do not conflate ozone depletion with global warming. | **Warning of prior tendencie**<br>At the topic ask the learners t stress the most important concepts and need to need to feel empowered because their individual practices when summed up together as famili and communities can make a big difference by changing their behaviors. They need to be warmed not to revert back their initial misconceptions ar should critically think before they engage in an action. Learners may feel limited in what they can do to engage their communities to minimiz the impacts of global climate change<br>**Challenging their views and capacities to cause change:**<br>When they participate in an open climate behavior quiz they can be empowered by th positive activities of others. This helps to motivate learner to make a difference in their communities. |

## Appendix 11- Sample of the teacher-researcher reflective journal entries

| **Lesson 3: Anthropogenic climate change**<br>**My own reflections** | | | |
|---|---|---|---|
| **What happened?** | **How do I feel about it? (interpret what it might mean)** | **What did I learn? (what is my opinion about the experience)** | **How can I do things differently next time?** |
| I introduced anthropogenic climate change by doing a short question and answer session on the socio-scientific issues that learners are exposed to in their communities. | I feel this was good to connect the topic to learners lived experiences. This session also gave me an opportunity to quiz learners on their specific conceptions as an extension activity to the questionnaire. | I have learned that it is important to engage learners by allowing them to share their prior and pre-conceptions because only then did I get the full picture of their thinking. This gave me knowledge on which concepts I should focus more on to make the topic teachable to my grade 11 learners | While a pre questionnaire is a good source to detect learners' misconceptions, other teaching tools that I could use is a pre-test with a continuum of questions to give learners an opportunity to express their prior knowledge. Any form of baseline activity is good and effective to tap into the learners' prior knowledge. |
| | | | |
| Discussions were dominant in this lesson. | I feel It is important to allow discussions because learners learn best from their peers (socio-cultural) My role was to keep learners pinned down to the concept of anthropogenic climate change because the learners had come up with a various issues in their communities. | The teacher then allows learners to report to the class about the group discussion outcome which helps to detect the learners' misconceptions and help them to restructure their thinking | Allow learners to report their group discussion outcomes through short presentation and allow the rest of the class to play audience roles by critiquing the presenters. |
| | | | |
| Learner's explanation shows the link between the science and society when they say "its human activities sir" that cause global climate change. | The terminology could have been difficult but I feel that I did stress the differences between normal emissions and anthropogenic emissions. This means learners could connect daily activities and anthropogenic climate change. | I have learned that it is important to allow learners to make the links between science, technology and society. In this way they can develop knowledge and skills to deal climate change as the future citizens | I would need to involve more learners to participate with specific rewards so encourage learners to be active in the classroom |

**Lesson 3: Anthropogenic climate change**
**My own reflections**

| What happened? | How do I feel about it? (interpret what it might mean) | What did I learn? (what is my opinion about the experience) | How can I do things differently next time? |
|---|---|---|---|
| I introduced anthropogenic climate change by doing a short question and answer session on the socio-scientific issues that learners are exposed to in their communities. | I feel this was good to connect the topic to learners lived experiences. This session also gave me an opportunity to quiz learners on their specific conceptions as an extension activity to the questionnaire. | I have learned that it is important to engage learners by allowing them to share their prior and pre-conceptions because only then did I get the full picture of their thinking. This gave me knowledge on which concepts I should focus more on to make the topic teachable to my grade 11 learners | While a pre questionnaire is a good source to detect learners' misconceptions, other teaching tools that I could use is a pre-test with a continuum of questions to give learners an opportunity to express their prior knowledge. Any form of baseline activity is good and effective to tap into the learners' prior knowledge. |
| | | | |
| Discussions were dominant in this lesson. | I feel It is important to allow discussions because learners learn best from their peers (socio-cultural) My role was to keep learners pinned down to the concept of anthropogenic climate change because the learners had come up with a various issues in their communities. | The teacher then allows learners to report to the class about the group discussion outcome which helps to detect the learners' misconceptions and help them to restructure their thinking | Allow learners to report their group discussion outcomes through short presentation and allow the rest of the class to play audience roles by critiquing the presenters. |
| | | | |
| Learner's explanation shows the link between the science and society when they say "its human activities sir" that cause global climate change. | The terminology could have been difficult but I feel that I did stress the differences between normal emissions and anthropogenic emissions. This means learners could connect daily activities and anthropogenic climate change. | I have learned that it is important to allow learners to make the links between science, technology and society. In this way they can develop knowledge and skills to deal climate change as the future citizens | I would need to involve more learners to participate with specific rewards so encourage learners to be active in the classroom |

