University of the Witwatersrand

MSc- Science Education

Using Climate Change as a context to teach Chemistry topics in my Physical Sciences FET classrooms - a Self-Study

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Declaration

I declare that this research report is my own work and that all the sources I have used have been fully referenced. It is being submitted in partial fulfillment of the requirements for the degree of Master of Science in Science Education, at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other university.

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Caroline Mandava Chipato

5 April 2019

To my family,

-without whom this study would have been completed earlier!

(I still love you though!)

AND

to my critical friends and Dr E. Nakedi

-this would not have been if you were not part of it! Thank you!

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Abstract

The general realization that knowledge about Atmospheric particle activity and related phenomena has the potential to promote the understanding of Climate Change aspects as reported in (Grassian & Stone, 2015; Mahaffy, 2014; IPCC, 2013; Seinfeld & Pandis, 2006) has been fully turned into a global challenge such that some education systems elsewhere has steered towards the teaching of such phenomena, on a large scale (IPCC, 2013; Quest, 2011). Studies (Quest, 2011), commissioned by UNESCO, studies leading to the White Paper of 1995 and 2011, have called for more intense Climate Change education in South Africa. The new Curriculum Assessment Policy Statement (CAPS), (2011) apportions a diminishing focus on socially-relevant topics such as global warming and atmospheric chemistry in the Physical Sciences curriculum (Nakedi, 2017). This study focuses on my personal learning journey, as a teacher investigating their own knowledge shifts and its implications to issues of relevance in the teaching and learning of climate change aspects in Physical Sciences, in a South African school. A Self-study methodological approach is undertaken by me, the researcher (and the researched) so as to explore and trace my efforts of using Climate Change as a context to teach Chemistry topics in the South African Physical Sciences curriculum. The process is also opened up to a collaborative team of critical peers (my colleagues and research supervisor). In this study, PCK is used as a conceptual framework whilst the Learning for Teaching through Participation (LTtP) model (Nakedi 2017) which is a framework for studying teacher learning environments, is used as an analytical tool to capture my shifting perceptions as I plan and teach the topic to my learners. Since climate change is not catered for fully in the current curriculum, the strategy used was teaching it as a context in teaching the relevant chemistry topics at grades 10 and 11. In this way exploration of its possible place in the current chemistry curriculum is possible. As an outcome of these efforts, learners were generally able to express themselves fully when explaining mining and related events that eventually lead to Climate Change. They showed an ability to integrate what they have learnt in other subjects to Chemistry and come up with plausible explanations to events or phenomena surrounding climate change. Self-Study requires the use of a variety of qualitative research tools and this study employed two-staged concept mapping and construction of Concept Representations (CoRes), development of lesson plans and tasks as well as entries into a reflective journal. Drawing from socio-cultural and cognitive perspectives, the LTtP model in conjunction with PCK, offered pre-determined categories which were then used to analyse my research tools and procedures and weigh the study. The study ultimately unveils some conceptual shifts in my understanding of Climate Change phenomena, my strategic curriculum knowledge, and my knowledge of learner's prior concepts knowledge as I planned, taught and reflected on my teaching. Results indicated some profound conceptual shifts in my understanding of climate change phenomena, my strategic

curriculum knowledge and my knowledge of possible learner's conceptual challenges, as I taught this topic.

Keywords: Climate Change, atmospheric chemistry, knowledge, context teaching, chemistry topics, Physical Sciences, curriculum, Self-study,

Acronyms

CAPS- Curriculum and Assessment Policy Statements

GDE- Gauteng Department of Education

FET- Further Education and Training

NCS- National Curriculum Statement

NGOs- Non-Governmental Organisations

PCK-Pedagogical Content Knowledge

UNESCO- United Nations Educational, Scientific and Cultural Organisation

UV- ultraviolet

CHAPTER 1: BACKGROUND AND CONTEXT OF THE STUDY

1.1 Introduction and Background

All over the world there is a realization that the knowledge about Atmospheric particle activity and related phenomena has the potential to promote the understanding of Climate Change aspects. In particular, the field of Chemistry deals with the world at the molecular level, which can provide a fundamental basis for understanding the phenomena that determine Earth's climate as well as how human activities are altering the atmosphere, (Grassian and Stone, 2015; Mahaffy, 2014; IPCC, 2013; Seinfeld and Pandis, 2006). This potential has been fully turned into a global challenge, even the education system has steered towards the teaching of such phenomena, on a large scale (IPCC, 2013). South Africa needs to heed to the call in a more visible way than it is currently doing. There exist studies (Quest, 2011), commissioned by UNESCO leading to the White Paper of 1995 and amended in 2011 (DoE (2011)), that call for more intense Climate Change education in South Africa. The coverage of Climate Change concepts in South African Physical Sciences (Chemistry) classes as indicated in CAPS (2011), at FET level, leaves much to be desired. Unlike in the Senior Phase level, grade 10-12 South African learners who do not study Geography are not fully exposed to the whole picture of what happens in the atmosphere. In turn, the learners may not fully understand when they hear talk about Climate Change, either in the classroom or in any other media.

It is worth mentioning that under the National Curriculum Statement (NCS), the theme of Climate Change was dealt with under Chemical Systems at grade 11 and this focus was somehow however, lost with the move to CAPS. This omission is not justifiable because most of the Chemistry concepts underpinning this theme are covered under the Chemical Systems in grades 10 and 11 (Nakedi, 2017). Much of the present content which learners are exposed to, is about exploiting the hydrosphere, the lithosphere and vague information, if any, about mechanisms found in the atmosphere exists. Most aspects of Climate Change are covered in detail in one of the FET subjects, Geography. The subject Life Sciences also looks at the teaching of Climate Change from a Natural Science perspective. Of worry is the amount of detail covered in Physical Sciences versus what the learners are expected to know, given that Climate Change phenomena is also

explainable using Chemistry. After passing through the current education system, and according to CAPS documents, our learners are expected to show that they have acquired more advanced, complex knowledge and skills as well as reasoning which they can apply to everyday phenomena. However, this may not be the case for some Physical Sciences learners in South Africa when it comes to issues like the enhanced greenhouse effect, ozone depletion and global warming as related to Climate Change.

In this study, I used a Self-study to trace my efforts of trying to make the learners understand Climate Change from a Chemistry point of view. Since Climate Change is not catered for fully in the current curriculum, the strategy was to use the theme as a context in teaching the relevant Chemistry topics at grades 10 and 11. In this way the possible place in the current Chemistry curriculum was explored. As an outcome of these efforts, the researcher aimed to get the participant learners to express themselves when explaining the events related to Climate Change. It was expected that they would be able to integrate what they have learnt in other subjects to Chemistry and come up with plausible explanations to events or phenomena surrounding Climate Change. An analysis of the coverage of Chemistry concepts that lead to and/or link with Climate Change aspects at FET level, in order to reveal how I evolved as a teacher as I taught and tried to improve my learners' understanding, is thus necessary.

As part of the Self-Study approach, an investigation was done, on my practice as a Physical Sciences educator (who has mostly a Chemistry teaching background), as I taught Chemistry aspects that are associated with Climate Change to FET Physical Sciences learners, some who study Geography and others who do not. The purpose was to study my planning and eventual teaching as I attempted to address Climate Change as a theme, with the aim of aiding my learners to understand and be able to differentiate the mechanisms associated with global warming and Climate Change as topical phenomena that have a direct impact on our lives. For the concern to be addressed it was necessary that I be more knowledgeable in my content, know any associated misconceptions I or the learners might hold, plan well on the topic and eventually deliver the content to my learners. From thereon, my performance was then looked at from

different perspectives and analysed using an existing framework. Once my recorded data was carefully interpreted and analysed, the overall aim was to generate knowledge that will be of individual enrichment as well as to serve public interest. An improved teaching approach was thus envisaged.

Self-study is personal in that it has a focus on the development of one's practice as the researcher, hence, to ensure objectivity and rigour, its methodological requirement is that one should expose their research processes for public scrutiny. Therefore, in this study, a team of collaborators who serve as critical peers was established with my colleagues and my supervisor. The role of the team of collaborators was to essentially serve as a forum that analyse and critique my work-my planning, my presentation and my reflections and offer critical feedback for incorporation in a cyclic process as I framed and reframed my practice. With this in mind, I now look at associated literature reviews and then the overall research design and methodology.

1.2 Research problem

Through the Climate Change Response White Papers (1995, 2011), that were produced for South Africa as a response to the need for public awareness on matters of Climate Change, there has been an increase in Climate Change education awareness as well as occurrences of training and skills development (Quest, 2011). The assumption is that through the establishment of such policies, by the South African Government the value of Climate Education as seen by the rest of the world, is supposedly enhanced. The degree of the value however lies in how well educators and other stakeholders contribute to the achievement of the overall organizational objective.

The Physical Sciences educator (in this case, trained to teach both Chemistry and Physics) sees him/herself restricted by the CAPS document as to what to teach in the topic that talks about greenhouse effect, global warming and ozone depletion. It is against this background that such a Chemistry teacher should constantly seek relevance in the education field, by providing learners with information and knowledge that empowers them to describe and engage with phenomena that impact their lives, namely, Climate Change.

The current educational policy, the Curriculum and Assessment Policy (CAPS), 2011 talks of the need to provide learners with access to quality education, orient them on environmental issues, amongst other aims. Whilst it is appreciated that the CAPS curriculum upholds interdisciplinary issues, one can see that the teaching of issues related to Climate Change could be generally viewed as Chemistry more than any other subject. However, the scope of this theme is very much limited in the Physical Sciences curriculum, and unfortunately, the move from old NCS syllabus to a CAPS-aligned syllabus resulted in further reduction of thrust and focus on this critical theme. This needs to be addressed if the required knowledge is to be attained by the Physical Sciences learners.

There is also not much published research looking at the teaching of Atmospheric Chemistry (as related to Climate Change) to South African FET learners. The work is greatly covered in learning areas like Geography and Biological Sciences as well as at GET/ Senior Phase level, as evidenced in their resource books. Teachers could help by raising awareness of the important contributions that Chemistry can play in improved understanding of Earth's atmosphere and related climate to our students and communities, by teaching the scientific principles of Atmospheric Science and Climate Change through Chemistry, suggests Mahaffy (2014) as cited in Grassian and Stone (2015).

Besides the lack in thrust, there is also lack of detailed Chemistry content in resources for teaching Atmospheric Chemistry in Physical Sciences. Chemistry content (reactions and mechanisms) makes little or no appearance in an open way for learners to see that it is indeed there. Curriculum developers are indeed sifting the Chemistry content from the topics that relate the 'spheres' to each other and leave it to Geography and Life Science teachers. The Chemistry content is ignored. Of worry is the amount of detail covered in Physical Sciences versus what the learners are expected to know. Another issue with the Physical Sciences CAPS curriculum is that the portion in CAPS (2011, 2013) that speaks to how much should be covered, leaves the teacher to make a decision

as to how deep to go with the content on Climate Change, especially with grades 10 and 11.

This unfortunate background continues to downplay the importance of looking at the Chemistry involved in the atmosphere as a key to understanding related global phenomena such as Climate Change. More often than not, confusion between concepts such as ozone depletion and global warming arises as a result of not knowing where these two phenomena emanate from. An increased understanding of chemical processes (and feedbacks among them) that leads to global warming can provide the necessary scientific basis for understanding the factors that determine and are changing Earth's climate, suggests Grassian and Stone (2015). An educator trying to explain any of these highlighted issues therefore needs to have good Chemistry knowledge to be able to convince their audience hence my reasons for conducting a Self-Study to explore my efforts and leanings in using this critical theme as a context to address related Chemistry concepts in the grades 11 syllabus.

1.3 Research objectives

As highlighted earlier, a Self-Study research approach was used to trace my efforts as I taught Climate Change-related Chemistry concepts to Physical Science learners, all for the eventual understanding of Climate Change and its place in the Physical Sciences curriculum and in the society at large. The main intent was to carry out an investigation on my practice as a Physical Sciences educator who has a largely Chemistry teaching background, as I teach aspects of Climate Change to FET learners, some who study Geography and others who do not. The purpose is to study my teaching with the aim of improving how I teach portions of selected topics that are linked to Climate Change. I want to explore, work with and aid learners in understanding and differentiating the mechanisms associated with Climate Change, to slightly beyond the requirements of their syllabus.

Climate Change is a topical issue in our lives today, but to much dismay, the move from NCS to CAPS resulted in the detail in some of the critical topics such as Global Warming, being dropped from the Physical Sciences curriculum (Nakedi, 2017). This presents itself

as an unjustified drawback mainly because the prerequisite concepts underpinning this theme are already being dealt with under the themes or topics of Chemical Change and Matter and Materials that are dotted across grades 10 to 12 of the Physical Sciences curriculum.

This study uses PCK as a conceptual framework and Self-Study as a methodological framework. In the study, I essentially put my teaching on the spotlight.

1.4 Research Questions

Given the thrust of my study, which focuses on my efforts of learning to address the theme of Climate Change in my grade 11 class and exploring the place of this theme in the Physical Sciences curriculum, my study was guided by the following set of questions?

1. How is my pedagogical content knowledge for teaching Atmospheric Chemistry to my Grade 11 Physical Sciences learners transformed as I reflectively use Climate Change as a theme in my lessons?

2. How are my strategic curriculum knowledge, metacognitive capacities for teaching this topic and enhanced as I engage in this process?

3. What do I learn from this teaching experience and how can I use that knowledge to improve my teaching strategies in addressing learners' needs in this topic?

The procedures in the methodology section thus aided in capturing information that tried to answer these questions. The emanating analysis subsequently gives a measure of the extent to which the above-mentioned questions were answered.

A close examination and analysis of how I carried out this engagement was the focus of the study. My performance as a teacher was looked at from different theoretical perspectives. For data analysis, the study adopts an already field-tested Learning for Teaching through Participation (LTtP) model (Nakedi, 2017) which is a framework for studying teacher learning environments. The model draws from sociocultural and

cognitive perspectives and was designed to capture a holistic picture about a teacher in varied curriculum innovative space.

The methodology of choice in this study is Self-Study. Self-Study requires the use of a variety of qualitative research tools and in this study, two-stage concept maps and Concept Representations (CoRes) were constructed. Ultimately, a CoRe for the topic was generated. As part of the data collection tools, I also came up with lesson plans (preparations) and kept a reflective journal throughout the process. To be able to assess the impact of my efforts, participant learners were given a pre and post-perception test that also served as a concept challenge test. The study employed topological data analysis with pre-determined categories offered by the LTtP model. A framework for future use may be set from this study. Since Self-Study is personal and based on a learning journey of the individual, its nature requires that the work done be opened for public scrutiny. In this study, I therefore opened the processes of my research to a team of my colleagues and my supervisor who then formed a collaborative team of critical peers.

1.5 The Rationale and Significance of the Study

The Self-Study was carried out with the intent to investigate my practice as a Science Educator when it comes to teaching Chemistry of the hydrosphere, atmosphere and the associated Climate Change. I wanted to learn and to understand how I could engage learners in the Chemistry of the Atmosphere, and related ‘spheres’, so that they improve their understanding of Climate Change and I in turn also improve my teaching.

When I first taught Chemical Systems to Grade 10 learners as well as Exploitation of the lithosphere to Grade 11 learners, a few years after a long time of not teaching Chemistry and in a different country altogether, I faced a few problems. One of these was that I felt the syllabus was just too vague in connecting Chemistry to Climate Change, at FET level. I was not required to teach in detail. Faced with the contextual frustrations that had gathered up in these few years, I felt I could do something about the way I teach

contextual topics to high school learners that do Physical Sciences as a subject. I felt the need to come up with strategies that essentially work to enhance conceptual understanding and develop skills that would be used in the next grade or level of learning or even in a parallel subject such as Life Sciences or Geography.

It was difficult to create opportunities that relate Physical Science to a broader social goal of promoting human rights, environmental justice and social goals, as suggested by the set curriculum documents, the CAPS documents. The reason could be that, I continuously failed in my approach to deeply engage with the core concepts to be learnt in topics that look at human impact, topics such as mining and the environment. These topics are Geography and Life Sciences concepts. Apparently, I possess some knowledge of Biological Sciences but not of Geography. I am a Biological sciences and Chemistry educator by training and so it pained me to just teach surface information when I have an opportunity to go into detail. I felt that the CAPS curriculum set-up was somehow failing me at that point.

With this study, an opportunity for me (as the researcher and researched), a group of educators and some Physical Sciences learners to engage with Climate Change aspects from a Chemistry perspective was realized. The study generally made a substantial contribution to my knowledge, enabling me to gain insight into the concept of Climate Change, specifically Chemistry of the hydrosphere and atmosphere. The study also enhanced my own understanding of ways to effectively incorporate Climate Change Education into the current curriculum, without necessarily upsetting the system. The envisaged improved teaching styles and approaches in the researcher were also partially realized. For the ‘others’, who might teach the same topic(s), the challenges faced and the lessons learnt from this personal journey are equally narrated.

Why teach climate change aspects to Physical sciences learners? If it is left to other subjects other than Physical Sciences, the implications as suggested by researchers are quite significant (Guardian, 2014). The learners will not know much about why it is happening and exactly how it is happening. Climate change education is informed by some important theories in science and it also integrates lines of evidence from various

disciplines (Geography, Life Sciences and Chemistry). Making learners understand this underlying principle helps them to realise how powerful climate change knowledge is in their lives and it also allows for learners to engage in high order scientific thinking skills as presented in the integration. Previous research in Geography education by Anyanwu (2015), has shown that Climate change education that is interactive tends to change learners' everyday perceptions about causes of and effect of global warming as well as ozone depletion, aspects that are catered for in the Climate change topics. This study therefore tries to engage both the researcher (me) and the other participants (learners) with a semi-structured questionnaire, concept maps as well as worksheets to try and gauge what is currently known and what is essentially gained during the interactions (lessons).

1.6 CHAPTER SUMMARY

In this chapter, the overview of the study has been discussed, to include background information to the study, questions and the conceptual framework of the study. The rest of the report is structured as follows:

In Chapter 2, a review of the literature on similar studies and any shortcomings is discussed in detail.

In Chapter 3 a discussion on how the study was carried out is outlined, the overall research design, sampling, tools and procedures of data collection are also presented.

Chapter 4 focuses on data analysis and some findings.

Chapter 5 then outlines the summary of findings of the study, answers to the research questions as well as limitations of the study.

Chapter 6 then outlines the conclusion and recommendations of the study.

CHAPTER 2: LITERATURE REVIEW & THEORETICAL FRAMEWORK

2.1 Introduction

Anderson (1996) defines a literature review as a summary, analysis and interpretation of the theoretical and conceptual research literature related to a research project or topic.

In this section, literature pertaining to the study is reviewed. My study is essentially a Self-Study. My proposed topic narrows me down to these basic things- teaching, Atmospheric Chemistry concepts as related to Climate Change, FET learners, and Self-Study. My literature review therefore emanates from such aspects as highlighted in my research questions. These include but are not limited to the knowledge that a practising teacher needs to have, be it about the content of the topic they are teaching, about what the curriculum says, about the learners and about the context in which the teacher and the learners find themselves in.

2.2 Theoretical framework

I am going to consider the theoretical perspectives that serve as a foundation for the study. The study draws from cognitive constructivism and situated cognition perspectives. These perspectives are then the theoretical framework that serves to aid me in reviewing any underlying assumptions, select and justify methodological techniques as well as procedures for data collection. The perspectives aid in conceptualising a strategy for the study, one in which the researcher focuses on their PCK development and use of methodologies such as self-studies, which promote an experiential-reflective approach to practice, within a participatory framework of community of practitioners.

Self-studies tend to be multi-perspective in approach. According to Samaras (2002), even though Self-study scholars, as they carry out their research, may uncover their early attraction toward a particular theory, it is important to note that these scholars also come from multiple theoretical points of view. Self-study research in education feeds from other theories of teaching and learning. Eventually some self-study scholars may have a preference towards particular theories as say, observed in the work of Dewey (1916) or

Vygotsky (1978). In light of this, however, Self-study research itself therefore does not include a particular theoretical stance. Wilcox, Watson and Paterson (2004) (as cited in Samaras and Freese, 2006), self-study research has a non-linear and unpredictable nature and is therefore often noted to have its roots in a postmodern theoretical perspective. To shed light on what a postmodern Self-study researcher does, Wilcox et. al. (2004) argue that whilst a modernist researcher assumes knowledge as an entity given prior to the act of research, a postmodern researcher, on the other hand tends to understand knowledge production as a cultural production. With this approach, the researcher takes a rather reflective and analytical stance and seeks to identify the cultural, interpretive, and ideological basis built into his/her conceptions of knowledge, Samaras and Freese (2006). This is done by way of journaling personal experiences as they occur and in turn analyzing what they may mean to an observer. This is particularly important for teachers who are trying to overcome their biases which impact on their interactions and perceptions of others in their teaching. Self-study examines the practical and brings the theoretical underpinnings of one's work to the forefront, it is contextual based research. As self-study draws from the practical and brings forth the unexpected, any proposed theory will therefore be tacit up to and until when it begins to unfold and become more exposed with time, through the interactions with the others-persons and the environment associated with the researched.

Presently, I justify the theoretical base of this study by showing the links between situated cognition perspective and teaching- how situated cognition informs PCK. I also try to show where PCK, another visible research construct, fits in the teaching process. I also show how conceptual change in a teacher in this study existing in a social structure justifies the selection of a self-study methodology.

2.2.1 The Constructivism Perspective

Constructivist perspectives, specifically social constructivism as initially developed by Vygotsky (1978) and cognitive constructivism as postulated by Piaget (1972) and Bruner (1990), generally look at how children's understanding can be probed and possibly increased to a higher level. The teaching approaches within these perspectives advocate

for active involvement of individuals (learners) in the process of meaning and knowledge construction. Social constructivists, however, and unlike cognitivists tend to view science knowledge as being first constructed by a being in a social context and then used by that individual (McMahon, 1997., Bruning et al., 1999; M. Cole, 1991; Eggan & Kauchak, 2004 and Milera (2009). To them, learning is cannot be separated from its social context (Vygotsky (1978)) and according to McMahon (1997), meaningful learning occurs when individuals are engaged in social activities.

Whilst both theories recognize that learners come to instruction with some preconceived ideas, which are often in conflict with accepted science concepts and must learn within a social set-up to acquire knowledge, cognitive constructivists view knowledge as an individual construct. Learning is postulated by Vygotsky (1978) as being a social process Additionally, McMahon (1997), sees learning as a process that allows for the merging of selected, pre-existing knowledge and new knowledge, through the use of an individual's cognitive structures and within a social context-one that gets withdrawn with time as the individual begins to show signs of independence.

Accordingly, Smith, diSessa and Roschelle (1993) suggest that it is therefore essential that any teaching process therefore considers learners' prior experiences and conceptions and work towards helping learners to change or replace the misconception if any cognitive growth is to occur. Scientific knowledge is not to be just conveyed to learners; one must interact with the learners' ideas for change to take place.

Rather than giving a didactic lecture to learners and make them passive learners, a teacher who upholds social constructivism should act as a facilitator to the learning process in which a learner is put through. Bauersfeld (1995) upholds this stance when he indicates that instructors must be facilitators not teachers. Furthermore, the facilitators must not tell but ask, must give guidelines not answers. Belamy and Rhodes (1999) suggest that continuous and interactive dialogue should be dominant in a classroom of a social constructivist instructor. They envisage a dialogue which is embedded within a Zone of Proximal Development as postulated by Vygotsky. In the dialogue that occurs, learners get to expose their personal knowledge, until new knowledge is birthed, new

knowledge which is essentially made up of some additions and changes in their prior knowledge as part of learning. This however cannot be possible if the environment in which the learners is currently in is not supportive of such type of learning. The role of the Zone of Proximal Development (Vygotsky, 1978) is seen as very important in this teaching approach. The introduction and then eventual removal of support to the learner by the facilitator should be displayed when teaching.

2.2.2 Teaching as a Situated Practice

This study looks at the teacher as a learner whilst in their practice, a learner seeking to gauge and improve their PCK; hence the need to assign the situated learning perspective to it. According to Bandura (1977), observed behaviours can serve as information for anyone who is observing such behaviour and can act as a guide for future action. Smith (1999) suggests that if an experience is recorded, it can then act as a template to compare with standard behaviour. The individual seeking to learn does a rehearsal, interacting with an environment and compares it with modelled experience to see where they lie. From Bandura's model stems out a more radical approach to teaching and learning-situated learning, postulated by Lave and Wenger (1991). To them, knowledge is acquired in a social set-up, through co-participation rather than through cognitive processes. Learning involves participation in a community of practice. Learning is the relationship between people, it does not belong to individual persons, but to the various conversations of which they are a part, McDermott in Murphy (1999). Also defending situated learning, Tennant (1997) claims that there is a connection between knowledge and activity. The activity that is likely being referred to is what the participants do as they seek to acquire knowledge in their practice, which is essentially what the researcher is seeking to do.