| **Lesson 4: Greenhouse Effect**<br>**My own reflections** | | | |
|---|---|---|---|
| **What happened?** | **How do I feel about it? (interpret what it might mean)** | **What did I learn? (what is my opinion about the experience)** | **How can I do things differently next time?** |
| I made use of the VoCC questionnaire to see which concepts learners find difficult to conceptualize. | I feel like learners find thermal transfer problematic because they could not explain to me how an object can warm up. Furthermore, they gave me mixed responses on how the increase in heat energy could be detected. | Learners by the time they get to grade 11 are expected to have specific CK but it is good not to treat learners in a generic way. Specific learners will have specific problem and these can only be detected with prior checking tools.. | Use a variety of questions to give learners an opportunity to expose their prior conceptions. |
| | | | |
| I knew that the GHE was going to be a challenge for learners to understand. So I made use of an analogy to make the content more teachable. | This is one of the good tools I can use to make learners understand global warming because learners are familiar with this thermal situation. I was anxious because learners may fail to make sense of the model and that will lead to more misconceptions, so I was very careful in mapping out the analogy to the enhanced GHE. | It is critical to correct map out models, analogies to specific concepts to minimize the build-up of misconceptions due to the classroom set up by the teacher.. | Make a fill in worksheet to make learners active in the course of the lesson when I explain critical concepts. It is my contention that this helps to develop knowledge of the big ideas. |
| | | | |
| Science and society are interlinked in the graphical activity of how temperatures are on the increase due to the increase in $CO_2$ levels due to human activities discussed in lesson 3. | I feel learners find variables very difficult to deal with. They cannot easily identify dependent, independent and controlled variables in case studies or representations such as graphs. | I see that learners interpret graphs incorrectly. So this section on variables and graphs, procedural knowledge can be taught separately to give learners knowledge and skills to identify, define then describe and analyze data and evidence. | Even though I did teach some aspects of NOS including data and evidence learners still had difficulties in shifting from one situation to another. This was an area of concern that I felt I could have done more to prepare learners more so that they could learn climate change in an understandable way |
| | | | |
| An explanation of how global warming occurs in terms of the energy changes. | I feel this enable the learners to gain knowledge about big ideas in the topic in line with how warming takes places in open and close system. This knowledge is also critical when learners do chemical equilibrium. | Learners can understandings needs to be developed in terms of the big ideas so that they can solve problems and correctly answer questions in new situations. | Create worksheets to assess learners' big ideas. |

## Appendix 12- Teacher A and B lesson reflections

## Teacher A

## Lesson 2-The Nature of Science-Scientific models are tentative

| What happened? (describe objectively what you saw and heard) | How do I feel about it? (interpret what it might mean) | What did I learn? (what is my opinion about the experience) | How can I do things differently next time? |
|---|---|---|---|
| The teacher asks the learners what they know about the models prior to the lesson. | I feel like the teacher is a constructivist with a notion that learners are not blank slates, they come to the classroom with their own conceptions which are acquired through an experience. | My opinion on this is the idea of constructivism is that it allows the teacher to have a direction when explaining the concepts because the teacher will know the learners pre-conception status. | If the 3-d models are available, use them to also explain, but because they were available on the pictures, it is still effective. |
| | | | |
| There is a discussion and argumentative method implemented by the teacher in relation to two different models | The teacher allows learners to bring up their ideas about which one is the geocentric and heliocentric model and argue why. | As the argumentation and discussion takes place, the learners refer to their existing schema and work on restructuring it. The questions that are posed during the argumentative discussions allow the learners to also go through cognitive conflict within their mind. | Allow learners to report their group discussion outcomes through short presentation and allow the rest of the class to play audience roles by critiquing the presenters. |
| | | | |
| The models are represented on a worksheet which helps learners to develop the concept about geocentric and the heliocentric models. Authentic content graphics | The representations of models on a worksheet help learners to understand the two different models. In that way learners are able to develop the abstract knowledge which will form part of their cognitive structures. It shows that the teacher is creative in his lesson by using 2d models in the absence of 3d. | I have learned that a teacher has to be creative. Even if there are no 3-d models, you can always make graphics as an alternative way of explaining. | Do a PowerPoint presentation demonstrating two types of models and open for a discussion and allow argumentation on which model is which. |
| | | | |
| Worksheet is used to scaffold the concepts and also there are graphics of scientific models to support the construction of big ideas in the topic. | The graphics can be considered as the tools that are used to scaffold the knowledge and they are also used within the relevant context. | Tools are important for learning because they help learners to be able to develop abstract knowledge based on the content. They are the aids for learner's development of knowledge. | |

## Teacher B

## Lesson 5-The Greenhouse Effect

| What happened? (describe objectively what you saw and heard) | How do I feel about it? (interpret what it might mean) | What did I learn? (what is my opinion about the experience) | How can I do things differently next time? |
|---|---|---|---|
| Learning is situated in experience. Learners are aware of the overheating effects of the planet. They actively contribute their prior conceptions during classroom interactions. | I feel like learners do know the effects of overheating the planet and they are aware that in most cases humans are the agents. | Learners are able to connect the science and society. They are conscious that science and society are not isolated from each other. | Do a slide show presentation of pictures after the lesson and allow learners to critically analyze the pictures and build further understanding. |
| | | | |
| The teacher has a solid PCK because the way in which he explains the concepts shows strong content confidence. | The teacher can then detect the learners Misconceptions and will effectively deal with them and scaffold the scientific knowledge because they have a strong solid content knowledge based on the subject. | The teacher has to continuously expand their PCK so that he/she will be able to confidently deal with learners questions, inputs in form of pre conceptions. | |
| | | | |
| The teacher exposes learners to the socio-scientific discourse. Learners do get the sense that science and society are interlinked and do affect each other. They are able to reason on effects of global warming in relation to how they affect the society. | I can see from the learners' contributions that climate change impacts their livelihoods and they are aware. At the same time there are being exposed to education based on STS so that they become responsible citizens and sustain the environment. | Learners must not take science as a subject that they cannot connect I with anything in real life. It is good to learn about relevant content and this contributes to the authentic tasks. | |
| | | | |
| CS-the teacher synthesized the subtopic of GHE in a way that learners will be able to access the content. It is a continuation of 3 lessons and therefore learners can effectively go through conceptual change and gain more knowledge on the topic. | This enable the learners to gain knowledge about big ideas in the topic of GHE because it's been broken down and synthesized in a more accessible and understandable way. | The content has to be divided for learners to best access the concepts. So in this way, the teacher effectively did that. He broke the topic into two lessons, and he scaffold knowledge through discussions, arguments | |
| LPK- discussions and argumentation during teaching and learning. | Learning is a social process therefore discussions and argumentation method facilitate learning effectively. | Through discussions, learners are able to exchange ideas and also reflect on their existing cognitive structures and restructure their knowledge. | |
| | | | |
| Analogy of explaining the greenhouse effect was used for learners to develop an understanding of the concept. | If is a good method to be used during teaching and learning because learners are able to build their own mental structures as you explain using the analogy and that help with content development. | If the resources are insufficient, maybe the models or explaining in form of videos, you can use analogies and other method of RMAR such as representations to facilitate the development of the concept. | |

## Appendix 13- Rubric of a Concept Map

**Rubric of a Concept Map**

| Variable | Description | Type of score |
|---|---|---|
| **Concepts** | Concepts are objects, events, situations, or properties of things that are designed by a label or symbol | Score 1 point for each concept that is connected to at least one other concept by a proposition |
| **Groupings** | Groupings are the ways concepts can be linked or joined together. There are three types of groupings:<br>i. Point groupings: a number of single concepts emanating from one concept. Linear grouping is the simplest.<br>ii. Open groupings: three or more concepts that are linked in a single chain<br>iii. Closed groupings: concepts that form a closed system (a loop). More meaningful content for learning | Sorting of groups:<br>i. Point groupings: 1 point for each concept in the group<br>ii. Open groupings: 2 points for each concept in the group<br>iii. Closed groupings: 3 points for each concept in the group |
| **Hierarchy** | Concepts on a map can be represented as a hierarchical structure in which the more general, more inclusive concepts are at the top of the map; the specific and exclusive concepts are at the lower end of the map. | Concept hierarchy is based upon the extent that concepts are present in "assigned levels" 4 points are given to each concept correctly assigned to a level, 2 points for each concept on a level, one-removed from an assigned level, and no score for concepts that are on a level 2-or more levels removed from the assigned level |
| **Branching** | Branching of concepts refer to the level of differentiation among concepts, that is, the extent the more specific concepts are connected to the more general concepts | Score 1 point for each branching point that has at least two statement lines |
| **Proposition** | Relationships between concepts are represented by connecting word(s) and phrases written on the line joining any two concepts. A proposition is a unit of 2 concepts and a linking word<br>• A simple proposition is a simple word or phrase<br>• A scientific proposition is a phrase or statement that is composed of technical or scientific word(s) | • Simple propositions score 1 point for each word or phrase; give a half for repeated use of simple propositions<br>• Scientific propositions score 2 points for each proposition. Give 1 point for repeated use of scientific proposition |

Adopted from (Cronin, P., Decker, J., Dunn, J. G. (1982) A procedure for using and evaluating concept maps. *Research in Science Education*, 12 (1), 17-24.)

## Appendix 14- Baseline evaluation of my concept mapping

SANDTONVIEW SCHOOL

**Baseline evaluation of my concept mapping**

Grade: 11 Date: 20/03/2018

The base line evaluation was my prior meeting with peers to discuss our evaluation of concept mapping.

**Overview of the baseline evaluation**

I gave the collegiality a presentation of my intention to use concept mapping to determine the prior and post CK of climate change for teaching grade 11 learners doing Physical Sciences. I informed my critical friends that I plan to construct a pre concept map to portray key concepts to teach the topic and later on would construct a post concept map in the course of the study. I asked the critical friends to evaluate my pre and post concept maps with a concept map rubric.

**My reflection of the meeting with the collegiality**

The baseline evaluation meeting was with teacher A and B. The names of the teachers in this self-study are anonymous to keep their identities unknown in line with the code of ethics. The main objective of this meeting was to give an overview of my self-study research with regards to the evaluation of the concept maps. Teacher A stated that it was critical for me to use various teaching methodologies so that learners can understand the concept of climate change in full because it is a social issue and its content is in many FET subjects in the CAPS curriculum. Teacher B insisted that such topics do motivate learners. She stressed the importance of learning such socio-scientific as they connect classroom content to learners' home milieus. Teacher B contends that some of the learners who live in the vicinity of informal settlements may have a direct experience of the recurring urban flooding seen in recent seasons.