2.2.3 Pedagogical Content Knowledge

Based on my training to be a teacher, I view a teacher to be one that shows the capability to integrate their subject content with acquired teaching skills as well as with what they know about their learners, in any given situation. A good teacher is generally seen by their works how they prepare themselves and guide learners into understanding what they teach them. Even when faced with learners with different abilities, a teacher should

know what to do so as to make learners understand content. In doing all this, the teacher displays and openly exercises the extent of their knowledge. It is therefore necessary that one looks at a theoretical framework that associates a teacher with knowledge or knowledge domains. To guide this study, I look at pedagogical content knowledge (PCK).

There is very little published research that is done locally by Physical Science teachers about their own teaching of content. In South Africa, there are studies pertaining to the teaching of Climate Change, (Anyanwu, et. al., 2015; Bozdogan, 2011); Boon, 2010; Bello, 2015; Quest 2011) but none are produced about the topic being taught in Physical Sciences. Research as outlined in Berry (2008), amongst others, is showing an increase in the awareness that points out to the importance of content and context involved in teaching for understanding. If we want to really know what constitutes a good lesson where learners understand, we need to look at how learners understand concepts and also why they learn. Sometimes, the intended purpose is not the same for both parties involved in the lessons. Learners learn for assessment purposes, mainly to earn marks and qualify for the next grade or year. Despite this fact, teachers need to realise that they need to teach for understanding too.

When teaching a topic and expecting learners to understand the concepts, there are certain aspects of pedagogy that one is expected to hold. A teacher must have adequate content knowledge and they must also know how to present that subject in a way that one's audience can understand (Pedagogical Knowledge). Since the focus is on teaching or rather exposing the knowledge domains that best describe a teacher, it is necessary that one looks at PCK literature.

PCK was originally put across as a type of knowledge that is unique to teachers. Knowledge that is based on the manner in which teachers relate that which they know about teaching to that which they know about what they teach. Such an integration of a teacher's Pedagogical Knowledge and their Subject Matter Knowledge make up Pedagogical Content Knowledge (PCK), Cochran (1997). Lee Schulman is one of the proponents of categorising knowledge as we now know it. According to Shulman (1986) Pedagogical Content Knowledge

. .. embodies the aspects of content most germane to its teachability.

Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations- in a word, the ways of representing and formulating the subject that make it comprehensible to others . . . [It] also includes an understanding of what makes the learning of specific concepts easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning…. (Shulman 1986, p 9).

Here, Shulman considers PCK to include ways of representing and formulating the subject so that it is comprehensible to others. It is the understanding by the teacher, of what makes the learning of specific concepts easy or difficult, the understanding of conceptions as well as preconceptions (which students bring to class). Pedagogical Content Knowledge is a form of knowledge that makes science teachers be teachers rather than scientists (Gudmundsdottir, 1987). A science teacher is able to take science content and make it representable to learners. Shulman (1987) agrees with this and says that teachers, unlike scientists, with their PCK have the ability to reshape the knowledge, simplify and identify various representations for concepts to increase learners' comprehension.

Shulman (1986) argues that the knowledge that is expressed through metaphors, stories, pictures, amongst other things, is more of being practical and personal than being just a generalised form of knowledge. The assessment at the end, serves to gauge the learners' level of knowledge acquisition. How the learners perform influences both PCK from the classroom practice and the topic-specific Professional Knowledge and it eventually either upsets or enriches the teacher's knowledge base. Here, PCK is presented as being more personal but there is room for negotiated PCK, brought about as a result of the teacher reflecting his or her classroom practice. The negotiation is dialogical in nature, in that there is communication (oral or through assessment) about the classroom events, and these in turn effect PCK development or PCK growth in the concerned teacher. PCK is

generally knowledge which appears to go beyond the limits of subject matter, is found in the classroom and is exhibited by the teacher, includes but is however, not limited to; instructional values, retention of control in the classroom (classroom discipline), clear presentation of work, and creation of a relaxed and enjoyable atmosphere for the learners. Pedagogical Knowledge therefore includes the general, not subject specific aspects of teacher knowledge, about teaching and it ultimately influences teaching.

Having the above view of what PCK was envisaged and known to be as well as knowing the original components it was grouped with, it is then necessary to take a look at how PCK is related to effective pedagogy.

2.2.3.1 PCK and effective pedagogy

Bishop and Denley (2007) put forth a metaphorical representation of the relationship between PCK and other knowledge base elements as proposed by Shulman (1987), likening Professional Knowledge to a spinning top with differently coloured segments representing the different knowledge categories -the individual knowledge types which comprise knowledge of content, knowledge of learners and learning, knowledge of context (circumstances surrounding the subject), knowledge of curriculum, general pedagogical knowledge, and knowledge of values, ends and purposes.

According to their 'spinning top' PCK model, the individual knowledge base elements combine to form PCK. Here, PCK can be seen as being dynamic not static. It is that type of knowledge that changes with time and context, existing in its final form as a result of a 'blending' that occurs with time. The capabilities of a teacher are then measured as the abilities to combine or blend the individual knowledge types which comprise knowledge of content, knowledge of learners and learning, knowledge of context (circumstances surrounding the subject), knowledge of curriculum, general pedagogical knowledge, and knowledge of values, ends and purposes. Initially, the spinning top's individual coloured segments are distinguishable from each other but will present a totally different colour once the top is spun. Each category of knowledge therefore has its own individuality but once put in practice, the professional knowledge is appreciated as a whole. The

metaphorical representation of professional knowledge is an extension of Shulman's originally proposed idea discussed earlier.

Through lesson observations, analysis and discussions with science teachers, Bishop and Denley (2007) try to answer two questions namely; what one needs to know to be an accomplished science teacher and suggestively how one develops or acquires such knowledge then eventually transforms it for the benefit of the learner. They go in detail as to whether or not it is possible to unravel the knowledge that supports accomplished teaching of which pedagogical content knowledge is of utmost important. Through such work, we see that the concept of PCK is less operative if teachers forget that knowledge is constructed through active learning. Teachers should therefore not become satisfied with their current constructed knowledge lest their teaching knowledge becomes less effective but rather should maintain their PCK through continuous activity aligned with the teaching profession. This situation clearly also points out to me, hence the need for this study. This type of knowledge, PCK, is therefore an on-going, ever-changing entity that requires moulding with time. Other PCK models suggest that Pedagogical Content Knowledge results from active learning. PCK can therefore change to suit the needs of individual teachers and is unique to each one. Since PCK does not exist as an entity but is the result of different and interwoven professional knowledge bases, many views agree that all existing knowledge will therefore be accounted for by what we see being displayed by an experienced teacher.

Bishop and Denley (2007) make a meta-analysis PCK study of novice and highly accomplished teachers, focusing on teacher epistemology and effective pedagogy. Their study reveals, amongst other things, that a teacher should be able to use their different forms of knowledge to execute effective teaching. The proposed study also seeks to apply nearly the same analysis as done by Bishop and Denley.

2.2.3.2 The notion of pedagogical reasoning and action as related to PCK models

Pedagogical reasoning is a term that Shulman (1987) used to describe the process whereby teachers use their professional knowledge to make decisions about what to teach and how to teach it (Bishop and Denley, 2007). Pedagogical reasoning and action

is applicable to my study because when teaching in schools, there is use of one's professional knowledge to make decisions about what content to teach and how to teach that content. Shulman (1987) describes the Pedagogical reasoning framework as occurring in a cycle of six stages namely *comprehension*, *transformation*, *instruction*, *evaluation*, *reflection* and *new comprehension*. Every stage involves decision making by the teacher. In the first stage (comprehension), the teacher must seek to understand the content to be taught so that they make it presentable to the learners. Comprehension does not only refer to an understanding of content but also an understanding of purpose, of learners and of ideas within and outside the subject area (Shulman, 1987). In transformation, critical interpretation of subject matter and resources at hand occurs followed by looking at ways of representing the content to learners and finally designing lesson activities for the lesson. Instruction, the actual teaching is followed by evaluation of the learners then a reflection of the whole process by the teacher themselves. A new comprehension of the preparation and the actual teaching itself, is realised and leads to a new understanding of the self. According to Shulman (1987) this realisation is only made through documentation and analysis of the whole process. My study sought to follow a similar pattern of documenting data.

Rollnick, Bennett, Rhemtula, Dharsey & Ndlovu (2008) use the domains which Cochran, DeRuiter and King (1993) regarded as teacher's knowledge domains and present their model of PCK, the Tailored PCK Model. In it, they view teacher knowledge as an amalgam of four knowledge base areas, namely: subject matter knowledge, knowledge of students, general pedagogical knowledge and context knowledge. The model outlines separately the domains of teacher knowledge and the subsequent manifestations of teacher knowledge. Rollnick et al., (2008) suggest that knowledge of subject matter, of learners, of general pedagogy and that of context all lie within the teacher's domain. They further suggest that the domains combine to produce PCK which then manifests in various forms, in the classroom. The resulting PCK then manifests in the classroom as any of those representations that the teacher may use to put across the subject matter, the use of specific instructional strategies, the choice as to depth and breadth of curricular coverage (Curricular Saliency) and even the assessment itself. The manifestations may include any

visible products like Subject Matter Representations, Topic-specific Instructional Strategies, Curriculum Saliency and Assessment of teaching. The visible product is what the teacher does in class during teaching. They argued that when the manifestation occurs, in a classroom set-up, the other domains of knowledge such as Content Representation, Topic-specific Instruction Strategies, Curricular Saliency, and Assessment apparently begin to manifest too. The domains of teacher knowledge affect PCK, which then effects manifestations of teacher knowledge.

In the present study I have considered PCK as knowledge that plays a role in transforming subject matter into forms that are more accessible to students. I intend to take a look at how elements of my PCK, as described by various proponents of PCK, would be transformed during my own practice. Without good clear, appropriate analogies and explanations, a scientific concept can fade right in front of the learners. It can also deepen misconceptions in the learners. Unveiling the nature of PCK is likely going to help aspiring teachers. Using the knowledge domain, regardless of their model of origin helps to bring out the totality of a science teacher for use in research purposes and will definitely serve to bring out much information from already-practising teachers and benefit other aspiring science teachers.

2.2.3.3 Expected knowledge domains

The knowledge sub categories listed previously will be further elucidated in the research report. Under the domain of teacher knowledge is subject matter (Geddis and Wood, 1997), content knowledge (Shulman, 1986), knowledge of students (Cochran et. al (1993); Lee & Luft (2008)), pedagogical knowledge (Shulman, 1986) as well as knowledge of context. The manifestations of teacher knowledge will be seen under the representations used, curricular saliency held, assessment skills held and the topic specific instructional strategies taken. The knowledge that a teacher has will be looked at in two parts, the domains of teacher knowledge and the manifestations of that teacher knowledge (Rollnick, et.al, 2008).

Two more forms of knowledge related to teaching are discussed by Shulman (1986), - the l*ateral curriculum knowledge* and the *vertical curriculum knowledge*. Having lateral

knowledge means that the teacher is aware of the related content covered in other subject areas. This knowledge aids a teacher in that one can make use of the concepts that are taught in other subjects to promote an understanding of concepts in their own subject. The concepts intended to be taught in this study, Climate Change, cut across three subjects, namely, Life Sciences, Geography and Physical Sciences. It is therefore imperative that the teacher is aware of the degree and extent of coverage of the concepts under study. Vertical curriculum refers to knowledge of how the aspects have been taught previously in a given syllabus and as syllabi change with years as well as any associated issues.

In this study, it must be shown how I intend to assess the learners. After the lessons, learners will give activities in the form of a questionnaire (Kerr & Walz, 2007) and worksheets for each aspect. This will be done so as to check their understanding of some of the taught concepts. Knowledge of Instructional strategies, the different approaches that teachers use, like whole class teaching, problem solving strategy, group work, question and answer strategy needs to be displayed too. Geddis and Wood (1997) contend that instructional strategies are essential approaches that focus on the purpose for teaching a particular topic and simultaneously address misconceptions that teachers find in their learners' prior knowledge. The analytical framework (Methodology section) also provides the different knowledge aspects expected from the teacher.

Knowledge domains in the teaching of the Chemistry topic of concern

At this point, it is imperative that one looks at what literature says about the teaching and learning of Climate Change to Chemistry learners. The previously discussed concepts of Content Knowledge and Pedagogical Knowledge are linkable and lead to PCK in Chemistry teaching. When I try to make the link between Atmospheric Chemistry and Climate Change, I express my content knowledge, which as a person who is qualified to teach the subject is expected to have. When I am aware of, amongst other things, the conceptions (even if it is misconceptions) that the learners bring to the class, I express my knowledge about the learners and in doing so; I do not ignore the context in which they learn the topic.

2.2.4 The teaching and learning of Atmospheric Chemistry and Climate Change

Literature is rich in atmospheric studies and/or Climate Change studies in the Geography Curriculum or as associated with students or teachers at University level (Anyanwu, et. al., 2015; Bozdogan, 2011); Boon, 2010; Bello, 2015; among others). Most of the studies fall into these categories and the majority are international studies. Some of the international studies have focused on ways of understanding greenhouse effect and global warming as well as the status quo of global warming and climate change education in school environments. These studies described ways of conceptualizing the greenhouse effect and the ozone layer depletion- two phenomena that were found to be poorly understood by most US college students (Kerr & Walz, 2007; Morgan & Moran, 1995). In the UK, Spellman, Field & Sinclair, 2003, among others also found similar trends. In Australia, most learners were also reported in Cordero (2001) to have inadequate understanding of the role of the ozone layer.

In one of these studies, Kerr and Waltz (2007) reveal some misconceptions and misunderstandings that are associated with the teaching of Atmospheric Chemistry as related to Climate Change. They suggest that some of the misconceptions emanate from teachers as they teach and these are as follows: that global warming is caused by increased penetration of solar radiation; it is connected with the holes in the ozone layer; that it would result in the increased skin cancer and that the use of unleaded petrol would reduce it (Kerr and Waltz, 2007).

They argue for the inclusion of topics like global Climate Change into Chemistry curricula. As one of their findings, most of the misconceptions they realised were not entirely removed from the learners' thoughts. Perhaps, they suggest, the target should be on the sources of misconceptions rather than on the misconceptions themselves. The researchers discuss the existence of several studies documenting evidence of misconceptions among students, misconceptions regarding global warming and ozone depletion, one such being that the ozone hole' causes global warming. Such misconceptions reportedly arise mostly through schools and sometimes through media. The study sought to qualitatively assess and address the misconceptions. One cause of

misconception they identified is that, in the learners' textbooks, global environmental problems are often grouped and this leads to a fixation in the learner's minds, of incorrect linkages. In addition, other studies also support the main reason for all of these misconceptions and they agree that it lies in the complexity of the science involved as well as in the ever-shifting controversy around climate change mitigation

Kerr and Walz (2007) claim that students entering colleges hold misconceptions regarding environmental issues and that these misconceptions actually emanate from misconceptions held by the teacher themselves. They went on to qualitatively assess these misconceptions as well as to address them. For my intended study, the knowledge of the misconceptions gives me a basis on which to plan to teach my learners about any topic. My lessons could be centred on these misconceptions or have their foundation immersed in these. My focus (in this study) is therefore part of their (Kerr and Walz) broad focus. If their study could be generalised, then I believe I could go further and see to it how my learners can be helped with understanding the mechanisms around Climate Change phenomena. By including the Environmental Chemistry topics such as global climate and ozone depletion into the Chemistry curricula, the authors argue that, students get to apply Chemistry principles to familiar issues. Indeed, such topics are present in the CAPS curriculum and the extent to which they are covered needs to be re-looked.

Teaching approaches that dissect problems in Atmospheric Chemistry and aid in reducing misconceptions are advocated for (Kerr and Walz, 2007).The approaches involve computer-based data analysis exercises integrated with discussions, as well as a pre and a post-test in Environmental Chemistry assessment aspects such as global warming, ozone depletion and smog formation. Exposure of the learners to computer-based data analysis exercises, a pre and a post-test, group discussions resulted in moderate improvement in learners' performance in Environmental Chemistry assessment questions. Whilst the causes and effects associated with global warming, ozone depletion and smog formation were done fairly well by the learners, learners were however found to still hold confusion around the mechanisms involved in the different phenomena. Integrated teaching methods-online learning, group discussion and lecture, all help when

used together and not individually and such integration is more likely to reduce misconceptions and lead to a more enlightened understanding of Atmospheric Chemistry. Given this light, I therefore propose for a study that places more emphasis on the phenomena that lead to Climate Change. I also look at opportunities for teaching Climate Change-related concepts in the CAPS curriculum.

Much of the documented research on Atmospheric Chemistry and Climate change is found in Geography and rarely in Physical Sciences. Local research on these issues in Physical sciences are lacking in literature. The research literature on Atmospheric Chemistry and Climate Change teaching and learning that I have reviewed above identifies the misconceptions and misunderstandings that learners exhibit after instruction and the difficulties associated with the teaching and learning of the topics.

2.2.5 Perceptions on climate change

2.2.5.1 Public literacy and Climate Change education

The BBC World Service Trust report cited in the 'South Africa Climate Talks (2010) in Quest (2011) found that even though public awareness of global climate change is relatively high (The Gall-up Poll, 2007-2008), the science itself is often not well understood. In addition to the lack of African language terminology for such concepts like Climate Change or global warming acting as hindrances to the understanding of the concept itself, some key findings were given. Reportedly, most South Africans are aware of global climate change but they have a patchy understanding of the associated science, with most tending to use the words 'climate change', 'global warming' and 'ozone depletion' interchangeably.

Another finding was that there was an association placed between the term Climate Change with some global impacts such as melting ice caps, rising sea water levels, hurricanes and inundation of low-lying countries. South Africans generally do not see Climate Change as having any special relevance to South Africa or Africa at large. The term Climate Change has been found to be used as an umbrella term to refer to the destruction of the naturally-occurring environment over time. On the other hand, there are also people who view Climate Change as being a 'green' issue and being a topic for

the wealthy only. Most people distance themselves from anything to do with conservation and they see Climate Change as an issue that people who have money and time to spare should be the ones to deal with such matters. Scholes and Lucas (2015) also bring out similar views about Climate Change from sceptics and add that it is hard for many people to accept that a tiny change in carbon dioxide (CO_2) concentration (given that CO_2 normally occurs in small amounts) could cause massive Climate Change. They advocate that people need to know that it is such trace gases that absorb warming radiation and contribute largely to the greenhouse effect (as well as the enhanced greenhouse effect). They also advocate for the need to make reports on scientific proof and knowledge about Climate Change more public and much clearer than they currently are. This role is actively played by the Intergovernmental Panel on Climate Change (IPCC) in their periodical, comprehensive reports on trends in greenhouse gases and overall assessments of the Climate.

Climate Change is in South Africa, realized as a threat but its impact is not treated seriously (Quest, 2011). Interestingly, the media and schools are treated by these authors as the main sources of information on Climate Change. Whilst there is some evidence of effort from schools, the media is reportedly seen as failing to successfully engage audiences with the issue. Among other misconceptions, there are two prevalent ones- that smoke from cars and factories damages the ozone layer, making it hotter. Having read about the current science events as documented in Quest (2011), among others, I decided to meet the challenge they expressed…. of 'making schools into worldly, socially meaningful and relevant places', (Durrant and Green, 2000).

According to Quest (2011), most people do interact with scientific information, but rarely integrate it into their lives. These people also see the bulk of the information as being irrelevant to their current needs and interests. There seems to be more pressing issues than the Climate Change, suggestively, issues to do with peoples' socioeconomic status.

2.2.5.2 Climate Change and the Schooling Curriculum

Science concepts must be made relevant to learners if we are to expect to have future scientists produced from our educational system. In a local study by Anyanwu, Le Grange

and Beets (2015) on Climate Change education, high literacy levels in Climate Science were reported amongst the sampled Geography teachers. The higher levels of literacy reportedly occurred more when it came to knowledge of climate processes and Climate Change causes and was observed to be less when it came to impact and solutions. Anyanwu (2015) therefore then agrees with Milera (2009), Hestness (2013) that, to be able to explain the concepts underlying the causes, impacts and solutions of Climate Change as accurately as possible to learners, teachers must be fully literate in Climate Change science. Though the study was done with Geography educators only, it can be seen that some of the tackled concepts also touch on Chemistry content. There is a general agreement that Climate Change Science is a broad topic that is multi-disciplinary, it includes Geography, Life Science and Chemistry (Physical Science in South Africa). In the current CAPS syllabus, the Physical science teacher is required to describe the consequences of the current large scale burning of fossil fuels (especially in coal-fired power stations); and why many scientists and climatologists are predicting global warming. The claim held is that-the burning of fossil fuels – coal, oil, petrol & gas, releases incredible amounts of greenhouse gases into the atmosphere & many scientists believe this will lead to global warming. This topic is of great concern because South Africa's carbon dioxide emissions per unit of economic value generated (CO_2 per capita) are amongst the highest in the world; it makes over 1,5% contribution to the greenhouse gas emissions that cause global warming (Scholes and Lucas, 2015).

2.3 A conceptual and analytical framework

2.3.1 The Learning for Teaching through Participation (LTtP) model (Nakedi, 2014)

The model (illustrated if Figure 2.1) has its roots in cognitive constructivism, socio-cultural and situated perspective to learning and it essentially points out that a teacher's professional growth is affected by many factors in their diverse and dynamic environment. The model therefore serves as a multidimensional analytic framework and was used in the study.

With the model, teachers are viewed as active learners, shaping their professional growth as they teach reflectively. Whilst text only can be used to analyse and frame the

knowledge bases of a teacher, the LTtP model is an analytical framework that works best to show how the knowledge is transformed. According to Nakedi (2014), this framework identifies three interrelated domains which encompass the teachers' professional world and presents multiple professional growth pathways-the domain of *knowledge and views,* the domain of *action and practice* and that of *stimulation and challenge.* Within the domain of knowledge and views, the teacher's views, thoughts and initial knowledge are revealed. These are then carried on into the professional actions and responses to different situations in their work, the domain of *action and practice*. The actions lead to results that are seen as feedback and outcomes and a possibility or opportunities of the teacher's growth. These opportunities can then be harnessed and used within the *stimulation and challenge* domain to support teachers to engage and collaborate with each other with the aim of improving and reflecting on their own practice. Within the domain of *stimulation and challenge* we find the influence of peers in the community of practice on the teacher's knowledge- a stimulant towards learning.

The model serves to see where a teacher's PCK lies in terms of beliefs and views before the teaching process, and also how it gets transformed as interaction in various domains occurs. It does not stop at just seeing the changes in a teacher. After the teaching it can be seen, by means of the model, where a person's knowledge lies. The influence of the knowledge domains over each other, are ultimately gauged.

In this study, the LTtP model generally aids in showing how integration of Self-Study, social constructivism, situated inquiry and PCK elements result and fosters habits of praxis such as critical thinking and reflective practice, habits that aid in enculturating teachers into new norms, practices and habits of mind which are consistent with the effective implementation of chosen Chemistry topics in a new curriculum where the umbrella topic is barely touched on but is supposed to be-Climate Change.

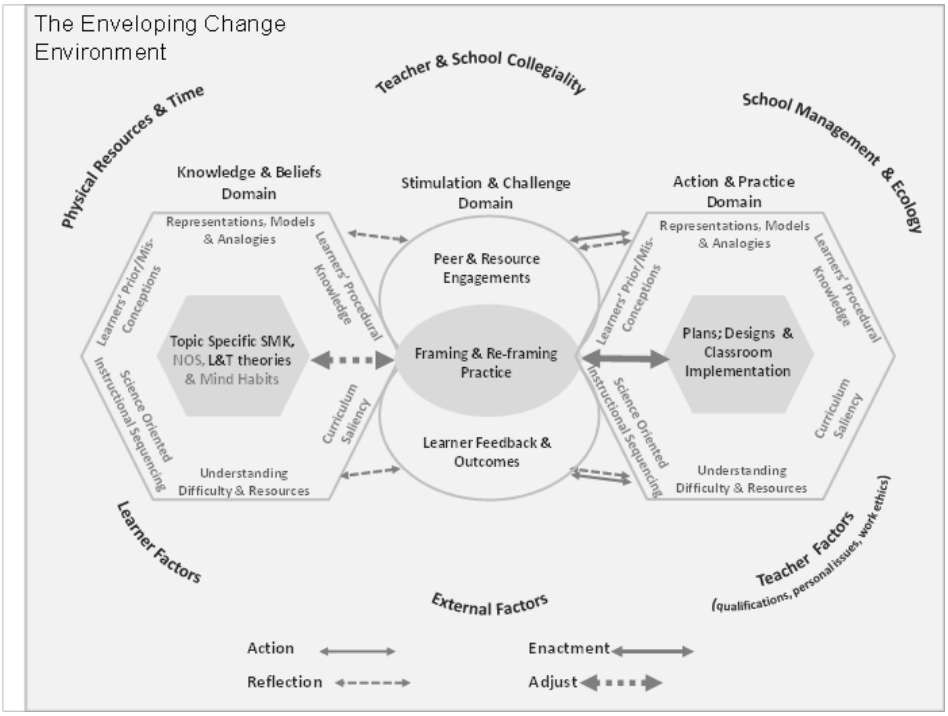

Figure 2.1: The Learning for Teaching through Participation (LTtP) model (Nakedi, 2017)

In addition it becomes the analytical framework for gauging the engagement of the teacher with content and with learners.Teacher professional growth is generally known to be situated. This means that factors affecting and effecting their growth cannot be ignored, but are considered in determining if there is a change in the teacher. The six factors, namely- teacher & school collegiality, school management and ecology, physical resources and time constraints, external factors, learner factors and teacher factors form

the environment from which the teacher draws from and in which the teacher thrives or does not. These factors are discussed in full details in the next chapter.

2.3.2 Aspects of Teachers' PCK in the LTtP model

These aspects are an indication of a teacher's knowledge, their ability to unpack content from its sources until it is delivered in the classroom. These aspects are *learners' prior conceptions, learners' procedural skills, representation forms and alternatives* used by the teacher, the range of *alternative curriculum resources* used or preferred, the teacher's *curriculum saliency as well as the science oriented instructional sequencing* used by the teacher.

Learners' Prior/ Mis-Conceptions (LP_MC)

These are the types of conceptions and preconceptions held by learners before they are taught. Such conceptions about a topic tend to either promote or hinder learning. The knowledge of learners' prior conceptions is seen in a teacher's preparation (the tasks), how they engage their learners' prior knowledge and assess for such.

Learners' Procedural Knowledge (LPK)

This aspect looks at how learners are allowed to partake in scientific knowledge and replicate scientific skills. Evidence of such engagement is found in argumentation. One looks at whether the following have been considered by the teacher: the learners' ability to relate the Nature of science, the ability to present an argument, resolve scientific problems, carry out scientific investigations in their totality as well as promote a sense of belongingness to a 'community of practice'. These procedures are seen in the teacher's plans, tasks and instructional strategies they put in place.

Representations, Models and Analogies (RMA)

These speak to any analogies, representations, demonstrations, models or even examples that the teacher, through their experience, employs in the classroom so as to make the subject matter comprehensible to the learners. This aspect can be seen in how

the teacher takes microscopic phenomena and uses everyday representations to link it with the macroscopic observations.

Alternative Curriculum Resources (ACR)

This aspect is about the teachers' awareness of what is out there to use as teaching resources for teaching a particular topic at any grade or level, their particular strengths and weaknesses in promoting learning as well as cost effectiveness, safety, convenience and accessibility issues related to their use. The resources may be in the form of text, experiments, videos, real-life machinery or even simulations, amongst other things and they all serve to support the learner as they conceptualise an aspect.

Curriculum Saliency (CS)

This aspect is about how the teacher displays their curriculum knowledge, performing rather informed and strategic sequencing of concepts during their planning and throughout their teaching. This aspect is what Shulman refers to as the *lateral and vertical curriculum knowledge,* as discussed previously. A teacher should clearly show how they map out and sequence the concepts in a topic, and how they pick out the necessary ones. To do so, it is expected that the teacher has to point out the big ideas of the topic and scaffold them in their planning.

Science Oriented Instructional Sequencing (SOIS)

This is when a teacher uses teaching and assessment strategies that value and engage learners' prior knowledge, as well as promote and capture the cognitive and the social dimensions of how scientific knowledge is generated. Science oriented instructional and assessment strategies, such as the *5Es lesson sequencing*, *argumentation,* use of *open inquiry*, use of a *scientist case studies* as well as *role playing* all allow for learner involvement in their own learning through dialogue and reflection. These are some of the strategies expected to be seen in the plans of a teacher who administers SOIS.

The table below (Table 2.1) illustrates my postulations as to how and where each aspect of the conceptual and analytical aspect can be seen in a Self-study. The information is based on the LTtP model.

Aspect	How to see it	Where to see it
LPC	Dialogue, written	In plans, tasks and teaching
LPK	Scientific skills and knowledge, argumentation	Activities
RMA	Use of analogies, examples	During teaching, worksheets
CS	Sequencing of subject matter	Planning
SOIS	Learning and teaching strategies	Planning and actual teaching

Table 2.1: Analysis aspects as derived from the LTtP Conceptual framework.

These aspects act as an analysis guide and allow for zoning in into the research. They act as lenses into the research. The researcher's knowledge can then be gauged from these aspects.

The situated perspective theoretical basis of the LTtP model (Nakedi 2016, 2017) used in this study requires that any process involving teacher professional growth will naturally be subjected to the constraints and affordances of the existing enveloping change environment (Nakedi, (2014)). Nakedi proposes six factors, which are as follows: teacher & school collegiality, school management and ecology, resources and time constraints, external factors, learners and teacher factors can be considered as affecting where a teacher's PCK falls. Analysis for these aspects will also be carried out.

2.4 CHAPTER SUMMARY

In this Chapter, a review of the literature on similar studies is discussed in detail.

The next Chapter, Chapter 3 deals with a discussion on how the study was carried out is outlined, the overall research design, sampling, tools and procedures of data collection as well as ethical considerations taken.

CHAPTER 3: Research design and methodology

3.1 Introduction

This chapter discusses the research approach that was employed so as to gain more insight into the researcher's approach to Climate Change related topics or aspects in Physical Sciences. The research approach overarching the research is discussed and justified. It is also linked with the methodological choice of your study. In that light, a detailed look is offered into the research design, Self-study methodology and data collection methods and procedures, as well as the basis of data analysis done in this chapter.

3.2 Research design

A research design is a basic plan or strategy of the research and the logic behind it, Oppenheimer (1996). The study is a Self-Study. The study fits in the description as postulated by Samaras and Freese (2009), it has the dispositions of reflection, collaboration, and openness and situated inquiry are all integral to the methodology characteristics or requirements that suit a Self-Study. An analysis of these characteristics helps remove the cloud around what Self-study is about. For example, reflection and inquiry are seen as stepping stones to Self-Study. The Reflection is presented as being first personal, then being collaborative, but nevertheless a reflection of one's conduct as they grow. The reflection creates opportunities for support and offers new insights and different perspectives. The second characteristic, collaboration exists, not only to allow for validation of findings, it also reduces potential bias. With the openness nature of Self-study inquiry, comes risk taking and vulnerability of the researched. The researched persons opens themselves to such elements but must still prevail. The situated inquiry characteristic is seen in that there is inquiry into one's own practice (Loughran, 2004), a display of authority of self-experience (Pinnegar, 1998) which allows for the world out there to see and understand the dilemma and contradictions found in learning and teaching whilst one is practicing.

The methodology of Self-study was a development by Self-study teacher educators to enhance their teaching practice and provide evidence within their context to understand

their practice (Hamilton and Pinnegar, 1998). Teachers take informed action from lessons learnt through situated inquiry as well as from the dialogue with critical friends. The methodology emphasises the self as having central importance. Self-study approaches place more emphasis on the context and nature of a person's activities, rather than the way the study is carried out.

LaBoskey (2004), an early proponent of Self-studies, outlines four requirements of Self-study. Besides that the study be self-initiated and self-focused, be interactive as well as be formalized for further deliberation, she advocates that Self-study employs multiple, primarily qualitative methods. This is so as to allow for opportunities to understand the educational processes under investigation. The Self-study discipline therefore employs qualitative research methods referred to by Samaras and Freese as the procedures and techniques of the Self-Study discipline, procedures that are carefully selected by looking at the purpose of the study. Since Self-Studies are associated with multiple data collection methods, a lot of data will be yielded and one has to select what is useful. It is however more important for Self-study researchers to dwell on the qualitative aspect of the data.

In this study, multiple constructions of reality (Cresswell, 2003) were envisaged and were therefore justified by the data collection procedures. LaBoskey's (2004) list of various techniques or methods which a Self-study teacher can select from allows for one to pick education-related life histories, narrative inquiry, autobiography, journaling, story-telling, video recordings of one's teachings, visual representations, performance, photography and art as options for data collection. In this study, concept maps, CoRes, video lessons and the panel discussions will yield the main data of concern, qualitative data which is essentially made up of my views, my peer educators' views, and their experiences, belief and/or motivation. Coding and scoring of this qualitative data is likely to yield quantitative information which may need just basic interpretation.

3.3 Research Methodology

Methodology refers to the overall approaches and strategies to a particular research project, Opie (2004). The Self-study methodology has been outlined in the previous section. The procedures or methods are referred to as, the specific research techniques

used to collect and then analyse data. The methods and procedures one intends to use essentially determine the nature of findings one gets in a study.

In this study self-study was used as a methodology. In this study, I adopt Hamilton and Pinnegar's (1998) definition of self-study as "the study of one's self, one's actions, one's ideas, as well as the 'not self'" (p238). In this view, the methodology looks at the researcher's experiences, thoughts, reads, actions, knowledge, ideas as well as their conduct with the others in their environment. This also is supported in Samaras & Freese (2009) when they claim that self-study traces its roots from teacher inquiry, reflective practices and action research. The difference between Self-study and reflective practice, identified in Loughran & Northfield (1998) is that the Self-study goes further to show a researcher's interest that go beyond their professional development, it makes the researcher step outside their comfortable boundary and begin to interact with ideas that may otherwise fall beyond the ordinary. New knowledge and understandings therefore emerge from the experience.

Since self-study is personal in that it has a focus on the development of one's own practice, to ensure objectivity and rigour; its methodological requirement is that one should therefore expose their research processes for public scrutiny. The central focus is on personal experiences in a profession, for example, in the teaching field. According to Samaras (2011), the researcher opens themselves up reflectively and goes on to systematically examine their practice and at the same time allow for others to critique them in the process. Whilst the big idea is to bring the self to the front, the engagement with the more knowledgeable 'others' is also crucial.

In a typical example of where Self-Study is used, the researcher in Gatzke (2015) find themselves suddenly assuming a science educator role whereas all along they had been an environmental science educator and this brought about conflicts within the researcher as they assumed the new role. The purpose of their Self-Study research was to work through those conflicts. A Self-Study methodology was then used in light of the need to explore the researcher's own identity in these two varying fields of practice which the researcher suddenly found themselves in. This is the same methodology I used to carry

out my own study but the context is slightly different. In this study, since I sought out to research my own practice as I taught Chemistry topics that seemingly deal with climate change, the methodology of choice was thus a Self-Study. My understanding of Self-study by a teacher was that it entails an intentional and systematic inquiry into one's own practice, a tool that allows for reflective teaching. My study tries to address explicitly and clearly issues about knowledge, namely Pedagogical Content Knowledge (PCK) and how my PCK is transformed as I teach Climate Change and any aspects related to Climate Change to a group of Physical Sciences learners.

3.4 Research Methods/ procedures

Data was collected starting after the examination period of the third term in 2016. Due to contextual factors, it ran up to the next year too. The justification and details of the data collection procedures in each phase (planning and teaching) are outlined below. In Table 3.1, there are summaries of the lessons conducted during the study. It helps to see where these procedures are used.

Table 3.1: Summary of the lessons conducted during the study

ASPECT	LESSON THEME	LESSON No//	Time frame
Planning (CoRe making and presentation)			May, July-August 2016
Engage	Pretest-learners do questionnaire on global warming Concept map-learners do their concept map on what they know about climate change Show online video on….the sun as an energy source and use it to get their attention. Aspects to be covered-Where does all the heat come from? -Where does the radiation go?	Lesson 1	May –August 2017
Explore	Investigation Teacher models enhanced greenhouse effect in beakers, observe	2	Aug 2017
Explain	Concepts: greenhouse gases, greenhouse effect, enhanced greenhouse effect, global warming.	3	Jan 2018
Elaborate	Linking enhanced greenhouse effect to climate change	4	Jan 2018
Evaluate	Assessment that includes research, presentations/task, application questions	5,6	Throughout 2017,Jan 2018

3.4.1 General procedures in this study

The study was carried out in my natural setting, a well-established acceptable educational school setting. Normal educational practices (the teaching strategies, the set CAPS curriculum, acceptable classroom management practices, and common instructional techniques) existed within this school. As part of the initial planning process, the

researcher drafted a pre-discussion-CoRe (a pre-CoRe) and a concept map and then presented this to the supervisor and then to the discussion panel at the workshop. A discussion ensured and adjustment of the CoRe was done. From there, the draft lessons were further developed and tuned to the remaining short time-frame. After completing the pre-test on global warming and drawing out the concept maps, the learners listened to the teacher's explanation of the enhanced greenhouse effect and then went on to do two more tasks, one related to water and the other on greenhouse effect, enhanced greenhouse effect and global warming (This is outlined in Table 3.1).

The plan was to teach in a manner that engages the children in conversations with the teacher and possibly in groups. In such settings, I expected the learners to unveil their understanding of phenomena associated with Climate Change. As a teacher, and a researcher seeking answers, I was also expected to play a probing as well as a facilitating role with the learners. Leading questions of the form, "what do you think causes global warming?', "give examples of greenhouse gases" and "is there a relationship between carbon dioxide accumulation and ozone depletion?" were expected. As we continued with the lessons, some of the learners brought forth related questions and shared their knowledge. The lessons were both video and audio-taped to gather the teaching and learning experience. It was also necessary that I conduct some assessment and use the completed documents (questionnaire, concept maps and classwork) to help me to reflect on the learners' understanding of the taught topic and consider what was more effective than the other. Throughout the preparation and the lessons, I made some journal entries into my project journal. The entries have some notes as well as reflections on the lessons (see Appendix 11-reflection journal samples).

3.4.2 How my PCK was captured and portrayed from planning to teaching

Self-study methodology uses qualitative methods of data collection mainly for enrichment purposes. LaBoskey (2004) states the gathering of data from various sources as an important feature of the self-study methodology. Data collection commences during the planning (CoRes, mind maps, lesson plans, journaling and the reflective sessions as well as the actual teaching itself. Use of these tools generally shows what I knew about the

content, my learners and how I used it to plan, execute and evaluate my lessons. Data collection was done by means of lesson planning to include a concept map and a CoRe, carrying out a semi-structured discussion panel with peers so as to validate the CoRe and concept map, issuing out questionnaires to participants, use of a reflective journal as well as the actual teaching process.

Content Representation (CoRe)

To try to capture and reveal a teacher's PCK, two complementary schemata of analysis are suggested in literature, the Content Representation (CoRe) as well as the Pedagogical and Professional – experience Repertoires (PaP-eRs) as described in Loughran, Berry, and Mulhall (2004). A CoRe (my choice for this study) focuses on capturing the teacher's knowledge, the teacher's understanding of the aspects that shape the content to be taught and PaP-eR's brings life to the ideas in the CoRe, they are a narrative description of a teacher's PCK, it is a way of capturing what is happening in classroom and what influences the teaching and learning. It articulates the various aspects a teacher considers when preparing to teach, presenting the lesson for a particular topic. According to Loughran et al. (2004), a CoRe (Content Representation) provides an overview of how teachers approach the teaching of the whole topic and the reasons for that approach - what content is taught, how and why - in the form of propositions, to a particular group of students. It gives a framework for organising your thinking around a particular science topic. CoRes are represented as a grid with 'big ideas'-those science ideas which a teacher regards as significant for understanding that particular topic (Loughran *et. al,* 2004), statements of scientific propositions that are central to the topic being taught. To complete the grids in a CoRe, one has to draw from past experience as well as knowledge of a topic and derive or state the 'big ideas' related to the particular topic to be taught, whilst also responding to assigned series of prompts (see Appendix 8). My pre-CoRe was completed by January 2016 (see Appendix 8a) and my post-CoRe presented in Appendix 8b was completed by May 2016 in line with the submission of my proposal.

Qualitative data was collected from the CoRes as was expected. To synthesize the qualitative data then, constant comparative methods were utilised. Both inductive and deductive categorisation of data was done on the CoRes by way of utilising the LTtP's aspects as themes as described before in Table 2.1. The research questions were also revisited so that the objective was not lost entirely. The data was interpreted so as to answer the posed questions and draw conclusions on the research. The aspects of the researcher's PCK could now be seen after the analysis of the CoRe. A CoRe table is a powerful tool to reveal what the teacher and even the learners know about any topic. For comparison purposes, two CoRes were done and used as a planning tool before the actual engagement with the learners. The CoRe pointed out to my curriculum saliency, my ability to identify learners' prior conceptions and how I planned on addressing them. The CoRe also pointed out what was discernible from the tasks that I had prepared for the learners, tasks which I used to gauge the learners' conceptual change.

In this study, I carried out the following procedures: journal reflections on my daily teaching experiences (after each lesson); CoRes, concept map, and other lesson plans (showing planning and reflections on the implementation of the lessons); everyday classroom records (work pertaining to the study); audio and video-recordings of my own teaching, lessons and pre-lesson discussions with peers. Concept maps allow for capturing of growth of a teacher's content knowledge (Novak & Canas, 2008) whilst the discussions also allow for dialogue and the eventual validation of findings (Samaras & Freese, 2006). Below is a description of what I did with each procedure, starting from sampling, to peer engagement with my CoRe, audio and video recordings of the lessons up to the use of reflection journals.

Sampling

The respondents to the questionnaire were purposefully selected, they comprised the researcher, her colleagues, each who teach Life Sciences, Geography and Physical Sciences (for the CoRe presentation) and her class she taught (for the lessons). This is convenience sampling (Merriam, 1998).The researcher is the main participant and the researched in this study. The supervisor will be part of the research as a critical friend.

Purposive sampling (Opie, 2004) has already been done to select the other participants. The teachers chosen as peer educators hold various levels of qualifications and teaching experience either in Geography, Biology and/ or Physical Sciences-they were chosen for their content knowledge. Two Physical Sciences classes of Grade 10 and 11, of an average of thirty-five learners between the ages of fifteen and sixteen, both male and female with varied abilities, and varying in ethnicity (with a major representation from black Africans, followed by Indians and a handful of coloureds). The study involves very minimal risk to children in my classroom. The learners in this project, all study Physical Sciences and Life Sciences. Nearly half of them do not do the third subject of concern (amongst other subjects), that is, Geography. They would however all have studied Natural Sciences (where the topic is dealt with better than at FET phase) as well as Social Sciences in Senior Phase too. It is however important to note that the learners' attendance was not so regular.

Peer Engagement with my CoRe

The initial plan was to allow for observations to be made by my peer educators (critical friends), of me teaching or in videos of me teaching, in several lessons. I however resorted to a presentation of my lesson plans in a workshop set-up, followed by a panel discussion with my critical friends, discussions on how I intended to teach. A critical friend, in self-study research, refers to someone who can listen to a researcher's account of their practice then offer a critique to their work (Kemmis and McTaggart, 1992). Critical friends are trusted colleagues who serve to mediate, provoke and support new understandings, Samaras (2011). When one converses with colleagues in their profession in a formal set-up, one is likely to get unbiased analyses and views from them.

With this in mind, I set up a workshop date for my peer educators from the various departments of Life Sciences, Geography and Physical Sciences as well as with my Supervisor to attend. Initially, there were some unforeseen clashes and delays due to some disturbances at school such as unscheduled staff and departmental meetings but eventually the two-day workshop was done. The main activities for the two days was to engage with peer educators who were also my critical friends, to seek ideas on how to

teach certain concepts and for them to critique and improve my lessons based on the plans. I succeeded in enlisting the services of one Physical Sciences teachers, one Life Sciences teacher and one Geography teacher. The main reason for the selection was due to the content to be in the study itself, content that touches on each of these mentioned subjects. I also had my supervisor, as a participant observer to come up with narrative observations/ evaluations critiquing my lesson plans then and later my lessons.

Audio and Video-recording

The observational nature of my research also entailed that I do video-recording and/ or audio-recording. Events were captured as they happened in the lessons by way of mounting an audio-visual recorder to focus on me as I presented the workshop and the lessons. Observation through videos helps to identify any teaching strategy employed during the presentation of the lesson, which cannot be possible when using other methods. This often makes it easy to carry out analyses of the lessons and presentations. The critical friends can critique well, even if they were not present in the lessons. Video-recording allows the observer to observe many aspect of teaching and provides heuristic and accurate information (Opie, 2004). In this study, it also allowed immediate gathering of information which was later analysed once information has been stored. It also permitted the study of verbal and non-verbal human behaviour during the teaching of a lesson.

Lesson videotaping makes it possible for the researcher to determine people's perceptions of events and processes expressed in their actions and expressed as feelings, thoughts and beliefs (Macmillan & Schumacher, 2006). One disadvantage however, of using video-taping as supported by Opie (2004) is that people consciously or unconsciously, may change the way they behave when being observed. Another disadvantage is that videos offer unwanted video and non-verbal blur. Besides being recorded on the audio and visual recorders, it was essential that I carry out other complimentary recordings too. I made journal entries of my actions and the actions of the 'others'-my critical friends and my learners as the study progressed. Table 3.1 shows how

the lessons were structured. The basis of this table is the 5E strategy as discussed before in the literature review.

Reflective Journaling

As I planned for, presented and eventually taught the lessons, I made some journal entries of the occurrences. Cochran-Smith and Lytle (2004) see a journal in the field of education as a record of an educator's account of their classroom life; the observations that they make, their life experiences as well as reflections on their practice. I used journaling to capture and record my observations, experiences, personal concerns, frustrations, achievements, thoughts and ideas before, during and after my planning and teaching. A journal also aids reflection and provides a means for sharing those thoughts and experiences with critical friends so that they can offer their input and perspective (Samaras, 2011). One can also use it to critically reflect on their practice. The success of a journal as a method of data collection is based on the extent of one's openness as well as their own ability to self-reflect in their experiences. The reflection that emanated from such evidence collection is of importance because it adds some insight into as well as improved my own practice. Some of the journal entries are captured in Appendix 11.

3.5 Validity and Rigor

Trustworthiness, credibility and dependability of the study

Given that the study is more qualitative than quantitative, issues of validity and reliability are therefore of little concern. Trustworthiness, unlike validity is a central issue in Qualitative research. To ensure that this factor is upheld, Lincoln & Guba (1985) suggest that the following occur within a study: constant member check, corroboration of methods, and peer de-briefing and prolonged engagement with that which is being researched. Qualitative methods are subjective and grounded in practice and as such, their suggestion which is further supported by White (2003) would work to further reduce researcher subjectivity. Triangulation of data is essential and here it is evident in the Procedures section discussed earlier where different forms of data collection procedures are seen.

Credibility and dependability are also issues that need dealing with in a qualitative study such as this one. Credibility was ensured with the existence of external observers and not just one-way reporting. Since Self-Study is personal and based on a learning journey of the individual, its nature requires that the work done be opened for public scrutiny. In this study, I opened the processes of my research to a team of my teaching colleagues and my supervisor who then formed a collaborative team of critical peers. I also kept a reflective journal throughout the research, to record details pertaining to the study. At the end of the data collecting process, I also made a submission of typical evidence for scrutinisation by a non-participant. In this particular case, the supervisor took this role.

3.6 Ethical considerations

As the researcher, I briefly outline my intended research to the Ethics committee at Witwatersrand University in order to be cleared on ethical considerations in the research an ethical clearance was obtained from the University (protocol number 2016ECE040M -see Appendix 1. Permission was sought first from the Department of Basic Education (DBE). The researcher filled an application form to the Department of Basic Education attached the ethics clearance letter to it, seeking permission to conduct a research in one of its schools. The permission was granted and a research approval letter was sent to the researcher (letter in Appendix 4). After the DBE approval, I then approached the Principal for permission to carry out my research in their area of jurisdiction. This was done by means of a letter (see Appendix 2-letter to Principal). The Principal then asked that the research be carried out without interrupting the learning programme. Permission had to be sought to involve the peers outside of the school times and I had to liaise for time shifts and make a plan in the event of unexpected turns. This ultimately made the process strenuous.

To ensure the protection of participants' identities, responses and behavior, the handling as well as the eventual destruction of data, I adhered to the protocols as set by the Witwatersrand University in conjunction with the School of Education. Approval to undertake the study was sought and granted by the Ethics Committee before the commencement of the study. I had sought permission to use my school as well as the

three available FET classes for my study but was later told by the school authorities to use my class only and to make provision in my own extra time.

Since the study involved minors- children in my class, as well as adults-my teaching colleagues, all in a Government school, consent from Gauteng Department of Education as well as parental/ guardian consent needed to be granted before I could proceed. Consent forms, with a response section, were sent home with learners to their parents/ guardians. I also explained in detail what the research was about to the learners and I sought verbal consent from the learners themselves. In carrying out the study, I ensured that it posed very little-to-no physical, social, financial or psychological risks to the minor participants. The teacher participants came willingly to the presentations. Moreover, there was also no deception involved in my study as live video and audio recordings were made. The learners' written responses were coded for their anonymity. Videos were taken from the back to try to protect the learners' identities. In this report, emanating from the study pseudonyms were generated for all participants including the school itself.

3.7 Chapter summary

In this chapter, the basis of the research methodology, the Self-study research methodology, sampling technique, tools used and mode of data collection, actual data collection as well as ethical considerations are discussed.

The next chapter, Chapter 4 deals on data presentation, interpretation, and analysis.

CHAPTER 4: DATA ANALYSIS, DISCUSSION OF RESULTS AND FINDINGS

4.1 Introduction

In this chapter, data is analysed and the findings are summarised so as to try to answer the questions raised in chapter 1. The data obtained was quite rich and extensive. The framework used for the analysis (the LTtP model) is discussed first.