**My lessons from the interaction with the community of practice**

For my personal growth I gained CK for teaching from interactions with my collegiality. I have seen that it is important to teach Physical Science topics in a way that connects to learners' everyday experiences. The use of learners' home knowledge in the form of similar cases, analogies and examples can be drivers to make content teachable in the classroom when teaching climate change. This is more critical as I explain difficult or abstract concepts.

## Appendix 15- Summative evaluation of my concept mapping

SANDTONVIEW SCHOOL

**Summative evaluation of my concept mapping**

Grade: 11 Date: 21/09/2018

**Overview of the summative evaluation meeting**

I gave the collegiality a follow up presentation of my use of concept mapping to validate my CK of climate change. By looking at the pre and post concept maps knowledge shifts in my CK of climate change could be seen at the beginning and end of the study. Before the summative evaluation teacher, A and B had to do a solo appraisal of my post concept map. The objective of the summative evaluation meeting was to get a sense of how teacher A and B defend their scores, to find out what aspects of climate change stood out for them in my post concept map and to agree on the final scores.

**My reflection of the meeting with the collegiality**

Teacher A stated that I had all the critical concepts for the topic of climate change in my post mapping because the post concept map had the anthropogenic activity of burning fossil fuels, the impacts of $CO_2$ on the global ecology and the conceptual model of climate change in the enhanced GHE. This is in contrast to the pre concept map that did not specify the activities that emit $CO_2$ and had no mention of the GHE as a model to explain global warming and current climate change. Teacher B mentioned the importance to use ICTs when teaching such an intricate topic so that the representations I use will minimize the build-up of misconceptions and promote more understanding of specific concepts. At the end of the session all agreed scores were summarized in a table.

**Table: Show the average scores of pre and post concept mapping.**

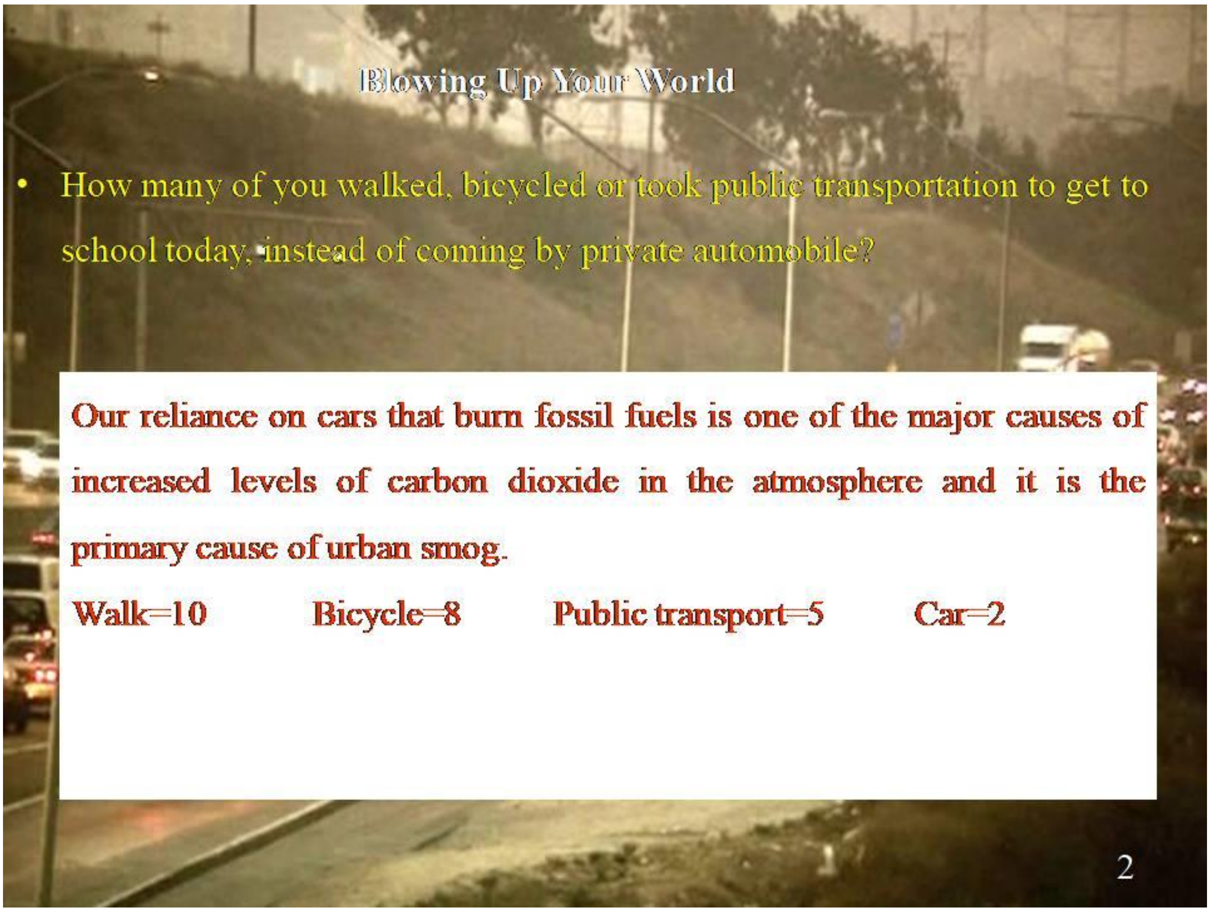
| **Concept map** | **Category** | | | | |
|---|---|---|---|---|---|
| | Concepts | Grouping | Hierarchy | Branching | Proposition |
| Pre-Concept Map | 4 | 7 | 3 | 4 | 17 |
| Post-Concept Map | 10 | 17 | 8 | 9 | 30 |