4.2 Analysis instrument -Framework for analysis

There are three options for analysing qualitative data from self-studies as cited in Tidwell, Hesta and Fitzgerald (2009), namely, the use of text as data to examine meaning and value of teacher educator practices; using discourse and dialogue as data and analysis tools for examining practice and lastly, use of different forms of visual representations for examining practice. Nakedi (2014) formulated and has applied one such model of analysis as the third one, the Learning for Teaching through participation (LTtP) model. The model essentially illuminates the ideas, assumptions and experiences underlying practice (teaching). I adopted this model to analyse data emanating from the study. I did this by way of undertaking topological analysis with pre-determined categories being offered by the LTtP model. Critical thinking and deep perusal into data was needed to synthesize the qualitative data.

Why focus on 'my engagement with knowledge'

According to Pinnegar and Hamilton (1998), allowing an analysis of the engagement between the researcher and the 'others' (the learners, the environment and the critical peers) helps to conceive practice (the activities of the researcher-the beliefs, knowledge) in context. This validates the whole process, comparing the teacher's professed (or initially held) knowledge and the practiced knowledge and it also allows for us to place the gained knowledge into the teaching field. Nakedi (2017), uses the same approach but in her framework identifies three interrelated domains, the knowledge and views, the action and practice and the feedback and outcomes and how they encompass a teachers' professional world and aid in professional growth.

The shifts in one's knowledge can be looked at in these here domains: during planning, during peer engagement and in the actual teaching.

This study looks at the teacher as a learner whilst in their practice, a learner seeking to gauge and improve their knowledge and teaching approaches. In accordance with the analysis framework discussed before, observed behaviours were recorded and acted as templates to compare with standard behaviour. Essentially, an individual seeking to learn does a rehearsal, interacting with an environment and compares it with modelled experience to see where they lie. The Learning to Teach through Participation model (LTtP) which, like preceding models on situated practice looks at knowledge as being acquired in a social set-up, through co-participation (participation in a community of practice) rather than through cognitive processes. The actions which were observed in the study were therefore used to gauge how different factors play a part in a teacher's journey to be constructivist teacher.

4.3 Analysis of the tools

My CoRe, concept map, classroom video/audio records, set tasks, reflective journals or lesson notes were used to profile the journey that I undertook. Data is generated from my experiences with the aim of revealing my unique journey as well as my considerate planning, learning, challenges experienced, draw-back points and motivational moments alike. The LTtP model was used as an analysis tool to code my knowledge and then profile me against the five categories based on variety of data which speaks to their plans/views/convictions/utterances (beliefs) about teaching and learning as well as their actual acts in the classroom (practice). The guideline for the coding was done according to Table 3 below. Primarily qualitative data was obtained.

To link with the LTtP Conceptual framework, five aspects of the researcher's PCK were taken and used across the tools, to gauge the researcher's knowledge, beliefs and attitudes. These were knowledge of learners prior conceptions (LPC), learners' procedural knowledge (LPK), alternative resource use (ACR), sequencing of instruction in science (SOIS), representation use (RMA) and curriculum saliency (CS). The

researcher derived a table (Table 3) to show where these aspects could be seen in tools of teaching.

Using the criteria in the table, the tool was then highlighted to indicate five of these six aspects, learners' prior knowledge (LPC), resources use (ACR), sequencing of instruction in science (SOIS), representation use (RMA) and curriculum saliency (CS). Table 3 below shows the LTtP conceptual framework themes as derived from the six aspects.

*

Themes	How to see it/ Observed	Where to see it
1. LPC-Learners Prior Concepts	Dialogue, text	In lesson plans, tasks and teaching.
2. LPK-Learners'.Procedural Knowledge	Scientific skills and knowledge, argumentation, dialogue	Activities done by learners
3. RMA-Representations, Models and analogies	Use of analogies, models, examples	During teaching, worksheets
4. ACR-Alternative curriculum resources	Use of alternative resources	Planning, teaching, activities
5. CS-Curriculum Saliency	Sequencing of subject matter	Planning
6. SOIS-Science oriented instructional sequencing	Learning and teaching strategies	Planning and actual teaching

Table 4.1: Themes as derived from the LTtP Conceptual framework aspects

Using these themes, a way of coding for teacher knowledge and coding of teacher explanations was done on the portions of each tool. Knowledge bases were identified by means of looking for expressions and actions that reveal the already classified expected knowledge domains/themes in the tool at hand, circling them and interpreting them qualitatively. To show this, any expressions that indicated the criteria in Table 3 above was highlighted. I then used the link between the highlighted coded data (the findings) in the tool at hand with the themes in the analysis LTtP tool so as to see any emanating knowledge bases which I held at that time, right from the planning throughout to the teaching phase. Here, I only focused on the tabulated basic themes. The observations I made are discussed in the next section.

4.4 Shifts in my knowledge

Aspects of Teachers' PCK in the LTtP model

These aspects, as discussed previously in the literature, are an indication of a teacher's knowledge, their ability to unpack content from its sources until it is delivered in the classroom. These aspects are *learners' prior conceptions, learners' procedural skills, representation forms and alternatives* used by the teacher, the range of *alternative curriculum resources* used or preferred, the teacher's *curriculum saliency as well as the science oriented instructional sequencing* used by the teacher. Below are discussions involving shifts in my knowledge (as a teacher and as the researcher who is also being researched) of the five areas chosen from the LTtP model and as observed from my tools used from the planning phase (the CoRe and concept map) to the teaching phase (the lessons and worksheets).

4.4.1 Knowledge Shifts in my curriculum saliency

This aspect is about how the teacher displays their curriculum knowledge, performing rather informed and strategic sequencing of concepts during their planning and throughout their teaching. It is an aspect which Shulman (2002) refers to as the *lateral and vertical curriculum knowledge,* as discussed previously. A teacher should clearly show how they map out or sequence the concepts in a topic, and how they pick out the necessary ones. In the given context, the researcher (teacher) had to point out the big ideas of the topic and scaffold them in their CoRe. CoRes are represented as a grid with 'big ideas'-those science ideas which a teacher regards as significant for understanding that particular topic (Loughran *et. al,* 2004), statements of scientific propositions that are central to the topic being taught. To complete the grids, one has to draw from past experience as well as knowledge of a topic and derive or state the 'big ideas' related to the particular topic to be taught, whilst also responding to assigned series of prompts.

I initially only had two big ideas which were crudely stated as: chemistry of the atmosphere and its role in nature; Human impact of mining activities on the atmosphere. In the Post CoRe (Figure 4.1), three more big ideas were added and these highlight the Energy interactions within the Earth system and the importance of water in Climate change.

Big idea / Prompts	Climate is regulated by complex interactions among components of the Earth system (sun, ocean and atmosphere)	Energy exists in systems, in various forms and its transformation and conservation occurs in processes that are predictable and measurable	Water has unique and special properties that contribute to nature through the water cycle	The chemistry of the atmosphere plays a role in nature	Human activities (such as mining activities) impact on the atmosphere

Figure 4.1: An extract showing the Post-CoRe Big ideas

The Big ideas in the Post-CoRe are a far cry from the original two big ideas and the way they have been expressed is now improved, see Appendix 8. The first big idea in the Pre-CoRe focused vaguely on the atmosphere and its interaction with nature, whilst the one in the Post-CoRe speaks wholesomely of the regulation of the Climate by complex interactions among components of the Earth system (sun, ocean and atmosphere). The chemistry of the atmosphere is now put nearly at the end of the big ideas sequence. Two more ideas that have been put in speak about the importance of energy and water in the Earth system. The big idea about human activities playing a major role in atmospheric occurrences had been previously shallowly expressed as 'Human impact of mining activities on the atmosphere'. In the new CoRe, it was now improved. It shows that I now display some adequate curriculum knowledge, performing rather informed and strategic sequencing of concepts during their planning and throughout as indicated in the next discussion. The types of decisions that I made, the nature of the tasks developed and the manner in which the I used these to engage my learners in the classroom, reveals a lot about the strength of strategic curriculum knowledge.

Looking into Prompt 4 of the Post Core (Figure 4.2) reveals that I am trying to raise my own level of understanding to be above that of their leaners who they are teaching. This is expected to be through consultation of a variety of textbooks, as well as curriculum documents as the following interview excerpt reveals:

4. What else do you know about this idea (which you do not intend your learners to know yet)?	Other factors that cause climate change The science behind the relationship	A reduction in energy usage helps in greenhouse effect mitigation efforts Temperature changes can be accounted for by Earth's tilt relative to the Sun. Ghgs also determine average global surface temperatures	Learners already know the layers of the atmosphere (troposphere, mesosphere, stratosphere and thermosphere)	Use and harmful impact of CFCs on the stratosphere

Figure 4.2: Prompt 4 of the Post-CoRE

This portion of the CoRe helped the researcher to know which inputs were not aligned with the CAPS curriculum policy. Knowing such an alignment is also a reflection of the teacher's knowledge.

In the portion of the CoRe (Figure 4.3-4), the researcher briefly outlines her intentions with the learners, what must be learnt with each big idea. The intentions are clearly stated under Prompts 2 and 3 and if they were to be combined with what is given in prompt 4, then one will clearly see what the researcher now knows more about the concept of global warming or climate change.

2. What you intend students to learn about this idea	The sun is the primary source of energy for Earth's climate system-heat from sunlight can heat the land, ocean and atmosphere. The ocean acts as a reservoir for a good temperature regulator, water. The amount of solar energy absorbed or radiated by the earth is modulated by the atmosphere and depends on the composition of the atmosphere.	Energy exists in various forms-mechanical, chemical, Electrical, radiant, thermal and nuclear. Amount of sunlight received by the Earth is affected by the reflectivity of the surface, the angle of the Sun, the Sun's output and variations in the Earth's orbit around the Sun. Sunlight reaching Earth can heat the land, ocean and atmosphere, some of it is reflected back to space by the surface, clouds or ice, Much of that which reaches the Earth is absorbed and warms the planet The transformation and conservation of energy occurs in processes that are predictable and measurable When the earth emits the same amount of energy as it absorbs, its energy budget is in balance and its average temperature remains stable.	To show that macroscopic behaviour can be accounted for by microscopic structure-melting, boiling, solvent, density etc. Link strong hydrogen bonding between water molecules to high specific heat capacity Link melting of ice caps, release of methane to density and structure of solid water (ice)	Identify the chemical species and role of each species in each layer. The chemical nature of greenhouse gases (ghgs) Ghgs in the atmosphere (carbon dioxide, water vapour) affect energy flow in the Earth system, they are transparent to most incoming sunlight but not to IR from the warmed Earth surface.	Sources and impact of greenhouse gases (ghgs) Mining of fossil fuels removes org carbon from underground and releases it into atmosphere as carbon dioxide

Figure 4.3: Prompt 2 of the Post-CoRE showing intentions of teaching the topic to learners.

3. Why is it important for students to know this?	So that they link climate to land activities and atmospheric activities	Learners must be able to make inferences about the temperature of the earth. They must know that a significant increase or decrease in the Sun's energy output would cause the earth to warm or cool but changes are just to small and earth temperatures fluctuations should then be accounted by some other factor	To understand the recycling of water in the water cycle Linking with other spheres Water contributes to the greenhouse effect	To realise that ghgs have polar bonds which allow them to absorb infrared radiation.	To link ghgs and global warming To distinguish between ozone depletion and global warming causes (chemical and physical) Help reduce CO_2 emission by Campaigning against sole use of coal-powered plants in energy production.

Figure 4.4: Prompt 3 of the Post-CoRE showing intentions of teaching the topic to learners.

In addition to knowing why it is important for learners to have the knowledge listed in the prompt 4 of the CoRe (Figure 4.2), the researcher also gave some difficulties that are associated with teaching the climate change aspect. These are presented in Figure 4.5. Besides the fact that ideas to do with the atmosphere are normally Geography ideas, the other difficulties are in trying to simulate a greenhouse set-up in the laboratory, discussing ozone depletion using radicals (which learners are not familiar with) and also in looking at microscopic activities (such as increase in tiny concentrations of carbon dioxide) to explain macroscopic observations (such as global warming).

5.Difficulties/ limitations connected with teaching this idea	Other factors are discussed in Geography only	Having to simulate natural occurrences in the lab is difficult and not really representative.	The microscopic nature of water is difficult for some learners to comprehend	This content is not part of the Physical Sciences syllabus.	The syllabus limits us to the effects of mining only Tiny CO_2 concentrations cause Climate Change. Confusion with ozone depletion Difficult to comprehend

Figure 4.5: Prompt 5 of the Post-CoRE showing difficulties associated with teaching global warming.

4.4.2 Knowledge shifts observed in my concept maps

To gauge the shift in my own content knowledge (the teacher's prior and post conceptions), I did comparative content analysis of my concept map (Figure 4.6) with the detailed expert one (Figure 4.7) for correct conceptions as well as misconceptions. My pre-concept map reflects some good grasp of concepts aligned with climate change. However, the standard post-concept map (Figure 4.7) gives more information, which because it was used, reveals a shift in knowledge.

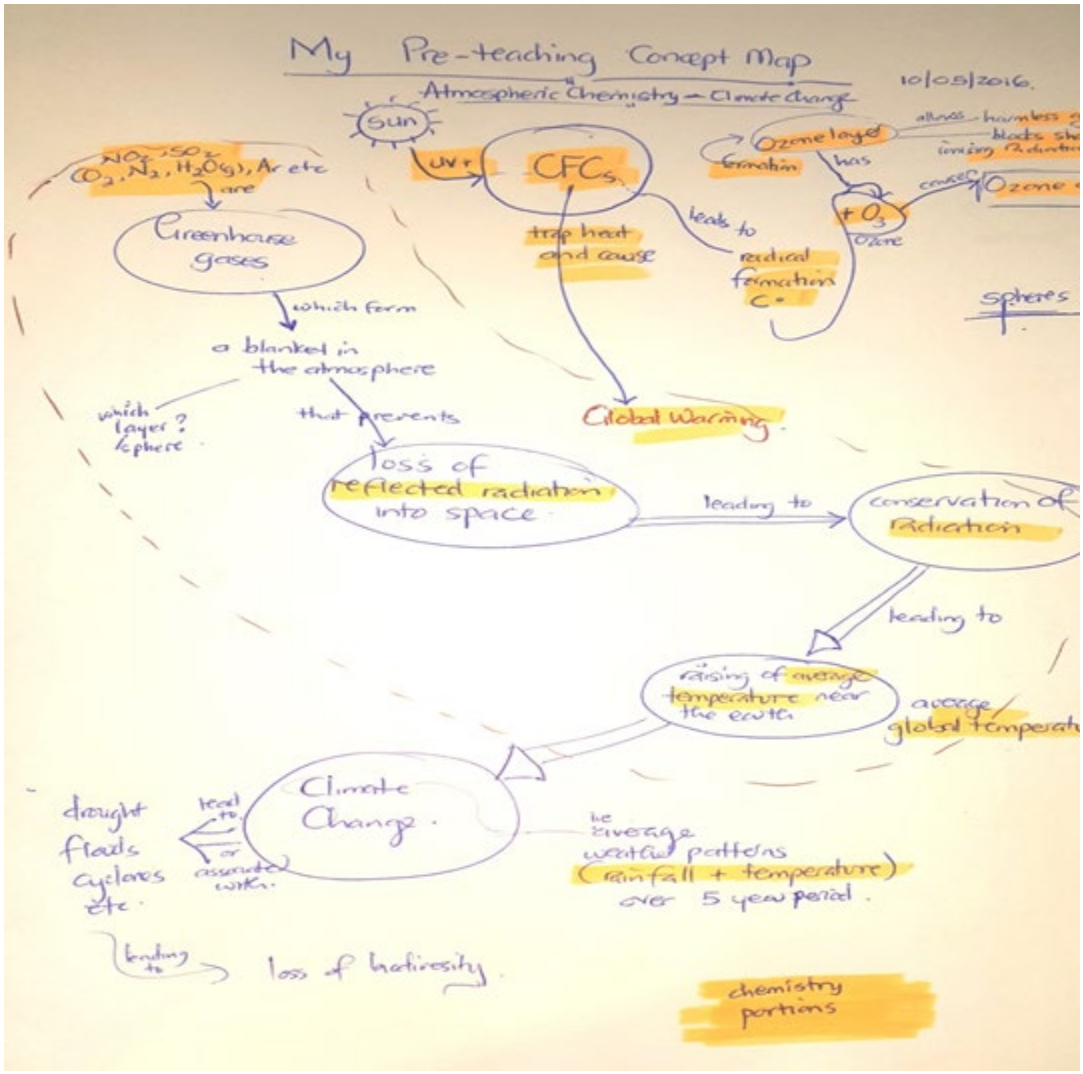

Figure 4.6: My pre-teaching Concept map

It can be clearly seen that my main focus when I was doing my own concept map was mostly on the Chemistry portions of the Climate Change aspect. The information I provided is not extensive enough, so basically I was found to be lacking in some aspects related to Climate Change especially the ones that are not in the syllabus.

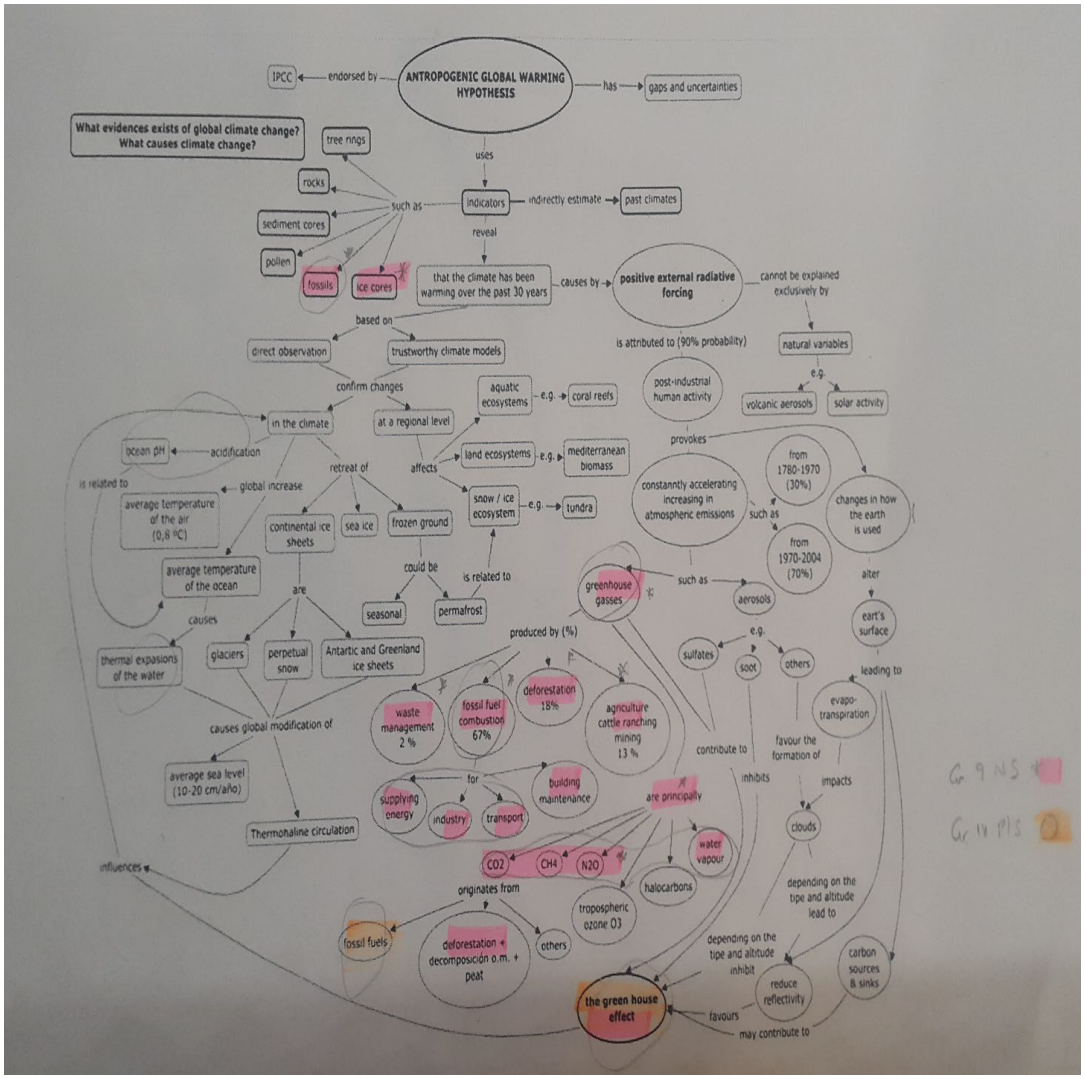

Figure 4.7: An Expert concept map for the teaching of Climate Change

The aspects that are highlighted in Figure 4.7 are expected to be known by a learner who has passed through High School Senior phase. I was expecting the learners to be having

this prior knowledge. The learners in Grade 10 and 11 would then look at the aspects highlighted in orange. The other aspects (not highlighted is what I had to know even if the learners did not know it. By the time I started my lessons, I already had this knowledge in Figure 4.7and I could say it was a lot to comprehend.

The new information pertains to the cause of the greenhouse effect from a Chemistry point of view- the bond properties in molecules. Both the pre-concept map and the pre-CoRe were presented to the critical peers for scrutiny. The group was familiar with concept maps but they were fascinated with the CoRe, which they had never been exposed to before. The Geography and Life Sciences feedback was quite helpful to the researcher.

The post-concept map task itself was a good and comprehensive tool which took into consideration all the related concepts that came up in the discussions before the lessons. During the CoRe and concept map presentation, the researcher expressed appreciation of possible learners' misconceptions as well as her own misconceptions. One of these was that CFCs in the presence of UV light, trap heat and cause global warming. There is also the aspect of self-realization of missing knowledge as well as a misconception as the researcher makes her presentation. This misconception is addressed when she explains the difference between the causes of ozone depletion and that for global warming…another is the listing of nitrogen instead of nitrous oxides as a greenhouse gas.

4.4.3 Shifts in my knowledge of the learners' prior knowledge

My knowledge of Learners' Prior Conceptions and Mis-Conceptions (LPC) in the CoRe

These are the types of conceptions held by learners before they are taught. Such conceptions about a topic tend to either promote or hinder learning, depending on how they are utilised. The knowledge of learners' prior conceptions is seen in the teacher's preparation, how they teach and assess. There has to be consideration of the misconceptions in this planning stage as well as throughout the teaching.

In the pre-CoRe which I generated without careful planning and resources (Figure 4.8) only two big ideas are stated, that is, they appreciate the role played by the atmosphere as a shield from harmful ultraviolet radiation and that human activities have an impact on the environment (including the atmosphere).

Big idea / **Prompts**	The chemistry of the atmosphere and its role in nature	Human impact of mining activities on the atmosphere
1. What you expect learners to know already about this idea	They appreciate the role played by the atmosphere as a shield from harmful ultraviolet radiation	Human activities have an impact on the environment (including the atmosphere)

Figure 4.8: Post CoRe excerpt showing what I initially know about learners' prior conceptions.

Figure 4.9 is an extract from the CoRe showing the learners' prior conceptions that I know after some extensive consideration. It is important to note that only the last two aspects of the post CoRe were in the Pre-CoRe.

Big idea / Prompts	Climate is regulated by complex interactions among components of the Earth system (sun, ocean and atmosphere)	Energy exists in systems, in various forms and its transformation and conservation occurs in processes that are predictable and measurable	Water has unique and special properties that contribute to nature through the water cycle	The chemistry of the atmosphere and its role in nature	Human impact of mining activities on the atmosphere
1. What you expect learners to know already about this idea**	The sun, water and the atmosphere are interconnected in determining the weather in a particular area.	The Sun is the primary source of Energy for Earth's Climate System. Energy, in changing form, is neither created nor destroyed. Energy is conserved in a closed system, an open system allows for the loss of energy Electromagnetic radiation and its relative strength	The shape of the water molecule The polar nature of water Phase changes of water on Earth The difficulty of separating atoms in a water molecule The Sun providing the energy that drives the water cycle	They appreciate the role played by the atmosphere as a shield from harmful ultraviolet radiation	Human activities have an impact on the environment (including the atmosphere)

Figure 4.9: Post CoRe excerpt showing what the teacher knows about learners' prior conceptions after careful consideration.

The new CoRe is comprehensive and able to touch on many aspects involving global warming that the learners are supposed to know, information they have to bring to the classroom. This is a noticeable shift, enhanced by the use of resources to plan.

Another prompt (prompt 6, shown in Figure 4.10) in the CoRe itself reveals my knowledge about learners' prior conceptions and how this knowledge influences the teaching of global warming also how it also helps me to know how learners think about the aspects being taught.

Big idea / Prompts	The chemistry of the atmosphere and its role in nature	Human impact of mining activities on the atmosphere
6. Knowledge about learners' thinking which influence your teaching of this idea	Any area where there is air around them is space.	Misconceptions pertaining to global warming, greenhouse effect and ozone depletion. Smoke from cars and factories and cigarettes damages the ozone layer and makes the earth hotter Ozone hole triggers global warming Greenhouse effect and ozone hole have the same causes. Learners interchange the words global warming, climate change and ozone depletion. Change in weather is Climate Change.