**My lessons from the interaction with the community of practice**

For my own personal growth, I have gained CK for teaching in the course of the self-study. Stories of good teaching are of use in line with various contexts. I did tap into this experiential knowledge from my critical friends and in particular a discussion that we had on energy transfer. Teacher B claimed that learners have the misconception on how solar energy warms up the globe. She sighted one of the sources of this misconception is that the topic of Energy changes at a global scale is an abstract construct. She picked that it was important for me to highlight that it is the IR radiation

**Appendix 16- A Snapshot of the C- footprint activity**

**C- footprint activity**



**Appendix 17- Worksheet Example**

**Worksheet**

Objective: To show how scientific models change and are formulated- a case study of geocentric and heliocentric models of the solar system

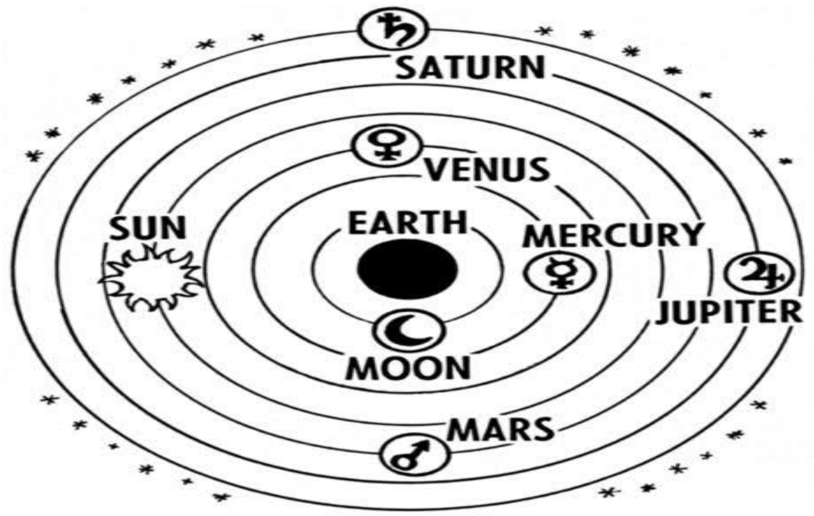
**Nature of Science**

| **Name:** | | **Surname** | |
|---|---|---|---|

**Teacher: TT Chigura**

**Class work: Individual work**

**Observing the Solar System Understanding Main Ideas**




Observers in ancient Greece noticed that although the stars seemed to move, they stayed in the same position relative to one another. These patterns of stars, called constellations, kept the same shapes from night to night and from year to year. The Greeks thought that Earth was inside a rotating dome called a celestial sphere. Since the word geo is the Greek word for Earth, an Earth-centered explanation is known as a geocentric system.

Kepler used the new scientific evidence gathered by Brahe to disprove the long-held belief that the planets moved in perfect circles. Since Galileo's time, our knowledge of the solar system has increased dramatically. T planets and their moons, and several kinds of smaller objects that revolve around the sun.

2

2.1 What is the main difference between the geocentric and heliocentric models of planetary-motion?

______________________________________________________________________________

______________________________________________________________________________

_____________________________________________________________________2

2.2 How did the Greek model and Ptolemy's model differ?

_______________________________________________________________________

_______________________________________________________________________ 2

2.3. How did Galileo's observations of Jupiter and Venus support Copernicus's model?

___________________________________________________________________________

___________________________________________________________________________

______________________________________________________________________________

__________________________________________________________________________

___________________________________________________________________________5

2.4 The sun-centered system of planets developed by Copernicus is an example of a(n) ________________________ model. 5. Kepler discovered that the orbit of each planet is a(n) ________________________, rather than a perfect circle. 6. An Earth-centered system of planets is known as a(n) ________________________ model. 3

2.5 Explain what data and evidence mentioning examples in the passage above to support your answer

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

_______________________________________________________________6

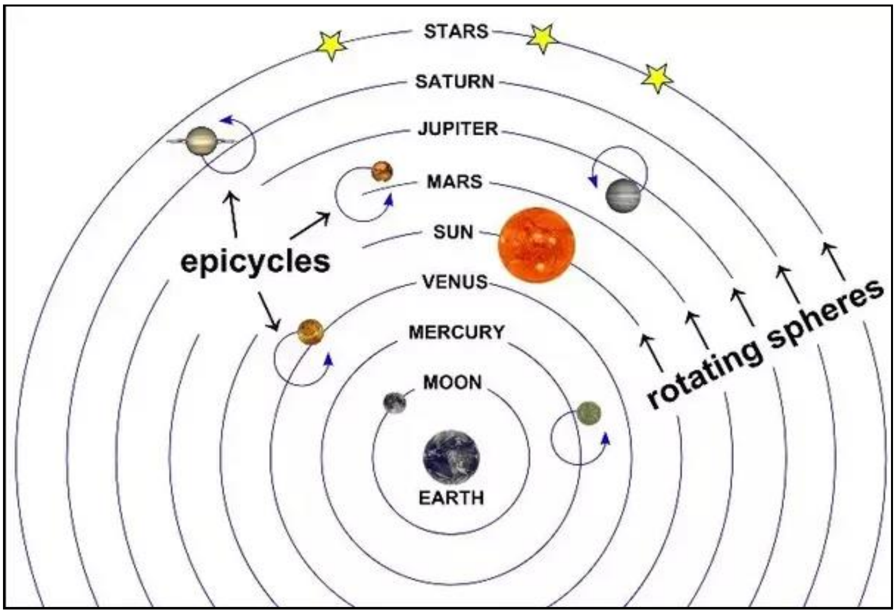
2.6 Why are theories in science tentative?

______________________________________________________________________________

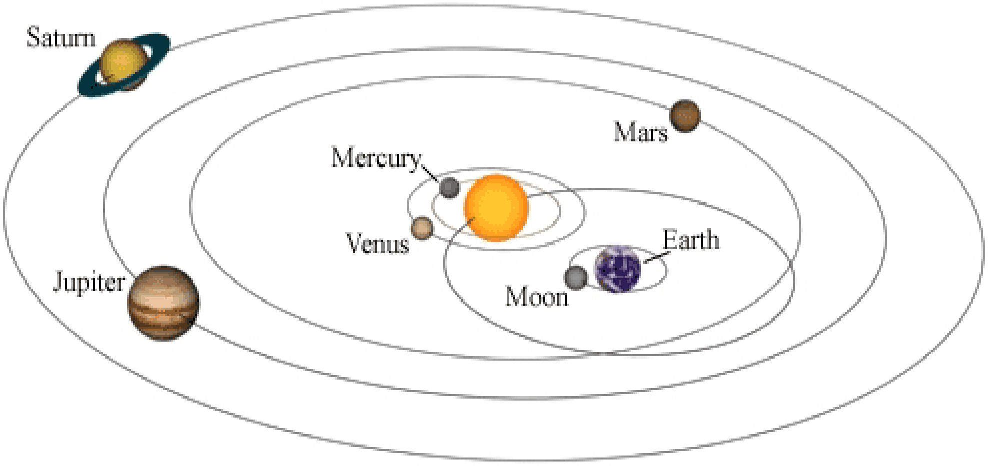
______________________________________________________________________________

______________________________________________________________________2

**Total 20**




In a geocentric system, Earth is at the center of the revolving planets and stars. About A.D. 140, the Greek astronomer Ptolemy further developed the geocentric model. Like the earlier Greeks, Ptolemy thought Earth was at the center of a system of planets and stars. In Ptolemy's model, however, the planets moved on small circles that moved on bigger circles. Copernicus was able to work out the arrangement of the known planets and how they move around the sun. A Greek scientist developed the heliocentric system. In a heliocentric system, Earth and the other planets revolve around the sun.




In the early 1500s, the Polish astronomer Nicolas Copernicus developed a new model for the motions of the planets. His sun-centered system is also called heliocentric. Helios is Greek for "sun." Copernicus was about to work out the arrangement of the known planets and how they move around the sun. Later, Galileo used the newly invented telescope to make discoveries that supported the heliocentric model. Copernicus thought that the planets' orbits were circles. He based his conclusions on observations made by the ancient Greeks. In the late 1500s, Tycho Brahe made more accurate observations of the planets' orbits. Johannes Kepler analyzed Brahe's data. Kepler found that the orbit