Figure 4.10: Pre CoRe showing some of learners' prior conceptions

It can be seen that I managed to identify some misconceptions (learners' thinking that could influence teaching) held by learners in the concept of global warming. These were as follows: the view by learners that any area where there is air around them is space; smoke from cars and factories and cigarettes damages the ozone layer and makes the earth hotter; ozone hole triggers global warming; Greenhouse effect and ozone hole have the same causes and that a change in weather is climate change. I also identified that most of the time, learners in past researches tend to interchange the words global warming, climate change and ozone depletion.

There is a noticeable improvement in my knowledge of learners' conceptions presented later in the post CoRe segments as compared to the pre CoRe segments. In the Big idea that talks about climate change being regulated by complex interactions among components of the Earth system (sun, ocean and atmosphere), I left it blank, an indication that at that time, I unfortunately did not know anything which the learners could bring to the classroom on this and perhaps that I had little knowledge of the Geography aspects involved here. The post-discussion CoRe shows that the following misconception was added: greenhouse effect is bad and will lead to eventual death of organisms. Here learners are expected to bring out their prior incorrect conception of the greenhouse effect being viewed as being bad whereas it is actually needed to sustain life on earth.

Big idea / Prompts	Climate is regulated by complex interactions among components of the Earth system (sun, ocean and atmosphere)	Energy exists in systems, in various forms and its transformation and conservation occurs in processes that are predictable and measurable	Water has unique and special properties that contribute to nature through the water cycle	The chemis try of the atmosp here and its role in nature	Human impact of mining activities on the atmosphere
6. Knowledge about learners' thinking which influence your teaching of this idea	.	Learners think that the earth gets heated by the sun directly (however, the distant sun emits light which objects on earth absorb and reflect, increase the kinetic energy of particles in the object and object gets heated up.) Belief that objects can only either absorb or reflect light but not both. Belief that light can only be reflected from shiny surfaces, Learners may think that the change in the Sun's energy output over time cause global warming.	The water that evaporates is lost to the atmosphere	Any area where there is air around them is space.	Misconceptions pertaining to global warming, greenhouse effect and ozone depletion. -Smoke from cars and factories and cigarettes damages the ozone layer and makes the earth hotter -Ozone hole triggers global warming -Greenhouse effect and ozone hole have the same causes. -Greenhouse effect is bad and will lead to eventual death of organisms (however, without the greenhouse effect, the earth would not be warm enough to support earth life) -Learners interchange the words global warming, climate change and ozone depletion. -Change in weather is Climate Change.

Figure 4.11: Post-CoRe showing some of learners' prior conceptions

I managed to establish the following learner conceptions (highlighted in Figure 4.11): that learners think that the earth gets heated by the sun directly; /beliefs that objects can only either absorb or reflect light but not both; belief that light can only be reflected from shiny surfaces; that the change in the Sun's energy output over time cause global warming; that the water that evaporates is lost to the atmosphere and that the Greenhouse effect is bad and will lead to eventual death of organisms.

I also managed to identify the following correct conceptions relating to the added Big idea, that the learners could probably bring to the classroom; that the weather of an area is determined by the temperature and rainfall in an area, the sun gives energy to the earth's climatic system, water is a polar molecule, the atmosphere shields us from harmful solar radiation and that human activities have an impact on the environment. In addition to these prior conceptions, learners were also expected to exhibit the following misconceptions: that the earth gets directly heated by the sun (that there is no energy

transference), that objects either absorb or reflect light but not both, that the sun is getting hotter and causing global warming, water evaporates permanently from the atmosphere, that global warming and ozone depletion have the same causes, that the greenhouse effect is bad and it will lead to the eventual death of organisms and that the ozone hole triggers global warming. Evidence of these were expected to be picked later on, in the learners' work (learners' activities, mind maps, pre and post-tests). The learners tend to hold more misconceptions than what literature predicted. I found out that, besides listing correctly water vapour and carbon dioxide as greenhouse gases, nearly half of the learners confidently went on to list nitrogen and oxygen as greenhouse gases in their concept maps which they gave to me before I taught them.

My views on learners' prior conceptions as outlined in the presentation of the CoRe shows that I appreciates the critical role they play and I am prepared to address them when teaching.

My knowledge of Learners' Prior Conceptions and Mis-Conceptions (LPC) in the lessons

In the lessons, a researcher is expected to engage or entertain any misconceptions the learners hold. It is very important to look into detail how these LTtP-generated themes were initiated and further sustained throughout the teaching process.

Learners' Prior Conceptions in lessons

On the issue of use of misconceptions in facilitating learning, the analysis I made (as the researcher) below, as I was evaluating my learners' work during the process of their activities, and at the end while marking, reflects a deeper appreciation of the complexities inherent in the learning of climate change aspect when embedded into lessons to try to elicit their existing ideas and misconceptions. I started by asking them to do a concept map or use the questions used in the article to bring their pre-conceptions to the fore. This forms part of the 'explore and evaluate' stages of the 5E lesson plan. From the ideas and attitude towards learners and their learning presented in the CoRe the researcher shifted from a position of very wide planning to dwelling mostly on subject matter,

implementing what I thought was good for the learners during the teaching stage, to seeing the importance of seeking their existing ideas and allowing them to express themselves at the end, thereby minimally achieving the situated cognition perspective of the power of learning through participation.

The journal extract below shows that I was aware that a situated learning approach (that learning happens through participation) was supposed to be implemented but it failed. There was need to effectively integrate the learner assessments into the lessons so that the learner's prior knowledge that they have does not hinder their learning of new concepts.

> *My planning needs to be done differently, I was doing most of the talking in the lesson. I could have posed a lot of questions and allowed learners to engage in these.* (Reflection journal-post lesson)

Whilst I appreciated the central role played by learners' prior conceptions in the construction of knowledge during planning, I also minimally appreciate the critical role that social interactions play in mediating and promoting the requisite procedural skills inherent in the nature of science and its learning. This generally resulted in me using at most, transmitting methods of teaching that disempower learners most of the time. There is however room shown at the end where learners are able to take charge of their learning and profess some knowledge and dwell on some decision-making and some form of role playing. (see Appendix 9-Worksheets6-South Africa's response)

Though minimal and most of the time, self-answered, I was able to pose some questions when teaching. An instance is given below.

> *13What is it that is in the carbon dioxide and the H_2O that causes temperatures to rise above the normal that we want okay. Greenhouse gasses are beneficial but if we have an increase in the carbon dioxide,H_2O and other greenhouse gases then we are having a problem ……*

Follow-up question really bring out the learners' conceptions as well, it invokes their memories and if they had any misconceptions, they are dealt with then. Effective

questions are therefore necessary so as to stimulate their thinking. An opportunity was realised in a lesson on anthropogenic factors when I (the educator) had to pick out learners to stress certain points. One such was on the aspect of deforestation.

T: When I look at deforestation, how do you think ….it causes an increase in carbon dioxide?
L: Ma'am can I answer that.
L: iLife Sciences?
T: Yes, my girl.
L: When we cut down the trees, the carbon dioxide that the trees contain will be released…….
L: Nooo. (Noise)
T: One person please

At this point many learners wanted to talk about what they know. The educator had to pick one.

L: Isn't it we give out carbon dioxide? Trees absorb carbon dioxide, so if more trees are cut, then humans breathe out carbon dioxide and it will go up. (Using hand gestures)
T: So you are saying, let's put people here (drawing illustration on the board). People here, what do they give out?
L: Carbon dioxide
T: The trees uptake the carbon dioxide. If we cut these trees here? What will happen now?
L: We have a carbon dioxide increase (shouting)

Another opportunity arose when I also had to call out another learner who had confidently called out CFCs on the list of greenhouse gases that cause Carbon dioxide build-up.

T: This part is very important to us coz we are required in our syllabus to connect the occurrences that are causing climate change to what we learn in class. Ok. Alright. You are going to look at mining in Grade 11 and under mining you study coal mining and gold mining.

Coal mining is one of the industrial activities that causes huge amounts of Carbon in the form of carbon dioxide to be released into the atmosphere. And also carbon is released (out).

Another example which we can look at and which we will be talking about is the anthropogenic activities. Anthropogenic, remember, I said these are activities in which humans take part and causes changes in the climate.

Think about the growing number of cars we have on the road….planes in our skies in our skies. Generate electricity. They release emissions which we are greenhouse gases. Think about others. What other activities are also anthropogenic? Besides the ones that I just gave to you.

L: Perfumes

T: Hold it there

L: Transportation (teacher writes them down), number of vehicles we have on our roads.

L: Burning of fuels

L: Burning of fossil fuels

L: Deforestation...

T: When I look at deforestation, how do you think ….it causes an increase in carbon dioxide?

I had told her to hold it and then after a few minutes came back to her for explanation.

T: Ok. Let's go back to Nelushi's point. Nelushi, can you repeat it, what you said before (pointing to the writing on the board .

L: Perfumes and other aerosols….

T: Ok.So you think they increase in the amount of carbon dioxide?
(Laughter from some learners)

L: Ma'am, in class u told us that when we spray perfumes and stuff, we are damaging the ozone layer. You are damaging the ozone layer.

T: Ok. Damaging the ozone layer. It's very important that you separate the greenhouse effect and the ozone depletion. Why I put your point on the side? Does it cause an increase in carbon dioxide? No.
In aerosols, perfumes and other stuff, we've got what we call CFCs, chlorofluorocarbons (some learners finish off and laugh). Those are the ones that lead to the damage or the depletion of the ozone layer. In large amounts not just a few of them. You with your one perfume. It's not much to say. Much of it and the other aerosols from other sources can cause ozone depletion. Ozone depletion and other anthropogenic activities that release carbon dioxide into the atmosphere, just separate it a bit…….

Here, I could have taken the opportunity to talk about other greenhouse gases that were not necessarily carbon dioxide and water. Another opportunity was also realised when a learner, who was persistent with her methane response, was called out.

T: Let's get back to you. You were talking of methane. CH_4. You said you saw it in a book. What was it talking about?

L: Ahh, Ma'am I don't know. In the book I was looking at, Methane was there and I don't know where it was coming from.

Realising the opportunity, I then went on to explain to the learner about decomposition and release of methane from living and decomposing organisms as well as from ice. In the worksheet on water, some learners still did not realise that melting of ice resulted in the release of methane into the atmosphere and went on to give responses like the excerpt below…..

Q1.4 Suggest why ice melting in Polar Regions leads to global warming

L1: it release oxygen.

Others were able to say that gases are released (they could not remember the actual gas released), some said carbon dioxide. Only a few were able to indicate that this would increase the amount of water vapour in circulation.

My knowledge of Prior and Post-conceptions in the Tests

The majority of the learners in the studied school initially demonstrated average literacy levels regarding Climate Change science. They showed higher levels of literacy in climate change impacts and solutions rather than in the climate change processes and causes of climate change. The difference in their knowledge differed significantly between the initial lesson and the last lesson as shown in the pre and post-test (Appendix 6-Test results). However a growth was seen with time, through the expressions made in writing in the open-ended question.

My own prior and post conceptions in the CoRe

The researcher's literacy levels in climate processes and causes of climate change, knowledge of the impacts to and impacts of climate change, mitigation measures (as well as the capability to handle such issues in the classroom) were looked at by analysing the tools of research by the researcher (me). The researcher's initial CoRe (pre-CoRe) reflects some gaps in the expected concepts aligned with global warming and climate change (Figure 4.6 Pre-Core Big ideas).

However, the post-CoRe (see Appendix 8) gives more information on the big ideas, which reveals a shift in knowledge after exposing herself to her peers and more literature. The new information pertains to the cause of the greenhouse effect from a Chemistry point of view- the bond properties in molecules. Both the pre-CoRe and the post-CoRe were presented to the critical peers for scrutinisation. During the CoRe presentation, the researcher expressed appreciation of possible learners' misconceptions as well as her own misconceptions. One of these was that CFCs in the presence of UV light, trap heat and cause global warming. It was put out as a strong point over other greenhouse gases. There is also the aspect of self-realization of missing knowledge as well as a misconception as the researcher makes her presentation. This misconception is addressed when she explains the difference between the cause of ozone depletion and that for global warming. The group was familiar with concept maps but they were fascinated with the CoRe, which they had never been exposed to before. The Geography and Life Sciences educators' feedback was quite helpful to the researcher by way of helping the researcher to flow from one aspect to another in the table. The Researcher could have improved the process by giving the peer educators a blank template of the CoRe to get the most of their ideas. It is important to note that it was such a big struggle to get them in one place for the presentation itself.

The way the researcher also sequenced and addressed the concepts in the CoRe, the lesson plans and the tasks indicate some good planning that takes learners' knowledge and knowledge of assessment well into context. The post-CoRe task itself was a good and comprehensive tool which took into consideration all the related concepts that came up in the discussions before the lessons. Together with the concept map, very little information is left out. These tools were quite handy in the planning to teach process.

4.4.4 Shifts in my knowledge of the learners' procedural knowledge

My knowledge of Learners' Procedural Knowledge (LPK) in the CoRe

This aspect looks at how learners are allowed to partake in scientific knowledge and replicate scientific skills. Evidence of such engagement is found in argumentation and actions in a lesson. One looks at whether the following have been considered by the teacher-the learners' ability to relate the Nature of science, the ability to present an argument, resolve scientific problems, carry out scientific investigations in their totality as well as promote a sense of belongingness to a 'community of practice. These procedures are expected to be observed in the teacher's plans, tasks and instructional strategies they put in place. The following extract from the post CoRe breaks down the processes that the researcher planned to use as a means of gauging the learners understanding.

7.Teaching procedures (and particular reasons for using these to engage the idea)	Discuss diagram showing interrelationship so that learners contribute to discussion and are able to complete worksheet	Questions based on Diagram showing radiant energy sources and transfer	Analysis of a Diagram of the water cycle	Activity on Atmospheric layers- to test what they know about the atmosphere.	Use of models/ illustrations to represent the greenhouse (it makes learners understand the effect), the greenhouse effect and global warming
8. Specific ways of ascertaining learners' understanding or confusion around the idea	Questions based on Diagram showing interrelationship-worksheet	Questions based on Diagram showing radiant energy sources and transfer	Questions on the structure and properties of water	Use a sketch of the atmosphere layers and space in worksheets	Probing questions-oral & written. Survey on Climate Change Pre-test and post-test of taught aspects.
9. Preferred assessment strategies or tasks to facilitate learning	Watching a video of the interrelationship	Use closed systems in experiments	Use of models to explain structure of water	Video of atmosphere layers	Pre and post tests Short test on taught aspects Experiment on greenhouse effect

Figure 4.12: An extract from the Post CoRe showing how I planned to engage with learners' ideas

In a bid to show how learners could be allowed to partake in scientific knowledge and replicate scientific skills, I came up with activities that could be carried out by the learners across the topic (Figure 4.12). These were then followed by the implementation process.

The scientific investigation skills, the learners' ability to relate the nature of science, the ability to promote a sense of belongingness to a community of practice were then traced throughout the lessons.

7.Teaching procedures (and particular reasons for using these to engage the idea)	Activity on Atmospheric layers- to test what they know about the atmosphere.	Use of models/ illustrations to represent the greenhouse (it makes learners understand the effect), the greenhouse effect and global warming
8. Specific ways of ascertaining learners' understanding or confusion around the idea	Sketch of the atmosphere layers and space	Probing questions-oral & written. Survey on Climate Change Pre-test and post-test of taught aspects.
9. Preferred assessment strategies or tasks to facilitate learning		Pre and post tests Short test on taught aspects Experiment on greenhouse effect

Figure 4.13: An extract from the Pre-CoRe showing how I planned to engage with learners' ideas.

My knowledge of Learners' Procedural Knowledge (LPK) in the lessons

Below is an excerpt showing how I was trying to link conceptions from the previous lesson and worksheets to the current lesson, so that I could explain the importance of water vapour and carbon dioxide.

> We were talking about the presence of greenhouse gases, some of them .One example being water vapour. And I said to you that do you know that water vapour is one of the most important greenhouse gases. Some of you didn't know that, some of you said ummh like they knew but they had forgotten. And then the other

one was carbon dioxide and then you mentioned several other ones….. (Greenhouse effect lesson transcript)

Even though the learners are not actively participating in the dialogue, I manage to harness them in by using their responses to the task in which they had mentioned the correct and incorrect greenhouse gases, after explaining how greenhouse gases really work in the presence of infrared radiation, the learners could now effectively respond to the worksheet that grouped greenhouse effect, enhanced greenhouse effect and global warming together (Appendix 9-Worksheet 2)

The design of the last task (Appendix 9-open inquiry task) in which the learners took up roles and assumed mitigation roles. In doing so, they engaged with a portion of a newspaper article that could be classified as an open inquiry task. The learners had to zone in on either the chemistry behind global warming, the Protocols and summits on climate change, evidence of climate change and what man can do about climate change. It was designed and used in such a way that it made the learners get exposed to information derived from a scientific context, talk about it in their groups and then respond to a task where they are expected to work as autonomous decision makers, using their own initiative and judgement in managing climate change. There is however still a lot of room for improvement in the design of the task and its use to engage learners further in these procedural skills. A further shift is needed in designing tasks like this.

The task has aspects of a written account at the end, which opened possibilities for the researcher to help her learners appreciate the nature of science as a human endeavor, socially constructed through logic, reasoning and evidence based on argumentation within a community of practice. The task presented an opportunity for me to create an environment where learners could have engage more with each other in a scientific discourse of proposing or arguing about climate change aspects.

Whilst good tasks were set to assist in assessing the learners' knowledge, their usage was rather minimal. I could have used the worksheets in a different way, to initiate and

allow for argumentation amongst learners. At the classroom implementation stage, I resorted mostly to lesson delivery by way of informing the learners' content about global warming. The lessons ended up being somehow subject matter driven and not concerned with promoting much procedural skills, which could have helped my learners appreciate the processes involved in the generation of scientific knowledge. The tasks had aspects of writing and one which gave the learners a chance to engage with science in everyday world, where they had to encounter outlines of what is happening in the world around them concerning Climate Change (see Appendix 9-Newspaper articles).

The last aspect of the lessons opened up a possibility for learners to appreciate the nature of science as a human endeavor, socially constructed through logic, reasoning and evidence based on argumentation within a community of practice. The learners then had to propose solutions in writing to global warming by taking climate change mitigation roles in the community (see Worksheet 6-South Africa's response).
Some excerpts are given shown below.

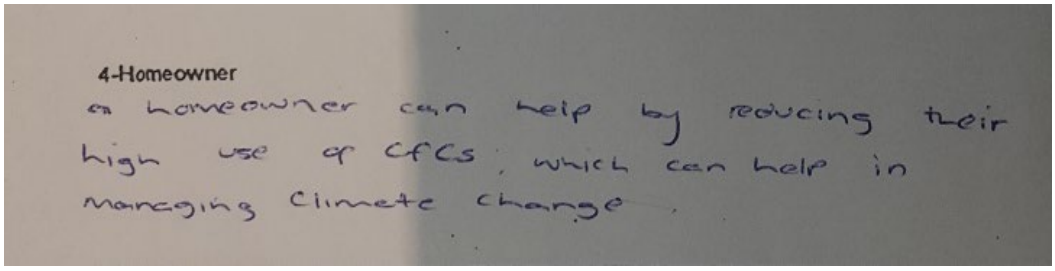

Figure 4.14: An excerpt showing a learner's solution to the Climate change.

In this excerpt, the learner chose the role of a home owner and suggested that he can help by reducing the use of CFC which can help in managing climate change. Whilst their focus is still on CFCs, I was also expecting a solution to do with some greenhouse gases.

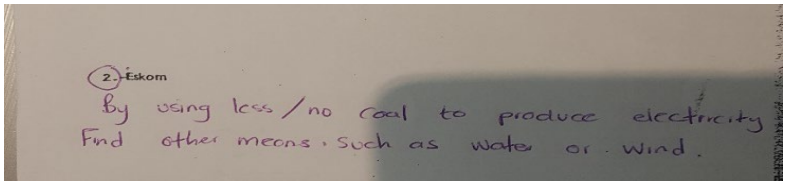

Figure 4.15: An excerpt showing a learner's solution to the Climate change.

In the worksheets

In the worksheet on water, most learners were professing misconceptions in statements like

'…When water freezes it is heavy, so its density increases and water becomes hard and solid so density increases; Density of ice decreases as it melts….(extract from water worksheet.)

Figure 4.16 is an excerpt of one learner's work the rest are in Appendix 10.

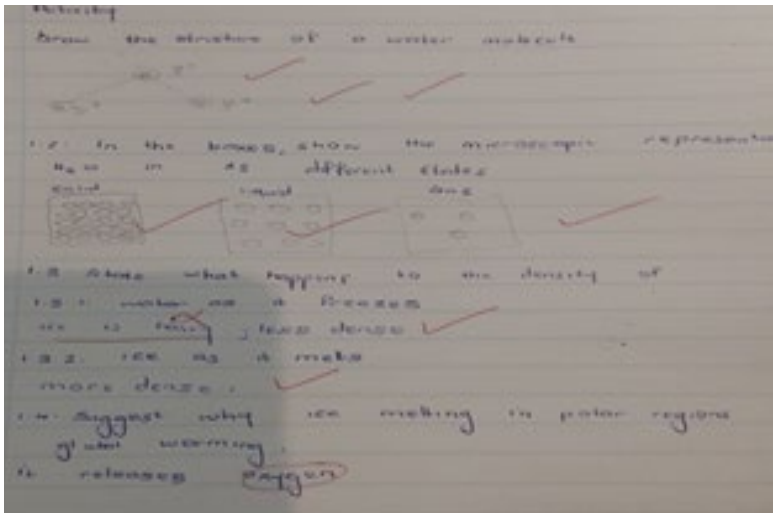

Figure 4.16: An excerpt showing one of the learners' worksheet showing conceptions of water structure

4.4.5 Shifts in my knowledge of representations, modelling and analogies

These speak to any analogies, representations, demonstrations, models or even examples that the teacher, through their experience, employs in the classroom so as to make the subject matter comprehensible to the learners. This aspect can be seen in how the teacher plans (in the CoRe) to take microscopic phenomena and uses representations to link it with the macroscopic observations.

1. What you expect learners to know already about this idea	The sun, water and the atmosphere are interconnected in determining the weather in a particular area.	The Sun is the primary source of Energy for Earth's Climate System. Energy, in changing form, is neither created nor destroyed. Energy is conserved in a closed system, an open system allows for the loss of energy Electromagnetic1 radiation and its relative strength	The shape of the water molecule The polar nature of water Phase changes of water on Earth The difficulty of separating atoms in a water molecule The Sun providing the energy that drives the water cycle	They appreciate the role played by the atmosphere as a shield from harmful ultraviolet radiation
2. What you intend students to learn about this idea	The sun is the primary source of energy for Earth's climate system-heat from sunlight can heat the land, ocean and atmosphere. The ocean acts as a reservoir for a good temperature regulator, water. The amount of solar energy absorbed or radiated by the earth is modulated by the atmosphere and depends on the composition of the atmosphere.	Energy exists in various forms-mechanical, chemical, electrical, radiant, thermal and nuclear. Amount of sunlight received by the Earth is affected by the reflectivity of the surface, the angle of the Sun, the Sun's output and variations in the Earth's orbit around the Sun. Sunlight reaching Earth can heat the land, ocean and atmosphere, some of it is reflected back to space by the surface, clouds or ice, Much of that which reaches the Earth is absorbed and warms the planet The transformation and conservation of energy occurs in processes that are predictable and measurable When the earth emits the same amount of energy as it absorbs, its energy budget is in balance and its average temperature remains stable.	To show that macroscopic behaviour can be accounted for by microscopic structure-melting, boiling, solvent, density etc. Link strong hydrogen bonding between water molecules to high specific heat capacity Link melting of ice caps, release of methane to density and structure of solid water (ice)	Identify the chemical species and role of each species in each layer. The chemical nature of greenhouse gases (ghgs) Ghgs in the atmosphere (carbon dioxide, water vapour) affect energy flow in the Earth system, they are transparent to most incoming sunlight but not to IR from the warmed Earth surface.

Figure 4.17: Post CoRe showing the plan for such opportunities for representations, modelling and analogies

The highlighted portions of the CoRe extract in Figure 17 show the plan for such opportunities, where I was outlining what I intended the learners to know in each big idea. In Figure 4.18 that follows, is another opportunity in the CoRe where I planned to use questions asking about structure of water molecules (and other greenhouse gases) and about how structure affects properties of substances.

8. Specific ways of ascertaining learners' understanding or confusion around the idea	Questions based on Diagram showing interrelation ship-worksheet	Questions based on Diagram showing radiant energy sources and transfer	Questions on the structure and properties of water	Use a sketch of the atmosphere layers and space in worksheets	Probing questions-oral & written. Survey on Climate Change Pre-test and post-test of taught aspects.

Figure 4.18: Opportunities for representations and modelling in plans Assessments as presented in the Post CoRe.

In explaining how energy is transferred in the system, the reactions that lead to the formation of greenhouse gases, the water cycle, the atmospheric layers, the bonds in molecules of the greenhouse gases and concept maps, the researcher creates an opportunity to utilise various ways of representing knowledge both when teaching and in the assessments (see Appendix-worksheets).