## Appendix 18- Sample of lesson transcripts

**Lesson 1: The Nature of Science Grade 11 Date: 25/08/2018**

| | |
|---|---|
| Mr. Chigura: | Good Morning |
| Learners: | Good morning Mr Chigura and welcome. |
| Mr. Chigura: | Fine thanks and let's sit down. |
| Mr. Chigura: | Today you are going to learn about what is known the nature of Science. It deals with the activities involved when scientific knowledge, science concepts are constructed by scientists. How is scientific knowledge generated? |
| Mr. Chigura: | How is scientific knowledge? What is a theory? |
| | Alexina what is your understanding of a theory? |
| | Give an example an example of a theory that you know Alexina. |
| Alexina: | Kinetic Molecular theory. |
| Mr. Chigura: | Dineo. What does the kinetic Molecular theory state? |
| Dineo: | It talks about the kinetic energy. |
| Mr. Chigura: | What about Kinetic energy does the theory say? |
| Dineo: | …It is about the molecules through, the molecules seek to change state |
| Mr. Chigura: | This is grade 10. What is matter made up of and how does it behave? The kinetic energy is dependent on the temperature. When the temperature increases what happens to the kinetic energy of a gas? |
| Khanyi | …..it increases. |
| Mr. Chigura | That is one of the concepts in the Kinetic Molecular Theory. Another e.g. of a theory please. Yes. Karabo. |
| Karabo: | Sir I'm not sure. |
| Mosa: | Plate tectonic theory |
| Mr. Chigura: | Plate tectonic theory in Geography? What does the theory say? What explanation does it give us? |
| Anelisa: | sir it explains continental drifting does it? |
| Mr. Chigura: | it is an explanation that the current continents sit on plates that move. In line with this theory how does it explain the evolution of continents? |
| Mahlatse: | all continents were one land mass. |
| Mr. Chigura: | …One super continent. What was the name of that super continent? Yes |
| Class: | Pangea |
| Mr. Chigura: | What happens to those pieces of that super Pangea land mass? |
| Class: | …. drift apart. |
| Mr. Chigura: | They moved apart which is what we call continent drifting. ….so what is a theory? Yes, Mosa. |

| | |
|---|---|
| Mosa: | A theory is an explanation of something that is taking place. |
| Mr. Chigura: | a scientific explanation such as how humans evolved from Apes. There are many theories that explain human evolution. However, these theories are prone to change and revision. Give me an example of such a theory and describe the changes that took place, |
| Learner: | Pluto example. |
| Mr. Chigura: | Plutonic example. … What happened to Pluto? |
| Learner: | It is no longer a planet it is too small. |
| Mr. Chigura: | Where is the change now? |
| Learner: | The solar system has 8 planets |
| Mr Chigura | The older solar system model in terms of the structure of our solar system was nine planets orbiting around the sun of our solar system but now our current understanding is that the model has changed to eight planets. So the way we explain things can change. Theories are tentative. |
| Mr. Chigura: | Nice, now let us define what a law is. Tell me one law that you know. |
| Anelisa: | law of conservation of energy. |
| Mr. Chigura: | The Law of Conservation of Energy. That is one, another one? Yes. |
| Learner: | Ohm's Law. |
| Mr. Chigura: | Ohm's Law. …. now let us define laws. … what is common in these 2 laws? |
| Learner: | Formulas |
| Mr. Chigura: | What do you mean. Explain further… |
| Learner | …. for Ohm's law R= V/I |
| Mr. Chigura | …. so laws can be written in the form of equations. What do we call the things that make up the equation? What are those things in a formula? … such as voltage, resistance, and current in Ohm's Law… |
| Learner | Amperes. |
| Mr. Chigura | No those are units. There are? |
| Learners: | Components. |
| Mr. Chigura: | …. Components of the formulae. ….. are variables. |
| Class: | Yes variables |
| Mr. Chigura | …. therefore, laws are fixed mathematical relationships of variables |
| Mr. Chigura: | …. come and write Ohm's law in front on the board…. |

Trust writes the equation on the board….

| | |
|---|---|
| Mr. Chigura: | … tell us what you wrote? …give the meanings of those symbols. Tell what V means... |
| Learner: | V times R. |
| Class: | current times resistance they correct the learner (Trust) |
| Trust: | Current x Resistance. |
| Mr. Chigura: | Thank you. IR = V good. Well done. |

Mr. Chigura: …now the relationship of the variables is correct. The relationship of the variables is fixed. It does not change…. for a specific resistor the V α I and this will be true for any conductor

Mr. Chigura: ….so the aspect of Nature of Science is that, is that a science theory is tentative it can change. However, laws do not change. So scientific theories can be revised. What can cause scientists to do this?

Learner: …after some research.

Mr. Chigura: So what comes out of the research?

Learner: New information

Mr. Chigura: New information in the form of new evidence is another component of Nature of Science. I have said that science has theories and laws. Science is also based on data and evidence. What is the difference between data and evidence? …

You have said that evidence comes from research. Scientists carry out investigations. The information that they collect in their investigations is scientific data. When they look at that data, they can make sense of it and give it meaning. For example, does it mean that now, the size of Pluto because it is so much it does not qualify to be a planet after doing their measurements and calculations. So data is information… in science what type of data do we collect most of the time?

Learner We measure mass…

Mr. Chigura: Yes, in science we measure quantities. The measurements become the data that can be used to do what?

Learner: To prove

Mr. Chigura: It is proof to support a specific claim or to disprove a claim.

Mr. Chigura: A hypothesis will be an idea of the relationship of variables that is testable. …we all have endless ideas but are they testable?

Class: No sir...

Mr. Chigura: Can you map out the variables that you need to test.

Mr. Chigura: So, he says that you start with a hypothesis. So I will come here with scientific method and then I will write hypothesis first. That is what he is saying and then?