Sustenance of such plans is looked at by focusing on how I carried out the lessons, for example, if there were any attempts to draw structures or give analogies of situations that help explain global warming aspects, examples like melting of ice, being in a car with closed windows or being in a greenhouse structure. Some scenarios are shown below, where I tried to draw out structures….

There are instances where the teacher had to use multiple representations to get to the learners. The excerpts below show some examples where illustrations invoke memories of previously done work.

T: These ones because of their nature….You did natural sciences and you are well aware of how nitrogen is like .N atom here ,N atom here sharing electrons in the bond (drawing) .We used to draw that nitrogen N_2.
Hello! .....

(Lesson transcript-greenhouse gases)

T: Okay what I am taking about is the nitrogen and another nitrogen there like that (draws on the board). And then for the carbon dioxide you write them like this .And drawing the bonds.

So the electrons are familiar? .....

L: Yes.....

T: These 2 now oxygen is how many bonds here....

L: Two.....

(Lesson transcript -greenhouse gases)

In addition to the talking, the teacher also had to draw out molecular structures. Most learners had forgotten how these looked like.

T: If you are drawing the structure of oxygen you understand that it's O_2.How many electrons around an oxygen atom?

(1 ,2 ,3,4,5,6) ,(,2,3,4,5,6) and when you pair them up so that we have 8 around each .Put these 2 and these 2 that will be 1 ,2,3,4.Take these out 4,5,6,7,8 and it's like this .2 double bonds and 2 non pairs of electrons here and 1 double bond there. You remember this structuring from grade 9 .If you don't then you will remember this, how you would write them out .And how would you call out these elements. Diatomic elements, these two because they have 2 atoms or atoms of the same element but they have 2, atoms of different elements but they are 2, diatomic!

Right,O_2 and N_2 .Now these 2 here oxygen and nitrogen are important to us. I' m going to draw out another one and use it later on .H_2O, you also remember this, neh! This is for water. There line structures, if you don't put these single lines you remember putting electrons there. You drew it out in the chemistry portion of natural sciences, okay, if you don't remember this please try to remember, you need it for your grade 10 and 11 also.

These write down they are formulae, oxygen, nitrogen, carbon dioxide and H_20 which is water.

Sometimes, I found myself having to be creative around showing symmetry in the drawn structures…

> *Someone does remember at least remembers ,Okay let's start with oxygen and nitrogen .Those 2 we say they are symmetric ,if I am to put a mirror here it will bring me the other oxygen .If I am to divide here this part and that part are the same. And when you talk about this one this is a bit bent .We can't say its symmetrical at all .We can't come and divide along this line, No!*
> *But when you look at these 2 they are diatomic and they are symmetrical. In chemistry okay, when it comes to such arrangements it affects even the way the particles behave in nature .Now these 2 because they are symmetrical they do not absorb radiation. Which type of radiation am I going to talk about there-Infrared radiation?*
>
> *(Lesson transcript -greenhouse gases)*

4.4.6 Shifts in my knowledge of science in society

Science Oriented Instructional Sequencing (SOIS)

This is when a teacher uses teaching and assessment strategies that value and engage learners' prior knowledge, as well as promote and capture the cognitive and the social dimensions of how scientific knowledge is generated. Science oriented instructional and assessment strategies, such as the *5Es lesson sequencing*, *argumentation,* use of *open inquiry*, use of a *scientist case studies* as well as *role playing* all allow for learner involvement in their own learning through dialogue and reflection.

The CoRe gives instances where such considerations are being made in the planning process. The researcher planned for the use of science oriented instructional and assessment strategies, such as the *5Es lesson sequencing*, *argumentation,* use of *open inquiry/ scientist case studies/ role playing* which could allow for learner involvement in

their own learning through dialogue and reflection. In reality, however, the use of such teaching and assessment strategies that value and engage learners' prior knowledge, as well as promote and capture the cognitive and the social dimensions of how scientific knowledge is generated could be seen in some instances but not all. In the extracts from the experiment and deliberative lessons, showing the purpose of each lesson. The worksheets are in the Appendix-worksheets. In the CoRe, concepts are clearly mapped out and sequenced. In addition to laying out the big ideas, the teacher also scaffolds them in their lesson planning before each worksheets, explaining how each big idea will unfold.

4.5 Consistency of my lessons with lesson planning.

Introduction of the concepts was done in an authoritative manner in all cases. Perhaps, the learners felt disempowered by this move, hence their minimal contribution in the lessons. On examining the nature of the tasks that I produced and how I use them (through action and practice) to engage learners in the learning process, it can be seen that I was trying to use the assessment tasks to gather more information on the learners' conceptions.

The concept maps which the learners did before the lesson began show very wide knowledge gaps in the learners. Most of them were not even standard concept maps to talk about. I managed to pick out that learners have holes in their knowledge of climate change and most put in nitrogen (instead of nitrous oxide) and oxygen (instead of ozone) as greenhouse gases. I then used this as an opportunity to address the holes and misconceptions by teaching on the enhanced greenhouse effect as related to human impact.

The researcher's views on learners' prior conceptions as outlined in the presentation shows that she appreciates the critical role they play and is prepared to address them when teaching. In the lessons, however, I take a dominating role over the learners in most of the lessons, and at most does not engage or entertain any misconceptions the learners hold.

In the planning phase, the researcher shows enthusiasm to involve learners in their learning, as seen in prompts 7, 8 and 9 of the CoRe. Given the common constructivist approach to the rather socio-scientific aspect at hand, the lesson atmosphere was supposed to be one in which the teaching and learning environment allows for active engagement between myself and the learners. I was expected to present myself as a constructivist teacher, facilitating the learning and allowing the learner to be in charge of their learning, at most.

4.6 Overcoming the factors which were working within my environment during my knowledge shifts

Here I discuss how my knowledge shifts were affected by teacher/peer factors and learner factors. This Self-Study was carried out with the intent to investigate my practice as a Science Educator when it comes to teaching Chemistry of the hydrosphere, atmosphere and other associated Climate Change aspects. I had wanted to learn and to understand how I could engage learners in the Chemistry of the Atmosphere, and related 'spheres', so that they improve their understanding of Climate Change and I in turn also improve my teaching. . Faced with the vagueness of the syllabus on socially-contextualised aspects like pollution and global warming and other contextual frustrations that had gathered up in these few years, I felt I could do something about the way I teach contextual topics to high school learners that do Physical Sciences as a subject. I felt the need to come up with strategies that essentially work to enhance conceptual understanding and develop skills that would be used in the next grade or level of learning or even in a parallel subject such as Life Sciences or Geography. In doing this study, I encountered the same frustrations that learners also encounter. One such is that teachers do not go into detail into many social aspects. Another frustration I experienced was the lack of or poor feedback thereof from my learners when I was trying to engage them in class. My content knowledge on this climate change aspect improved, not because of the interaction with my peers who were more knowledgeable in the aspects but more because the lessons I planned forced me to engage more with literature and get more information than I knew.

In the end I saw that it is not about my qualifications that matter but about how I strive to change the teaching strategies in my classrooms that will make a difference. Contextual

factors will always work against progress but I still need to focus on the ideological shift that I plan. With this study, an opportunity for me (as the researcher and researched), a group of educators (with different qualifications) and some Physical Sciences learners to engage with Climate Change aspects from a Chemistry perspective was realized. The study generally made a substantial contribution to my knowledge, enabling me to gain insight into the concept of Climate Change, specifically Chemistry of the hydrosphere and atmosphere. The study also enhanced my own understanding of ways to effectively incorporate Climate Change Education into the current curriculum, without necessarily upsetting the system. The envisaged improved teaching styles and approaches in the researcher were also partially realized. For the 'others', who might teach the same topic(s), the challenges faced and the lessons learnt from this personal journey were equally narrated.

4.7 How environment affects a product-an insight into contextual factors

In this study, school contextual issues emerged so strongly as a factor impeding instruction that they should not be overlooked.

Even though an opportunity was created and used for teachers in three different learning areas to meet, engage and collaborate with each other in efforts to reflect on their own practice, this *stimulation and challenge* domain part of the model cannot be viewed as a success partially because the colleagues approached only availed themselves for the CoRe discussion and profaned ignorance to such forms of planning. Any expectations of them perhaps adopting the presented tools were thwarted hen they did not give constructive feedback pertaining the use of the concept maps and the CoRe itself. However, external expertise from peer engagements and supervisor feedback in my learning institution exposed me to a wider community of practice, which therefore served to reinvigorate and stimulate deeper analysis of my work. Such engagement should have come earlier in the planning stage and made a huge difference.

4.8 Conclusion

There is evidence of a huge shift in my own conceptual knowledge (as the researcher) of the topic which happened through from the planning stages (CoRe and lesson plans), the planned activities given to the learners and the lesson delivery.

The lessons were built around the big ideas covering fundamental concepts underpinning the topic of global warming. The philosophy of constructivist approach to learning inherent in the 5E lesson sequencing strategy was not entirely followed. The tasks and the teaching strategy adopted for the research brought out some features that are of a constructivist teacher who also tends to resort to transmittance of knowledge when put under pressure.

However, due to the learner engagement strategies that were mostly absent in the classroom, there is some level of compromise of these proposed great innovations to promote the learners' procedural knowledge inherent in the social aspect of the doing of science. The educator showed an appreciable understanding of climate change science and a willingness as well as a potential to raise and promote climate change education in a school set-up through making learners open up with their conceptions.

As the researcher being researched, I felt myself transformed as I worked with the theme of Climate Change. I found many opportunities for teaching Climate Change in Physical Sciences. One important thing I learnt in this study is that as a teacher I must engage my learners in dialogue and not leave it to the end where they are now looking at their own work. My planning skills were challenged throughout the study. I now know how to put together a CoRe and state the big ideas for the topics that relate to climate change. I hold the potential to utilise this planning knowledge with other topics.

4.9 CHAPTER SUMMARY

In this chapter, the analysis of the actual data was presented and findings on questionnaire, planning, and discussions were discussed.

CHAPTER 5: Summary of Findings and Limitations

5.1 Introduction

In this chapter, a summary of the findings, answers to the research questions and limitations of the study are presented. A reflective approach is taken in reviewing the research approach used in this study.

The research questions which this study sought to answer are revisited and these are:

1. How is my pedagogical content knowledge for teaching Atmospheric Chemistry to my Grade 11 Physical Sciences learners transformed as I reflectively use Climate Change as a theme in my lessons?

2. What do I learn from this teaching experience and how can I use that knowledge to improve my teaching strategies in addressing learners' needs in this topic?

3. How are my metacognitive capacities for teaching this topic and my strategic curriculum knowledge, enhanced as I engage in this process?

5.1 An insight into my own teaching

Though the journey has been long and not without pain, several lessons have been learnt. The transformation of my content knowledge, my strategic skills, how I address learner needs as I plan and teach has occurred to some extent.

In this study, I found that I took a less reflective and analytical stance to teaching during the actual teaching process unlike the time I spent in planning of material. It seems that I feel satisfied with my level of planning but I need to learn to reflect at all levels of pedagogy to improve my teaching. An ideological shift is thus needed on the part of the researched educator.

There is some evidence of me as the researcher trying to pick out some interpretive and ideological biases built into my conceptions of knowledge. This was by way of me analyzing my tools. Given that this was previously discussed as being particularly important for teachers that they should try to seek through any of their biases which might

impact their interactions with and perceptions of learners in their teaching. Other teachers may benefit by also taking such a reflective approach to their planning and teaching.

The theoretical base of this study was a link between situated cognition perspective and teaching- how situated cognition informs PCK and allows for some conceptual change in a teacher in a study existing in a social structure, involving a social context. This theoretical approach was barely maintained throughout the study. In teaching concepts associated with climate change, a teacher needs to recognise and consider in their planning and lesson delivery that learners come to instruction with prior ideas, which are often in conflict with accepted science concepts and must learn within a social set-up to acquire knowledge. Rather than giving a didactic lecture to learners and make them passive learners, as was observed in some lessons, I should have acted as a facilitator to the process of learning, allowing learners to take charge of their learning. As a result of the learner-engagement strategies that were mostly absent in the classroom, there is some level of compromise of these proposed great innovations to promote the learners' procedural knowledge, innovations normally inherent in the social aspect of the doing of science.

Another important thing I learnt in this study is that as a teacher I must engage my learners in dialogue and not leave it to the end where they are now looking at their own work. Engagement starts the very moment they enter one's classroom. As discussed previously in literature, instructors must be facilitators not teachers. Furthermore, the facilitators must not tell but ask, must give guidelines not answers. Literature suggests that continuous and interactive dialogue should be dominant in a classroom of a social constructivist instructor. This however cannot be possible if the environment is not supportive of such type of learning. The researcher had to deal with many contextual issues at the research site such as workload and extra duties clashing with research plans and this impeded on the smooth running of the research at her school premises. School managers and peer teachers are not sympathetic to those who seek to do extra academic work to improve themselves. In this study therefore, I did not act as a full social constructivist teacher and reflecting from this, I feel there is room for change if I am to be labelled as one.

5.2. Enhancement of my metacognitive capacities and strategic curriculum knowledge for teaching the topic

As the researcher being researched, I felt myself transformed in many ways as I worked with the theme of Climate Change. I found many opportunities for teaching Climate Change in Physical Sciences. I can now use my knowledge of learners, the curriculum and other contextual factors to come up with a concept map, my 'big ideas' in a CoRe to plan for my work. Even though both my planning and teaching skills were challenged throughout the study, it was a worthwhile journey, a journey of self-introspection, an area where not many teachers would want to enter. My teaching strategies have now improved as I can now reflect on my actions and re-consider my plans. I am also now able to utilise the new planning skills obtained in the study and I hope to utilise them as I approach any other topic that I will teach. Even though the topic Climate Change as a broad topic is not in the FET syllabus, I now know that I can imbed the theme across the year and still get to involve the learners.There is evidence of a huge shift in my own conceptual knowledge (as the researcher) of the topic which happened through from the intensive planning stages (CoRe and lesson plans), the planned activities given to the learners and the lesson delivery.

The journey through my experiences and practices has been made easier by having a knowledgeable mentors to help interpret it. They helped me see, through self-study and consultation how I could utilise new practices and tools in the teaching of contextual science, the climate change issue. They also helped to facilitate my growth because I was able to share with them ideas, suggestions and concerns.

The experience has made me aware of the support teachers need to be able to improve their teaching. In future endeavors, I will strive to teach more effectively and adequately address leaner needs during the teaching process.

5.3 Limitations of the study

The following were constraints that impacted on this research.

There were limited literature sources that spoke to Climate Change education in Physical Sciences. However, research in other subjects like Geography really helped. Another issue is that data collection may look inadequate as a result of self-reporting. The tool for analysis, the LTtP model used though tested, may not be used as a substitute to reality. However, most predicted behaviour was shown or highlighted and consistent with the model. The tool was most significant in showing most aspects. It however was difficult to use in differentiating two of the aspects-curriculum saliency and learners' procedural knowledge. The contextual factors in the school made it difficult for the researcher to carry out their research. One had to compromise with learners and school authority to get something done. Learners and some teachers alike, are impatient with research and some individuals openly express their intolerance. One of the most restrictive limitations was time and budgetary resources. The researcher did not have much local data to work with, for comparison's sake, especially studies that involve the teaching of climate change in the new curriculum, CAPS. It was important that this was there so that the study could be grounded in local studies. It would be beneficial if other Physical sciences teachers could undertake research in using Climate Change as a context for teaching in Physical Sciences.

CHAPTER 6: Conclusions and Recommendations

6.1 Conclusions

With this study, an opportunity for me (as the researcher and researched), a group of educators and some Physical Sciences learners to engage with Climate Change aspects from a Chemistry perspective was realized. The study generally made a substantial contribution to my knowledge, enabling me to gain insight into the concept of Climate Change, specifically Chemistry of the hydrosphere and atmosphere. The study also enhanced my own understanding of ways to effectively incorporate Climate Change Education into the current curriculum, without necessarily upsetting the system. The envisaged improved teaching styles and approaches in the researcher were also partially realized. For the 'others', who might teach the same topic(s), the challenges faced and the lessons learnt from this personal journey are equally narrated.

Why teach climate change aspects to Physical sciences learners? If it is left to other subjects other than Physical Sciences, the implications as suggested by researchers are quite significant (Guardian, 2014). Climate change education is informed by some important theories in science and it also integrates lines of evidence from various disciplines (Geography, Life Sciences and Chemistry). If one Physical Science educator showed an appreciable understanding of climate change science and a willingness as well as a potential to raise and promote climate change education in a school set-up through making learners open up with their conceptions, many others can strive to do the same too. Our learners do hold some truths about climate change and they are aware that pollution plays a part in climate change, they just differ as to what degree it does so and are sometimes confused by the principles underlying phenomena associated with the aspect. Making learners understand this underlying principle helps them to realise how powerful climate change knowledge is in their lives and it also allows for learners to engage in high order scientific thinking skills as presented in the integration. Previous research Anyanwu (2015), has shown that Climate change education that is interactive tends to change learners' everyday perceptions about causes of and effect of global warming as well as ozone depletion, aspects that are catered for in the Climate change topics. This study therefore tries to engage both the researcher and the other participants

(learners) with a semi-structured questionnaire, concept maps as well as worksheets to try and gauge what is currently known and what is essentially gained during the interactions (lessons)

6.2 Recommendations and possible areas for further research

If practising teachers are to undertake a similar study, it is advisable that they be conscious of the essence of a Self-Study were a socially-derived theme is used to teach- the implementation of the 5Es mentioned earlier. These must be adhered to from planning phase to the end so that one does not lose focus. There is great temptation to resort to non-constructivist teaching approaches, especially when one is in a non-conducive environment.

It is advised that teacher educators and policymakers to consider opportunities of interventions where there is interaction between teachers of three learning areas, namely: Physical Sciences, Geography and Life Sciences. These opportunities will enable involved teachers to develop deeper scientific knowledge and understanding of climate change and thus promote the development of climate change science literacy in schools. Given that learners showed little understanding of climate change before the issue was discussed, there is need for research to gauge the depth and levels of climate change science literacy among Senior Phase Natural Science teachers in South Africa. Resources are available for climate change related lessons that could fit into the FET band if the topic could also be further explored in Physical Sciences lessons. Using climate change as a context in the teaching of some Physical sciences topics is likely to imbed the climate change aspects into learners.

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8. Appendix

Below I have attached appendices of the instruments that I have used to collect and analyse data as well as samples of my work.

List of Appendices

1. **University of Witwatersrand Ethics clearance**
2. **Letter to the Principal**
3. **Letter to parents**
4. **Gauteng Department of Education Clearance Letter**
5. **Pre and Post Questionnaire**
6. **Results of Pre and Post Test**
7. **Preteaching Concept map & Expert concept map**
8. **Pre and post Content Representation (CoRe)**
9. **Worksheet samples**
10. **Learners' samples of work**
11. **Reflective journals**
12. **Sample of lesson transcripts**
13. **Table showing particulars of participants**
14. **LTtP model**

Appendix 1 University Ethics clearance

Wits School of Education

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 August 2016

Student Number: 756005

Protocol Number: 2016ECE040M

Dear Caroline Chipato

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:

Using Climate Change as a context to teach Chemistry topics in my Physical Sciences FET classrooms- a Self-Study.

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,

M Makgeta

Wits School of Education

011 717-3416

cc Supervisor - Dr Mpunki Nakedi

Appendix 2 Letter to the Principal

11/04/2016

The Principal

Lenasia South Secondary School

14 Cnr Sheffield & Ivy Street

Lenasia South

1829

Dear Mr. A. A. Kwinda

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

My name is Caroline Chipato. 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 Atmospheric Chemistry to Physical science learners.

My research involves the following. I would need to prepare for my lessons, teach two 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. I would also like to engage with at least three of your teachers, for purposes of evaluating my preparation and the quality of my lessons. They will be required to complete observation schedules 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 third term.

The reason why I have chosen your school is because it is where, I, the researcher will be working. It is a place of convenience 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, Lenasia South Secondary School, to participate in this research. Your teachers will stand to benefit from the content knowledge that will be unraveled as well as from other connected issues that will be brought forth in this study as teachers from various departments meet for one goal.

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,

Mrs. Caroline Chipato

5622 Keele Peak Place

Lenasia South, Ext 4

1829

chipamud@yahoo.co.uk

0733424463/0718983180

INFORMATION SHEET PARENTS 11

May 2016

Dear Parent

My name is Mrs. Caroline Chipato and I am an MSc Science Education student in the School of Education at the University of the Witwatersrand.

I am doing research on Teaching Atmospheric Chemistry to FET Physical Science learners. My research involves taking at least two extra lessons in a week with your child/ward. I intend to teach them on a topic in a normal class set-up but I have to record the events in the lesson so that I can be assessed by other educators.

The reason why I have chosen your child's class is because they are studying the subject of concern (Physical Sciences) and they will provide me with much information. I was therefore wondering whether you would mind if I take the extra time with your child/ ward and carry out my study. They will have to be in a lesson and allow to be recorded as well as be assessed (but not for marks).

Your child/ward will not be advantaged or disadvantaged in any way. S/he will be reassured that s/he can withdraw her/his permission at any time during this project without any penalty. There are no foreseeable risks in participating and your child will not be paid for this study.

Your child's name and identity will be kept confidential at all times and in all academic writing about the study. His/her individual privacy will be maintained in all published and written data resulting from the study. 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.

Thank you very much for your help.

Yours sincerely,

Mrs. Caroline Chipato

5622 Keele Peak Place

Lenasia South, Ext 4

1829

chipamud@yahoo.co.uk; 0733424463

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:

Teaching Atmospheric Chemistry to FET Physical Science learners

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_____

INFORMATION SHEET LEARNERS 11/04/2016

Dear Learner

My name is Mrs. Caroline Chipato and I am an MSc Science Education student in the School of Education at the University of the Witwatersrand. I am doing research on Teaching Atmospheric Chemistry to FET Physical Science learners.

My investigation involves, at most, teaching you on Atmospheric Chemistry as required by your syllabus. I would want you to understand Climate Change more after I have taught you this topic. It is a bit more than what you already know but will help you see the link between Chemistry, Geography and Life Sciences concepts too. You will have to complete a few questions for me to see how much you understand about Climate Change in Physical Sciences. We will meet at least twice in a week in the Third term to do this.

I was wondering whether you would mind if I have you attend my lessons during this time. I need your help in the following ways. I would want you to attend my 30-minute lessons, answer my questions, whether orally or in written form. There will be a video recorder to record me as I teach. I beg you not to mind it too much. It will serve the purpose of seeing the progress of the lesson and I assure you that it will not be used against you in any way.

Remember, this is not a test, it is not for marks and it is voluntary, which means that you don't have to do it. Also, if you decide halfway through that you prefer to stop, this is completely your choice and will not affect you negatively in any way.

I will not be using your own name but I will make one up so no one can identify you. All information about you will be kept confidential in all my writing about the study. Also, all collected information will be stored safely and destroyed between 3-5 years after I have completed my project.

Your parents have also been given an information sheet and consent form, but note that, at the end of the day it is your decision to join us in the study.

I look forward to working with you!

Please feel free to contact me if you have any questions.

Thank you

Mrs. Caroline Chipato

5622 Keele Peak Place

Lenasia South, Ext 4

1829

chipamud@yahoo.co.uk ; 0733424463/0718983180

Learner Consent Form

Please fill in the reply slip below if you agree to participate in my study called:

Teaching Atmospheric Chemistry to FET Physical Science learners

I (your name in full) _____ **am giving the researcher (C Chipato) permission to do the following.**

Permission to:	**Circle one**
1. Permission to observe you in class	
I agree to be observed in class.	YES/NO
2. Permission to be audiotaped	
I agree to be audiotaped during the interview or observation lesson	YES/NO
I know that the audiotapes will be used for this project only	YES/NO
3. Permission to be photographed	
I agree to be photographed during the study.	YES/NO
I know that I can stop this permission at any time.	YES/NO
I know that the photos will be used for this project only.	YES/NO
4. Permission for questionnaire/test	
I agree to fill in a question and answer sheet or write a test for this study. YES/NO	
5. Permission to be videotaped	

I agree to 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 name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audiotaped, photographed and/or videotape
- All the data collected during this study will be destroyed within 3-5 years after completion of the project.

Sign_____ Date_____

INFORMATION SHEET TEACHERS

11 May 2016

Dear ……

My name is Caroline Chipato and I am an MSc Science Education student in the School of Education at the University of the Witwatersrand.

I am doing research on Teaching Atmospheric Chemistry to FET Physical Science learners. My research involves taking a few minutes of your time at least 3 times in a week for Term 3. I know you are busy with preparation and lessons hence I will not disturb you much. I would very much appreciate it if you could share some of your knowledge and experience with me as I take on this journey of teaching the above-mentioned topic. I intend for you to see my lesson plans, comment on them and give me your thoughts. I also need you to give me some input where necessary as I seek to improve myself. You may or may not attend the group discussion panels. Please do accept my invitation as it would mean a lot to me and the other participants.

I guarantee you that your name and identity will be kept confidential at all times and in all academic writing about the study. Your individual privacy will be maintained in all published and written data resulting from the study.