Learner: The aim of what I want to investigate

Mr. Chigura: So the myth here is that scientists do not follow the scientific method. They use their innovativeness and imagination. Scientists can use the scientific method but they are not bound by it. They use it when it suites them.

could not. So there was a scientist called Kekule. He was a chemist, and the way that he deduced these ring structures. He claimed of dreaming of a snake biting itself on its tail and then he thought to him isn't this like those way structures are like. So that is how he discovered the structure of benzene and aromatic compounds. So what did Kekule use as a scientific tool?

Learner He used his imagination to be creative.

Mr Chigura Right so scientists use imagination to discover things and this is part of the scientific method. So in science there is no specific scientific method. What we refer to it as the Scientific Method helps us to carry out experiments.

**Lesson 4**

**Enhanced Greenhouse Effect: Grade 11** Date: 28/8/2018

Teacher: Today we will do the GHE. Are we all familiar with a normal greenhouse?

Learner: Yes

Teacher: What do people do with greenhouses?

Class: We plant some plants.

Teacher: We plant some fruits or vegetables? Why do we use them in farming?

Learner: it is about the amount of $CO_2$

Teacher: It is about the environment. Fruits and vegetables do not do well in winter. So they are grown in a greenhouse. So that must tell you about the conditions inside a greenhouse. How are the conditions inside?

Learner: They are warm.

Teacher: They are very warm, they are warm because the greenhouse traps warming energy, heat energy. Yes, Kevin.

Kevin: isn't that like light material light coloured material reflects heat?

Teacher: Light coloured. Yes, if you are comparing black and white surfaces. Light tends to reflect more radiation and black surfaces absorb more radiation.

Kevin: …is a greenhouse does it have glass or plastic?

Teacher: A greenhouse has plastic and it is transparent… The transparency of the greenhouse plastics means that light is going to pass through. It's going to pass through because it is transparent. So, light enters the greenhouse, why? Because light is short wave radiation and the moment it enters through this structure, it's reflected from the surfaces of the greenhouse and the reflected radiation is long wave radiation. Which is IR radiation and it warms up the greenhouse.

So at the same time, if we are talking about the GHE on the globe the same warming occurs. Energy from the sun, the solar radiation, is high frequency radiation. The solar radiation is reflected from the globe in the form of long wave IR radiation and will lead to global warming.

Learner …but has the planet been warming sir?

Mr. Chigura: …the average global temperatures have been increasing. It is all due to the enhanced GHE due to an increase in Greenhouse gases. infra-red (IR) radiation is released by the surface when the uv- radiation bounces off the ground. …the excess IR that is released by the globe is trapped by… Greenhouse gases e.g. $CO_2$ are able to absorb IR and emit it in the atmosphere. So, if you have a high concentration of $CO_2$ levels here the excess IR is absorbed, here and, the reflected radiation from the ground. … will lead to … global warming…so in the same way that is how the greenhouse works … Our greenhouse operates like our globe. Like our atmosphere, the plastics around the greenhouse are the atmosphere...they have the ability to trap the heat within the house itself, so Greenhouse gases have the ability to trap the heat... The surface of the greenhouse matches the earths' surface that emits excess IR radiation, there is no problem with uv/ visible radiation that passes through the plastics or atmosphere because Greenhouse gases do not absorb the high frequency or high energy radiation. It can only absorb IR which is on the lower end of the electromagnetic spectrum with low frequency. So …the Greenhouse gases can absorb IR and reflect it back to the ground

… Learners what have you understood from this explanation?

| | |
|---|---|
| Dineo: | What I understood… is that uv rays are radiated into the atmosphere and they go back as IR from the ground. |
| Mr Chigura: | Very good. |
| Thapelo: | …Greenhouse gases, can trap IR into the atmosphere. They absorb low frequency low frequency IR radiation. |
| Mr. Chigura: | What is that going to result in? |
| Precious: | Global warming. |
| Mr. Chigura: | … What traps the heat here? (Teacher points to the plastic cover of the greenhouse) |
| Class: | Plastic |
| Mr. Chigura: | It is the plastic which represents the atmosphere here. We have Greenhouse gases that are acting as a trap…a radiation trap in the atmosphere to cause the globe to warm up. |
| Teacher: | What are the impacts of when the temperatures start to increase? What will happen? What will start to melt in those regions? |
| Class: | ice. |
| Teacher: | Ice starts to melts in those regions. Right, because the temperature is increasing…so this is one of the evidence of global warming due to the enhanced GHE. And as a result the ice caps start to melt what will happen to the sea levels? |
| Learner: | … the sea levels will rise. |
| Teacher: | Sea levels very good. Rise in sea levels and then how does this affect coastal cities? |
| Learner: | …there is flooding experienced in coastal cities |
| Teacher: | … we have experienced this recently. Which city in South Africa has had flooding? |
| Learner: | Cape Town. |
| Teacher: | It was in Durban not Cape Town. These cities have high population densities due to the economic activities they offer in terms of various industries and trading sites. So the impact of flooding can be devastating on cities like New York and Amsterdam |