All research data will be destroyed between 3-5 years after completion of the project. You will not be advantaged or disadvantaged in any way. In addition, your participation is voluntary, so you can withdraw your permission at any time during this project without any penalty. There are no foreseeable risks in participating and you will not be paid for this study.

Please let me know if you require any further information.

Thank you very much for your help.

Yours sincerely,

Mrs. Caroline Chipato

5622 Keele Peak Place

Lenasia South, Ext 4

1829

chipamud@yahoo.co.uk

0733424463/0718983180

Teachers' Consent Form

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called:

Teaching Atmospheric Chemistry to FET Physical Science learners

I, _____ give my consent for the following:

Permission to	**Circle one**
1. Permission to observe you in class	
I agree to be observed in class.	YES/NO
2. Permission to be audiotaped	
I agree to be audiotaped during the interview or observation lesson	YES/NO
I know that the audiotapes will be used for this project only	YES/NO
3. Permission to be interviewed	
I would like to be interviewed for this study.	YES/NO
I know that I can stop the interview at any time and don't have to Answer all the questions asked.	YES/NO
4. Permission to be photographed	
I agree to be photographed during the study.	YES/NO
I know that I can stop this permission at any time.	YES/NO

I know that the photos will be used for this project only. YES/NO

5. Permission for questionnaire/test

I agree to fill in a question and answer sheet or write a test for this study. YES/NO

6. Permission to be videotaped

I agree to 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 name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I 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 4: GDE Approval Letter

For administrative use only:
Reference no: D2017 / 153
enquiries: Diane Buntting 011 843 6503

GAUTENG PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

GDE RESEARCH APPROVAL LETTER

Date:	**30 June 2016**
Validity of Research Approval:	**30 June 2016 to 30 September 2016**
Name of Researcher:	**Chipato C.**
Address of Researcher:	**5622 Keele Peak Place; Lenasia South; 1829**
Telephone / Fax Number/s:	**073 342 4463**
Email address:	**chipamud@yahoo.co.uk**
Research Topic:	**Using Climate Change as a context to teach Chemistry topics in my Physical Science FET classrooms - a Self-Study**
Number and type of schools:	**ONE Secondary School**
District/s/HO	**Johannesburg South**

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 be 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;*

2016/07/01

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

3. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal and/or Director must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
4. *Research may only commence from the second week of February and must be concluded by the end of the THIRD quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*

Appendix 5: Pre and Post Questionnaire

Kenneth A. Walz & Sara C. Kerr

Madison Area Technical College UW-Madison

kwalz@matcmadison.edu

Atmospheric Environmental Chemistry Assessment

This assessment is part of an educational study being conducted between MATC and UW-Madison. The data from this assessment will be used to develop and improve further instruction. Your response is greatly appreciated.

1. Global Warming is a significant environmental problem: (Circle one)

Strongly disagree ←---------- ----------→ strongly agree

0 2 4 6 8 10

2. Which of the following statements accurately describes the relationship between the greenhouse effect and the ozone hole?

a) The hole in the ozone layer triggers greenhouse warming

b) Global warming due to the greenhouse effect results in ozone destruction

c) Both the ozone hole and the greenhouse effect are caused by automobiles

d) The greenhouse effect and the ozone hole are separate atmospheric phenomena that have different primary causes

e) Global warming and the ozone hole are natural processes that have been occurring for millions of years

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

a) A rise in sea levels

b) An increase in global temperatures

c) An increase in levels of harmful ultraviolet (UV) radiation reaching earth's surface

d) A change in global precipitation patterns

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

a) Increased surface temperatures

b) Increased rates of skin cancer

c) Changing weather patterns

d) Melting of polar ice-caps

5. Which of the following does not contribute to smog formation?

a) Motor vehicles

b) Industrial processes

c) Electricity production

d) Use of CFCs

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

(Circle all that apply)

a) Ozone is an environmental toxin that is hazardous to humans

b) Ozone is an essential component of the upper atmosphere

c) Ozone prevents the effects of harmful radiation (e.g. skin cancer, cataracts, etc.)

d) Ozone may be harmful or beneficial depending on its distribution in the atmosphere

e) Ozone levels vary greatly depending on meteorological (weather) and anthropological (human) variables

. Which of the following is NOT a greenhouse gas?

a) Carbon dioxide

b) CFC

c) Oxygen

d) Methane

e) Nitrous oxide

8. Chlorofluorocarbons (CFC's) are most closely associated with which of the following?

a) Urban smog

b) Ozone hole

c) Greenhouse effect

d) Acid rain

e) None of the above

9. Nitrous oxides (NOx) are most closely associated with which of the following?

a) Urban smog

b) Ozone hole

c) Greenhouse effect

d) Acid rain

e) None of the above

10. In 3 sentences or less, provide your best description of global warming.

_____

_____

_____

_____

Kenneth A. Walz & Sara C. Kerr

Madison Area Technical College UW-Madison

kwalz@matcmadison.edu

Appendix 6: Results of Learners' Pre and Post-Test

Learners' tests responses according to their subject choices

Responses to pre and post-test on climate change

	Pseudo		1	2	3	4	5	6				7		8		9		10 Description of Global warming
1	Km	pre	8	b	c	a	d	a	d	e		d		b	c	B	d	is the overall increase in the earth's atmosphere caused by human activities or natural activities
		post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Tia	pre	8	b	c	a	d	b	c	e		c		a		B		the increase in temperature of the earth's atmosphere that is caused by the increase of particular gases especially carbon dioxide
		post	10	d	c	a	d	a	b	c	e	d		b		C		the increase in temperature of the earth's atmosphere that is caused by the increase of particular gases especially carbon dioxide
3	Neo	pre	10	b	d	b	a	c				d			c	C		The overall increase in the earth's temperature due to the enhanced greenhouse gases caused by human activities.
		post	10	b	d	b	c	b	c	d		d		a		D		Is an overall increase in the earth's temperature caused by enhanced greenhouse effect?
4	Light	pre	10	d	d	a	b	c				b			c		d	The overall increase in earth's temperature. This is caused by burning of fossil fuels. This generates or destroys the ozone layer
																		Which protects us from sun's rays. The temperature increases results in the melting of polar ice resulting in high sea levels
																		And an increase in diseases and damage to infrastructure.
		post	10	d	-	b	d	a	b	c		b			e	c		is the overall increase in the earth's temperature leading to the increase of sea levels
5	Vic	pre	8	d	d	a	d	c				e			c	e		Extreme changes in temperatures. Rising sea level. Increase in uv
		post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Ziti	pre	10	b	c	b	d	a	c			b	d	b		c		an overall increase in the earth's temperature which results in climate change
		post	10	b	c	b	d		c			b		-		-		-
7	Sim	pre	10	b	a	b	d	c				c			c		d	The extreme increase in temperature and as a result of exposure of greenhouse gases and in some cases the burning of fossil fuels.
		post	10	a	c	a	c	a	b	c	d	c		c		c		Is the increase in atmospheric temperature as a result of greenhouse gases? Increase in cancer. Changes in weather patterns.
8	Pie	pre	10	b	d	a	d	c				c		b	c	b	c	The overall increase in the earth's temperature caused by natural and human activities e.g. the burning of fossil fuels.
																		Global warming has a negative impact on the environment and the people
		post	10	be	-	all	all	a	b	c	e	c			c	c	d	An overall increase in the earth's atmosphere caused by humans and natural factors.
9	Pam	pre	10	b	a	a	c			e		b	d	a	c	c		The rise in earth's temperature due to climate change. It is influenced by enhanced greenhouse effect
		post	6	d	a	d	c	b	c	d		c		c		a		is caused by greenhouse gases in the atmosphere such as burning coal, cars burning fuels
10	Bon	pre	10	b	d	b	d	a	d	e		c		a			d	An increase in the temperatures of the earth caused by both natural and human activities leading to the greenhouse effect.
																		This results in the rising of sea levels, extremely high temperatures and loss of good crops and fertile soil.
		post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	Keisha	pre	10	a	d	c	d	d				b		a			d	The overall increase of temperatures. It makes weather changes which disturbs the ecosystem of the world.
		post	6	b	b	b	d	a				c		e		-		an overall increase in temperatures in the environment
12	Buy	pre	10	a	d	d	d	d				e		c		a		The increase in temperature resulting in polar ice caps melting.
		post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	Rita	pre	10	e	c	d	d	a	b	c		b		c	e		d	It is an overall increase in the earth's temperature. It is harmful to humans
		post	10	a	c	b	d	a	b	d		c		e		c		an overall increase in the atmosphere caused by human impact(burning of fuel which affect the atmosphere)
			1	**2**	**3**	**4**	**5**	**6**				**7**		**8**		**9**		**10 Description of Global warming**
14	Kruse	pre	10	b	a	b	d	c	d	e		c		c			d	increased levels of high temperatures to the earth from the sun that is influenced by high levels of carbon dioxide in the atmosphere
		post	10	b	d	c	d	c	d			a		a		c		-
15	Thebe	pre	10	b	d	d	d		b	c		c		e		c		it is an excess amount of greenhouse gases causing high levels of greenhouse effect and causing less ultraviolet rays being reflect
																		off the ozone layer
16		post	10	b	d	d	d	c	d			c		c		d		gases in the atmosphere if in excess will damage ozone causing the rays to enter the earth's surface and increase in temp and global warming
	Kitty	pre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Tabs	pre	6	b	c	b	a	b	c	d		b		b		a		Is the overall heating of the earth that leads to the trapping and reflection of heat rays?
		post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

18	Vijay	pre						c				c		c		b		the increase in concentration of greenhouse gases that will allow more radiation through the atmosphere due to the ozone layer
																		Being damaged and it will in turn increase temperatures and influence climate change causing extreme temperatures.
		post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	Binky	pre	-	-	-	-	-	c				c		c		b		is due to many harmful gases harming the ozone layer which prevents too much of radiation from the sun entering the earth
																		Which results in extreme temperatures and climate changes which in turn causes many diseases and natural disasters.
		post	10	b	d	c	d	a				c		b		b		Is the change in climate due to harmful effects and the overall increase in the earth's temperature?
20	Kay	pre	10	b	d	b	a	b	c	e		c		e			d	Is the warming up of the earth's atmosphere due to greenhouse gases being released in the atmosphere?
		post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	Zakie	pre	10	b	a	a	d		c			c		e			d	Is the extreme increase in the earth's temperature? These extreme temperatures are caused by negative human activities e.g. burning
		post																Of fossil fuel. These human activities can cause holes in the ozone layer and increase the greenhouse gases in the atmosphere.
		post	10	b	a	b	d	a	b	c	d	c		e		c		Is when the ozone is destroyed due to the human activities like factories and burning of fossil fuels? This enhances the greenhouse gases.
22	Busy	pre	10	d	c	b	c		c			c		a			d	Is the increase in global temperatures in the atmosphere causing weather changes/precipitation patterns?
		post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	Shari	pre	10	b	c	c	d	b	c	e		c		a			e	Is the change of weather patterns due to the change of the earth's temperature? Global warming is causing ice to melt and sea levels
																		Rise substantially. It is also causing massive amounts of radiation.
		post	8	b	d	b	d	b	c	d	e	c		a			e	Is the increase in the earth's surface due to the greenhouse effect, which is the burning of fossil fuels which destroys the ozone layer?
24	Tsebo	pre	6	d	d	b	d	b	c			c		b		c		The heating up of the earth's atmosphere due to the increased greenhouse effect.
		post																This is caused by greenhouse gases in the atmosphere such as burning coal or fuels
25	Nel	pre	10	b	c	c	d	b	c	d		c		c		c		Is the overall heating or increase in the temperature of the earth? This is caused by the enhanced greenhouse effect. Global
		post	6	b	c	b	d		c			b		-		-		--
26	Lin	pre	8	b	d	b	d	b	c	d		b		a			d	is the unusual heating up of the environment/atmosphere which leads to massive destruction of both the environment and humans
		post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			1	**2**	**3**	**4**	**5**	**6**				**7**		**8**		**9**		**10 Description of Global warming**
27	Ash	pre	10	e	c	d	d	b	c	d	e	b		c			d	is the increase in the earth's overall temperatures
		post	10	b	d	a,b,d	d	a	b	c	due	c		a			e	Is the increase in the overall Earth's temperatures due to greenhouse effect?
28	Yovi	pre	10	b	c	A	d	b	e	d	e	d		a		c		is the increase of the earth's temperature due to the greenhouse gases that are destroying the ozone, which protects us from
		post	10	b		C	d	b	c	d	e	c		a		-		is the increase in the earth's overall temperatures due to the greenhouse effect-which is the burning of fossil fuels which in turn destroys the
																		Ozone layer. This ozone depletion is the cause of the high temperatures experienced on earth because the barrier which once prevented
																		Harmful UV rays is now doing the opposite.
29	Del	pre	10	b	c	A	c	b	c	e		d		c		c		Is the increase in temperatures and destruction of essential atmospheric layers caused by pollution in the air (or on earth)?
																		It is increased heat in the atmosphere.
		post	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	Hem	pre	10	b	c	C	c	b	c	e		c		a		c		is the overall increase of the Earth's temperature due to human activities
		post	10		c	B	c	a				b		a		c		is the overall increase of Earth's temperatures due to human impact
14	geography	learners		pseudo-pseudonym														

Appendix 7a. My Concept map

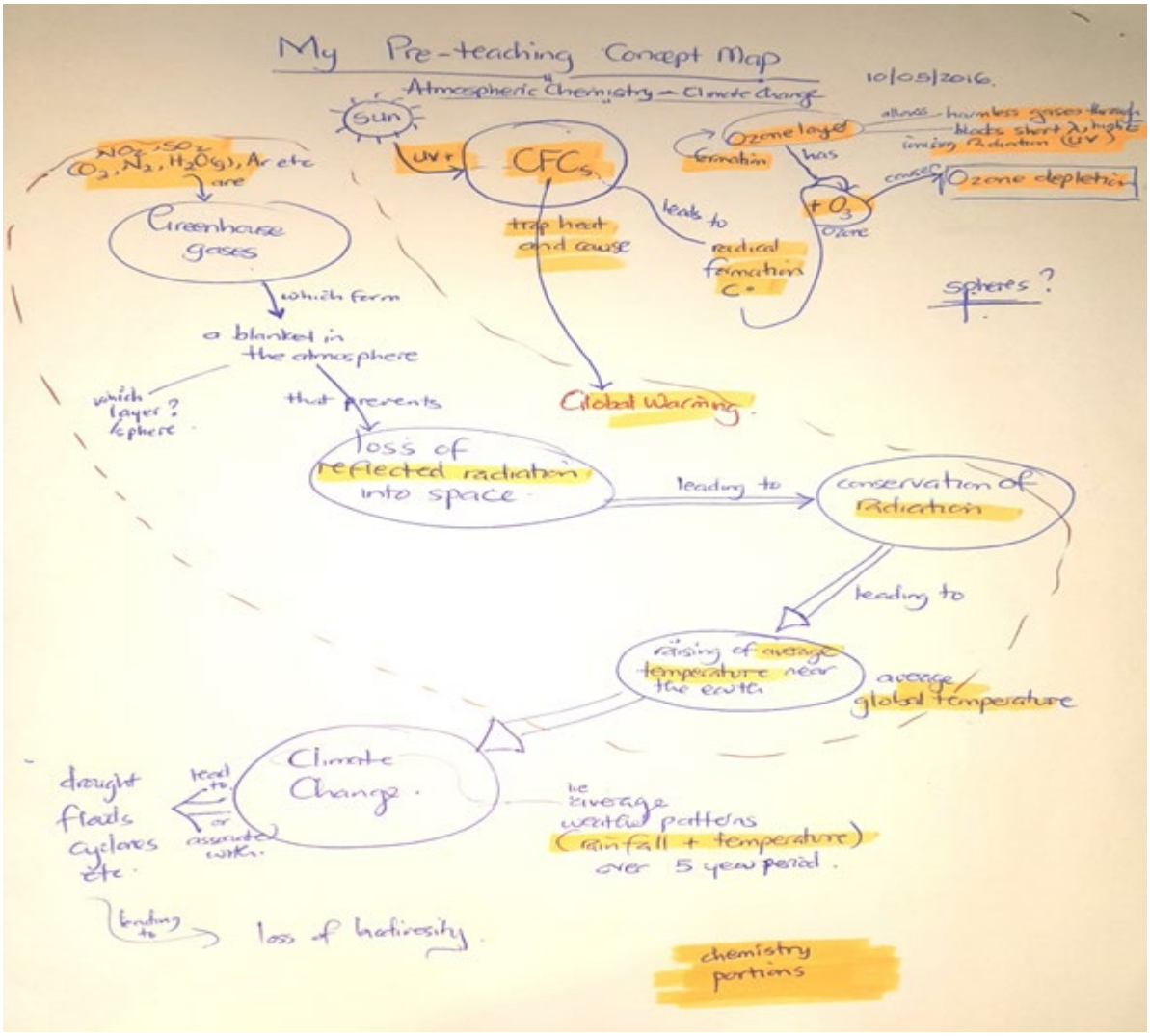


Figure 6: My pre-teaching Concept map

Appendix 7b. Expert Concept map

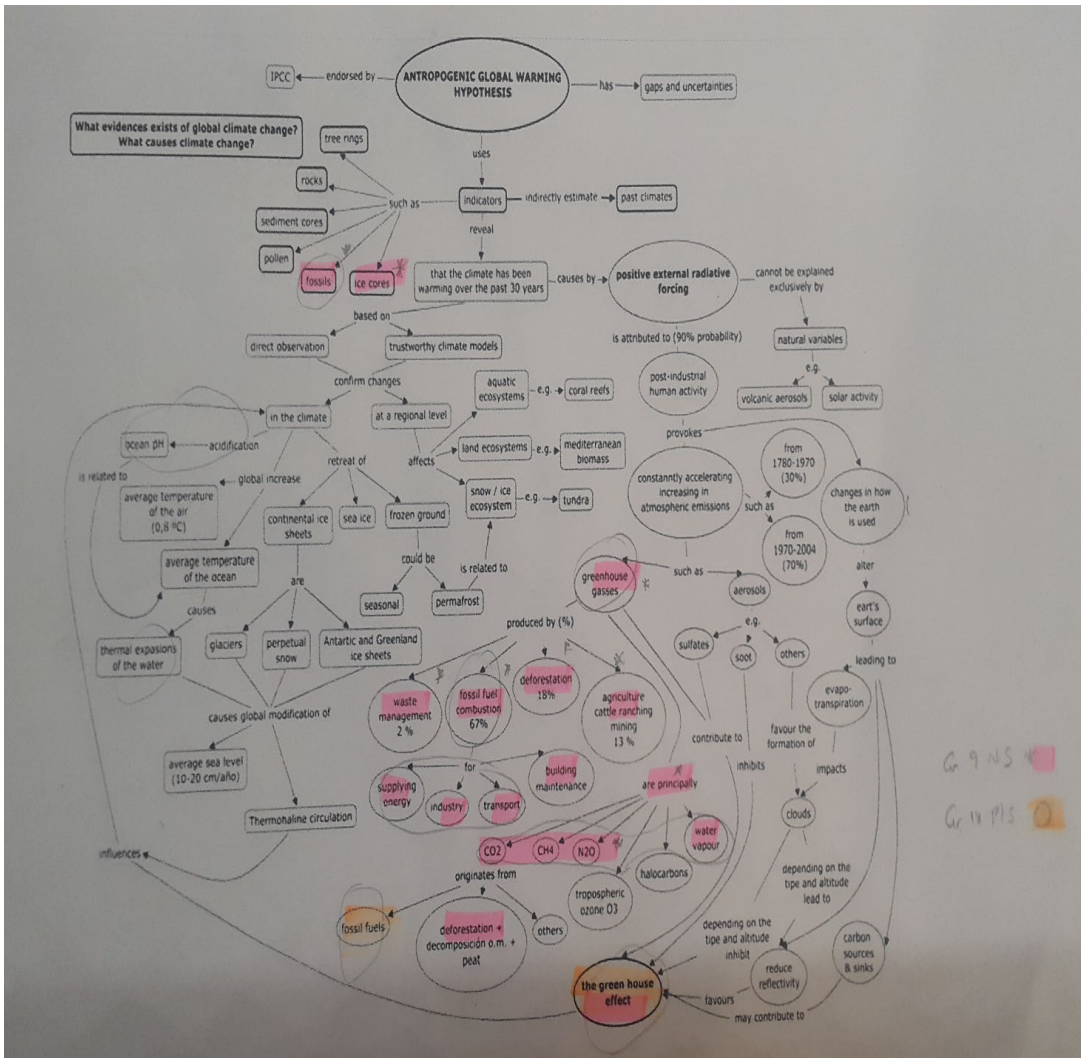


Figure 7: An Expert concept map for teaching climate change

Appendix 8a. Pre-Content Representation (CoRe)

Content Representation- CoRe 27/7 2016

Big idea / **Prompts**	The chemistry of the atmosphere and its role in nature	Human impact of mining activities on the atmosphere
1. What you expect learners to know already about this idea	They appreciate the role played by the atmosphere as a shield from harmful ultraviolet radiation	Human activities have an impact on the environment (including the atmosphere)
2. What you intend students to learn about this idea	Identify the chemical species and role of each species in each layer. The chemical nature of greenhouse gases (ghgs)	Sources and impact of greenhouse gases (ghgs)
3. Why is it important for students to know this?	To realise that ghgs have polar bonds which allow them to absorb infrared radiation.	To link ghgs and global warming To distinguish between ozone depletion and global warming causes (chemical and physical) Help reduce CO_2 emission by Campaigning against sole use of coal-powered plants in energy production.
4. What else do you know about this idea (which you do not intend your learners to know yet)?	Learners already know the layers of the atmosphere (troposphere, mesosphere, stratosphere and thermosphere) Use and harmful impact of CFCs on the stratosphere	
5.Difficulties/limitations connected with teaching this idea	This content is not part of the Physical Sciences syllabus.	The syllabus limits us to the effects of mining only Tiny CO_2 concentrations cause Climate Change.

		Confusion with ozone depletion
6. Knowledge about learners' thinking which influence your teaching of this idea	Any area where there is air around them is space.	Misconceptions pertaining to global warming, greenhouse effect and ozone depletion. • Smoke from cars and factories and cigarettes damages the ozone layer and makes the earth hotter • Ozone hole triggers global warming • Greenhouse effect and ozone hole have the same causes. • Learners interchange the words global warming, climate change and ozone depletion. • Change in weather is Climate Change.
7.Teaching procedures (and particular reasons for using these to engage the idea)	Activity on Atmospheric layers- to test what they know about the atmosphere.	Use of models/ illustrations to represent the greenhouse (it makes learners understand the effect), the greenhouse effect and global warming
8. Specific ways of ascertaining learners' understanding or confusion around the idea	Sketch of the atmosphere layers and space	Probing questions-oral & written. Survey on Climate Change

		Pre-test and post-test of taught aspects.
9. Preferred assessment strategies or tasks to facilitate learning		Pre and post tests Short test on taught aspects Experiment on greenhouse effect

Appendix 8b. Post-Content Representation (CoRe)

Topic: _____ Grade: _____

Big idea / **Prompts**	**Climate is regulated by complex interactions among components of the Earth system (sun, ocean and atmosphere)**	**Energy exists in systems, in various forms and its transformation and conservation occurs in processes that are predictable and measurable**	**Water has unique and special properties that contribute to nature through the water cycle**	**The chemistry of the atmosphere plays a role in nature**	**Human activities (such as mining activities) impact on the atmosphere**
1. What you expect learners to know already about this idea	The sun, water and the atmosphere are interconnected in determining the weather in a particular area.	The Sun is the primary source of Energy for Earth's Climate System. Energy, in changing form, is neither created nor destroyed. Energy is conserved in a closed system, an open system allows for the loss of energy Electromagnetic radiation and its relative strength	The shape of the water molecule The polar nature of water Phase changes of water on Earth The difficulty of separating atoms in a water molecule The Sun providing the energy that drives the water cycle	They appreciate the role played by the atmosphere as a shield from harmful ultraviolet radiation	Human activities have an impact on the environment (including the atmosphere)

2. What you intend students to learn about this idea	The sun is the primary source of energy for Earth's climate system-heat from sunlight can heat the land, ocean and atmosphere. The ocean acts as a reservoir for a good temperature regulator, water. The amount of solar energy absorbed or radiated by the earth is modulated by the atmosphere and depends on the composition of the atmosphere.	Energy exists in various forms- mechanical, chemical, Electrical, radiant, thermal and nuclear. Amount of sunlight received by the Earth is affected by the reflectivity of the surface, the angle of the Sun, the Sun's output and variations in the Earth's orbit around the Sun. Sunlight reaching Earth can heat the land, ocean and atmosphere, some of it is reflected back to space by the surface, clouds or ice, Much of that which reaches the Earth is absorbed and warms the planet The transformation and conservation of energy occurs in processes that are predictable and measurable When the earth emits the same amount of energy as it absorbs, its energy budget is in balance and its average temperature remains stable	To show that macroscopic behaviour can be accounted for by microscopic structure- melting, boiling, solvent, density etc. Link strong hydrogen bonding between water molecules to high specific heat capacity Link melting of ice caps, release of methane to density and structure of solid water (ice)	Identify the chemical species and role of each species in each layer. The chemical nature of greenhouse gases (ghgs) Ghgs in the atmosphere (carbon dioxide, water vapour) affect energy flow in the Earth system, they are transparent to most incoming sunlight but not to IR from the warmed Earth surface.	Sources and impact of greenhouse gases (ghgs) Mining of fossil fuels removes org carbon from underground and releases it into atmosphere as carbon dioxide

3. Why is it important for students to know this?	So that they link climate to land activities and atmospheric activities	Learners must be able to make inferences about the temperature of the earth. They must know that a significant increase or decrease in the Sun's energy output would cause the earth to warm or cool but changes are just to small and earth temperatures fluctuations should then be accounted by some other factor	To understand the recycling of water in the water cycle Linking with other spheres Water co0ntributes to the greenhouse effect	To realise that ghgs have polar bonds which allow them to absorb infrared radiation.	To link ghgs and global warming To distinguish between ozone depletion and global warming causes (chemical and physical) Help reduce CO_2 emission by Campaigning against sole use of coal-powered plants in energy production.
4. What else do you know about this idea (which you do not intend your learners to know yet)?	Other factors that cause climate change The science behind the relationship	A reduction in energy usage helps in greenhouse effect mitigation efforts Temperature changes can be accounted for by Earth's tilt relative to the Sun. Ghgs also determine average global surface temperatures		Learners already know the layers of the atmosphere (troposphere, mesosphere, stratosphere and thermosphere) Use and harmful impact of CFCs on the stratosphere	

5.Difficulties/ limitations connected with teaching this idea	Other factors are discussed in Geography only	Having to simulate natural occurrences in the lab is difficult and not really representative.	The microscopic nature of water is difficult for some learners to comprehend	This content is not part of the Physical Sciences syllabus.	The syllabus limits us to the effects of mining only Tiny CO_2 concentrations cause Climate Change. Confusion with ozone depletion Difficult to comprehend
6. Knowledge about learners' thinking which influence your teaching of this idea	.	Learners think that the earth gets heated by the sun directly (however, the distant sun emits light which objects on earth absorb and reflect, increase the kinetic energy of particles in the object and object gets heated up.) Belief that objects can only either absorb or reflect light but not both. Belief that light can only be reflected from shiny surfaces, Learners may think that the change in the Sun's energy output over time cause global warming.	The water that evaporates is lost to the atmosphere	Any area where there is air around them is space.	Misconceptions pertaining to global warming, greenhouse effect and ozone depletion. -Smoke from cars and factories and cigarettes damages the ozone layer and makes the earth hotter -Ozone hole triggers global warming -Greenhouse effect and ozone hole have the same causes. -Greenhouse effect is bad and will lead to

					eventual death of organisms (however, without the greenhouse effect, the earth would not be warm enough to support earth life) -Learners interchange the words global warming, climate change and ozone depletion. -Change in weather is Climate Change.
7.Teaching procedures (and particular reasons for using these to engage the idea)	Discuss diagram showing interrelationship so that learners contribute to discussion and are able to complete worksheet	Questions based on Diagram showing radiant energy sources and transfer	Analysis of a Diagram of the water cycle	Activity on Atmospheric layers- to test what they know about the atmosphere.	Use of models/ illustrations to represent the greenhouse (it makes learners understand the effect), the greenhouse effect and global warming
8. Specific ways of ascertaining learners' understanding or confusion around the idea	Questions based on Diagram showing interrelationship-worksheet	Questions based on Diagram showing radiant energy sources and transfer	Questions on the structure and properties of water	Use a sketch of the atmosphere layers and space in worksheets	Probing questions-oral & written. Survey on Climate Change

					Pre-test and post-test of taught aspects.
9. Preferred assessment strategies or tasks to facilitate learning	Watching a video of the interrelationship	Use closed systems in experiments	Use of models to explain structure of water	Video of atmosphere layers	Pre and post tests Short test on taught aspects Experiment on greenhouse effect

Prompts found in a CoRe

Included in a CoRe are prompts, questions to be answered for each big idea. The prompt questions are:

Prompt 1: *What do you intend the students to learn about this idea?*

In this prompt I must be clear in saying what learners should be able to learn. This is guided by the departmental policy at hand, in this case, the CAPS document.

Prompt 2: *Why is it important for students to know this?*

It is important to have sound subject matter in order to make a sound decision on what and why to teach. This is done by knowing what is relevant to science content and relevant to everyday lives of learners.

Prompt 3: What *else do you know about this idea (that you don't intend students to know yet)?*

What is brought out here is your broad content knowledge on the topic to be taught.

Prompt 4: *Difficulties/limitations connected with teaching this idea.*

What problems are associated with the topic? How am I limited in delivering an effective lesson? This is resource-related.

Prompt 5: *Knowledge about student thinking that influences your teaching of this idea.*

This prompt is useful when planning for a lesson. It acts as a guide on what learners know and what are the possible misconceptions on this idea. Teachers draw on their knowledge about alternative conceptions that are held by learners about the topic when planning their lessons

Prompt 6: *Other factors that influence your teaching of this idea.*

I will be indicating the general pedagogic knowledge in this prompt.

Prompt 7: *Teaching procedures.*

The purpose of teaching procedures is to influence learners' thinking in ways that promote a better understanding of science ideas.

Prompt 8: *Ways of ascertaining students' understanding/ assessment*

What strategies did I take to check if they were comprehending anything in the lesson?

APPENDIX 9- WORKSHEET SAMPLES

WORKSHEET 1a

Name:_____ Grade:_____

Physical Sciences Marks:

Topic: Mineral Resources in South Africa

Read the passage below and answer the questions that follow

South Africa is rich in coal reserves so it is relatively cheap to mine and burn large amounts of coal at power plants. However, the pollutants produced have a major negative impact on the life of humans and other living organisms.

Question One

1.1 Describe how the burning of fossil fuels may lead to climate change
_____
_____
_____
_____
_____
_____
_____
_____(4)

1.2 Carbon dioxide is one major gas released into the atmosphere

1.2.1 Write down a chemical equation to show the formation of carbon dioxide from burning fossil fuels.

_____ (3)

1.2.2 Coal also contains sulphur, nitrogen compounds, heavy metals and radioactive elements

Oxides of sulphur and nitrogen, soot fumes and a poisonous gas form when coal is burned. The oxides of sulphur, nitrogen and carbon react in rain water to give acids collectively called acid rain.

1.2.2.1 Give the NAME and FORMULA of the poisonous gas formed.
_____

_____ (2)

1.2.2.2 Write down one of the possible reaction equation to show formation of acid rain. _____ _____(3)

Notes:

Large-scale combustion of fuels increase the amount of carbon dioxide in the atmosphere, in addition to that released during respiration. Combustion is our principal energy source.

Combustion of fossil fuels also other gaseous pollutants (Sulphur dioxide and nitrogen oxides). Both molecules are polar (and reactive) and can absorb extra- terrestrial IR radiation, thus adding to the greenhouse effect.

Objectives

- Energy as a cross-cutting theme in the sections
- It is the main cause of Climate and Climate Change (Heating of the Atmosphere and The Earth's energy balance)
- The role of water (water vapour) in the energy balance in the atmosphere

    a. The vertical transfer of energy by evaporation, condensation and cloud development and latent heat transfer

    b. The horizontal transfer of energy through large ocean bodies by warm and cold currents and how they influence Climate (e.g. El Nino)

The drivers of the Climate System.

-Greenhouse effect-a result of fossil fuel burning

-a combination of natural forces (egg solar radiation, volcanic eruptions)

WORKSHEET 1b

Interaction of the hydrosphere with other global systems

1.1 Name the four global systems that the earth is composed of

_____

_____

_____

_____

1.2 One global system regulates the climate and contributes to earth's moderate climate, protecting living organisms in the biosphere against extreme fluctuations in the temperature.

1.2.1 Identify that global system_____ (1)

1.2.2 State the property that makes water contribute significantly to the moderate climate on earth (temperature moderation).

_____ (2)

1.2.3 Account and explain for the property stated in Q1.2.2 above.

Note:

Weather changes are noted through changes in the air's temperature, air pressure, the formation of clouds, humidity, winds and precipitation (rain, snow and hail)

ACTIVITY: To transfer core knowledge and information about energy transfer to learners.

PURPOSE: To provide leaners with pieces of core knowledge directly. Basically a pre-determined block of knowledge is transferred to the learners.

Link with CAPS:

This activity helps to develop the following knowledge and skills as described in CAPS

- Collecting and structuring information
- Processing, interpreting and evaluating data
- Using verbal, quantitative and symbolic data forms such as text, pictures, graphs, tables, diagrams and maps.

Core Knowledge: see CoRe attached

- Main idea- energy enters and is transferred through the atmosphere in specific ways.

WORKSHEET 2

Name:_____ Grade:_____

Physical Sciences

Classwork Marks:

Greenhouse effect, enhanced greenhouse effect and global warming

1.1 What is the greenhouse effect?

_____

_____

_____(2)

1.2 Name three gases, besides water vapour, that are responsible for the greenhouse effect

_____ (3)

1.3 For each of the gas named above, list the main sources

_____

_____ (3)

1.4 What changes to the climate does global warming cause?

_____

_____

_____

_____(5)

1.5 What can you and I do to reduce the emission of greenhouse gasses?

_____

_____

_____(3)

WORKSHEET 3

Name: _____ Grade: _____

Physical Sciences Marks:

The Greenhouse effect

What happens to the radiation of the sun that reaches the ground?

_____
_____
_____
_____

What type of radiation does the ground emit? What happens to the emitted radiation?

_____
_____
_____

Use the information in the diagram to explain what the greenhouse effect is?

_____
_____
_____

Why is the greenhouse effect a cause for concern in our times?

_____
_____
_____

WORKSHEET 4b- **Melting of ice to water**

1.1 Draw the structure of a water molecule (3)

1.3 In the boxes below, show the microscopic representation of water in its different states

_____

_____

_____

1.4 State what happens to the density of

1.4.1 Water as it freezes

_____
_____

1.4.2. Ice as it melts

_____
_____

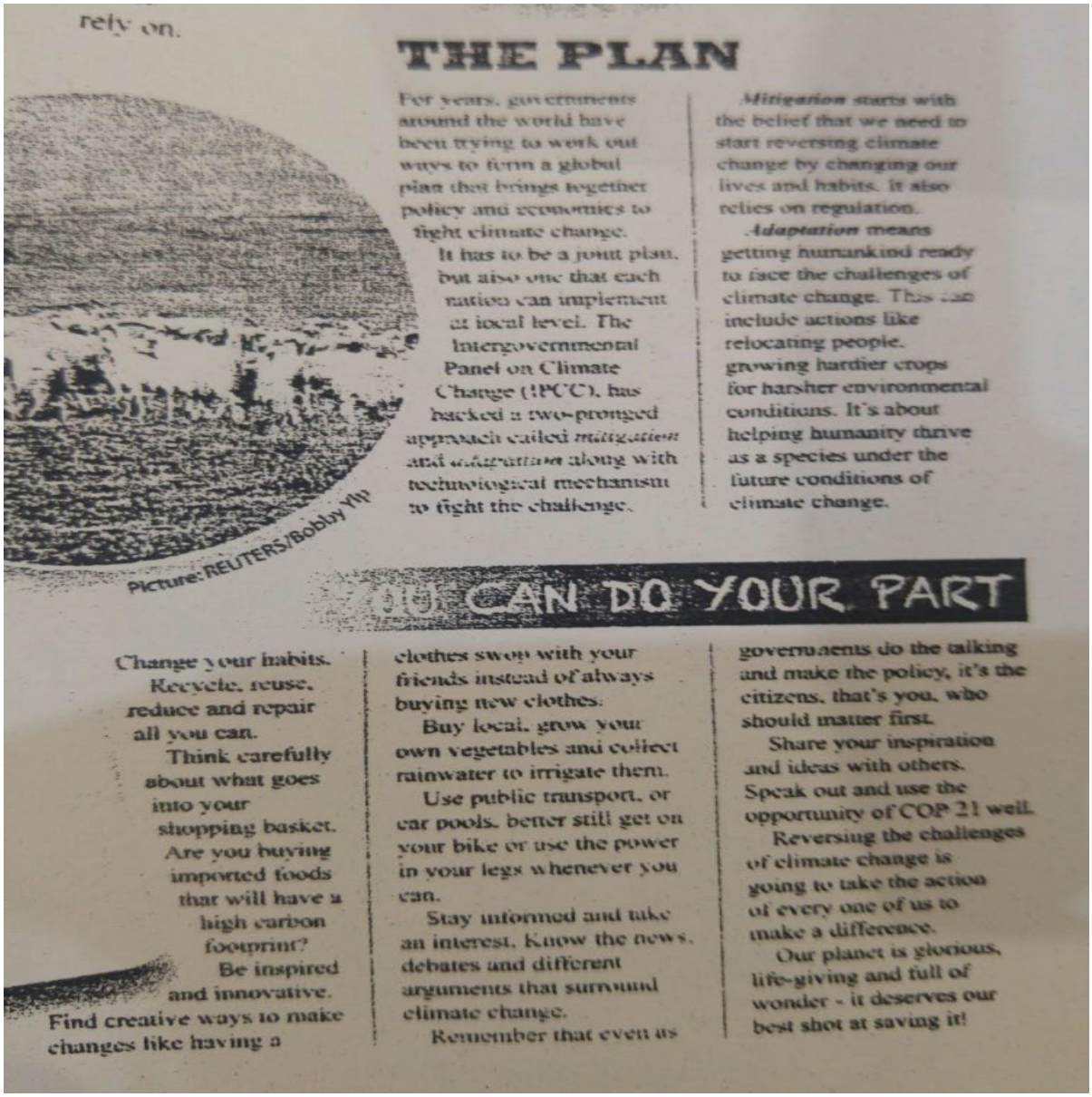
1.3 Why is the melting of ice considered to cause further global warming?

_____
_____
_____

WORKSHEET 6

Read your given article first then answer the question in the Worksheet

Sample of Articles used in the Group session /Deliberative lesson-advert feature



rely on.

THE PLAN

For years, governments around the world have been trying to work out ways to form a global plan that brings together policy and economics to fight climate change.

It has to be a joint plan, but also one that each nation can implement at local level. The Intergovernmental Panel on Climate Change (IPCC), has backed a two-pronged approach called *mitigation* and *adaptation* along with technological mechanism to fight the challenge.

Mitigation starts with the belief that we need to start reversing climate change by changing our lives and habits. It also relies on regulation.

Adaptation means getting humankind ready to face the challenges of climate change. This can include actions like relocating people, growing hardier crops for harsher environmental conditions. It's about helping humanity thrive as a species under the future conditions of climate change.

Picture: REUTERS/Bobby Yip

YOU CAN DO YOUR PART

Change your habits. Recycle, reuse, reduce and repair all you can.

Think carefully about what goes into your shopping basket. Are you buying imported foods that will have a high carbon footprint?

Be inspired and innovative. Find creative ways to make changes like having a clothes swop with your friends instead of always buying new clothes.

Buy local, grow your own vegetables and collect rainwater to irrigate them.

Use public transport, or car pools, better still get on your bike or use the power in your legs whenever you can.

Stay informed and take an interest. Know the news, debates and different arguments that surround climate change.

Remember that even as governments do the talking and make the policy, it's the citizens, that's you, who should matter first.

Share your inspiration and ideas with others. Speak out and use the opportunity of COP 21 well.

Reversing the challenges of climate change is going to take the action of every one of us to make a difference.

Our planet is glorious, life-giving and full of wonder - it deserves our best shot at saving it!

Article 3: Mitigation Plan-You can do your Part (www.environment.gov.za), accessed 12/2015.

Name: _____ Grade: _____

South Africa's response towards controlling climate change

South Africa has accepted the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. Accepting the urgency in dealing with the issue, the government now holds a vision to make a contribution towards controlling climate change. Choose ONE department/parastatal/area where you will work towards meeting the government's vision.

In your response, think about the following:

How will you help in **managing and adapting to Climate Change**? What are your **mitigation** plans in that role?

1-Tax department

_____
_____
_____**2.-Eskom**

_____
_____
_____

3-Environmental Affairs ministry

_____
_____
_____

4Homeowner_____
_____
_____

5.Any.other.role_____
_____
_____

Appendix 10:

a. Some of the learners' concept maps

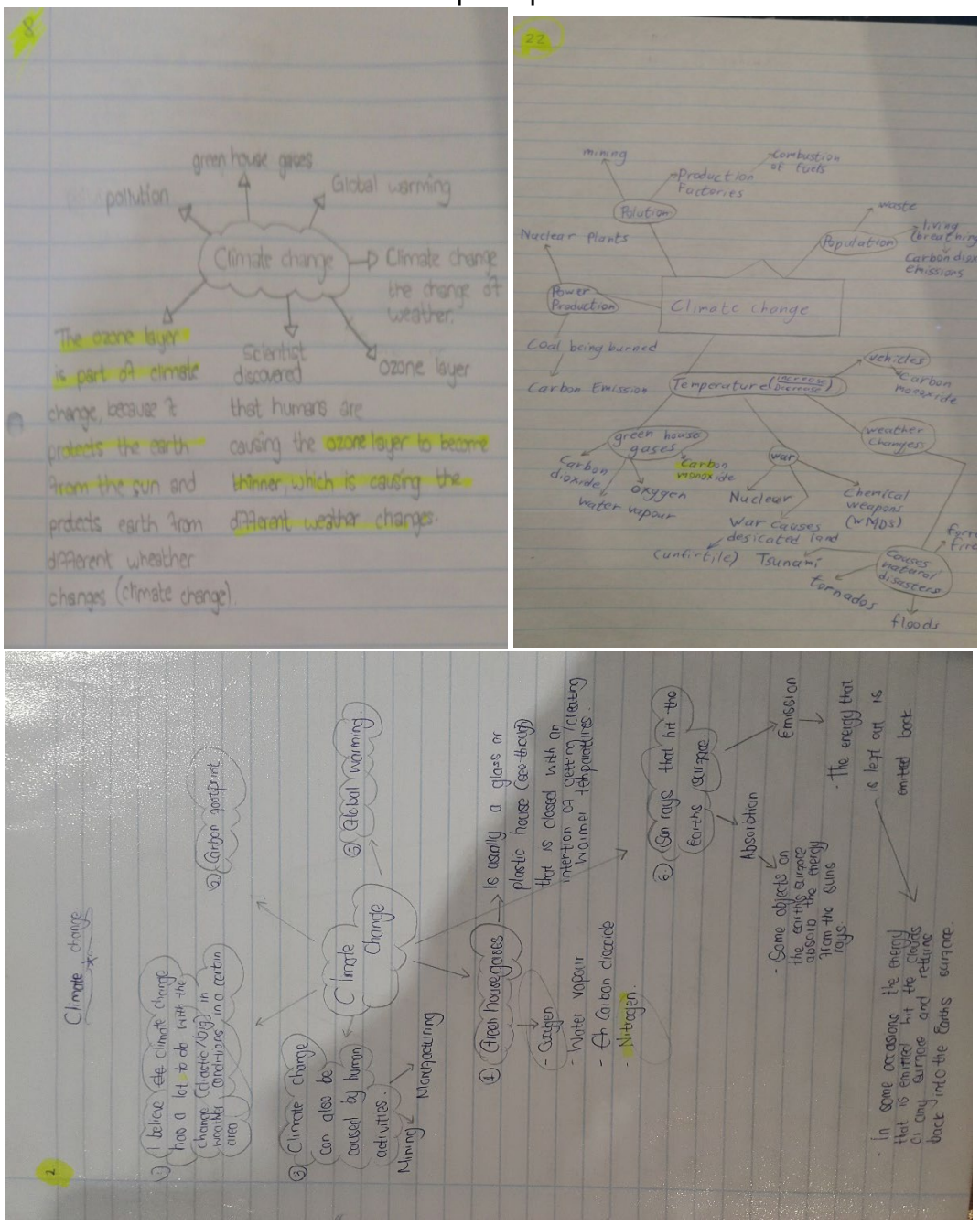
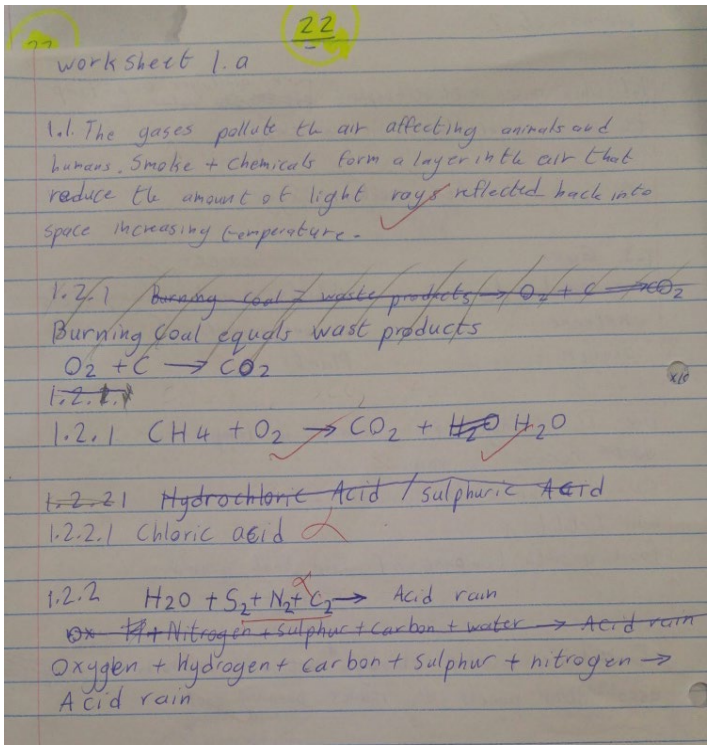


Figure 2: Samples of Concept maps by some learners

10b: Samples of learners' completed worksheets



worksheet 1.a

22

1.1. The gases pollute the air affecting animals and humans. Smoke + chemicals form a layer in the air that reduce the amount of light rays reflected back into space increasing temperature.

1.2.1 ~~Burning coal + waste products → $O_2 + C \rightarrow CO_2$~~

Burning coal equals wast products

$O_2 + C \rightarrow CO_2$

1.2.1 $CH_4 + O_2 \rightarrow CO_2 + H_2O$

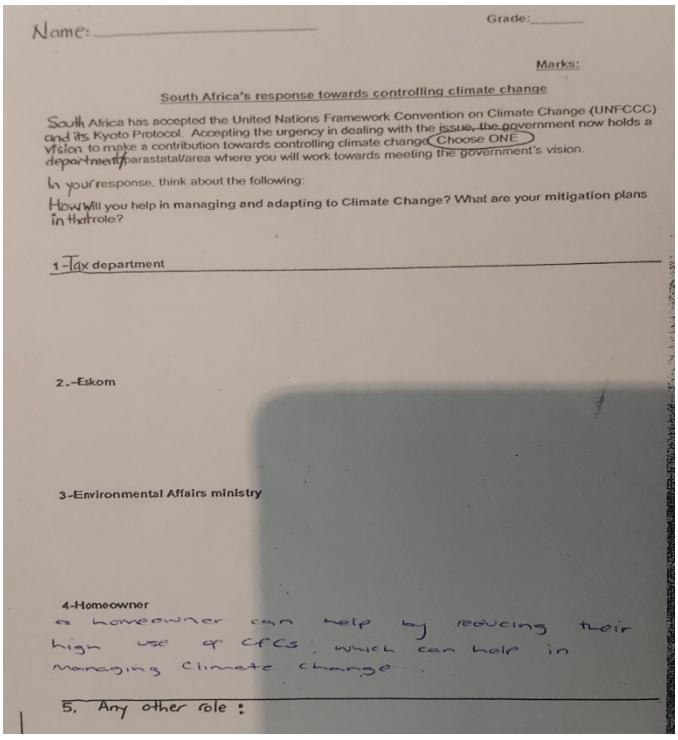
~~1.2.2.1 Hydrochloric Acid / Sulphuric Acid~~

1.2.2.1 Chloric acid

1.2.2 $H_2O + S_2 + N_2 + C_2 \rightarrow$ Acid rain

~~$O_2 + H_2$ + Nitrogen + Sulphur + Carbon + water → Acid rain~~

Oxygen + hydrogen + carbon + Sulphur + nitrogen → Acid rain



Name: _____ Grade: _____

Marks:

South Africa's response towards controlling climate change

South Africa has accepted the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. Accepting the urgency in dealing with the issue, the government now holds a vision to make a contribution towards controlling climate change. Choose ONE department/parastatal/area where you will work towards meeting the government's vision.

In your response, think about the following:

How will you help in managing and adapting to Climate Change? What are your mitigation plans in that role?

1-Tax department

2.-Eskom

3-Environmental Affairs ministry

4-Homeowner

a homeowner can help by reducing their high use of CFCs, which can help in managing climate change.

5. Any other role :

Figure 3: Samples of learners' worksheets

WORKSHEET 3

Name: _____ Grade: _____

The Greenhouse effect

What happens to the radiation of the sun that reaches the ground?

Once the suns energy reaches the ground, it is intercepted by the Atmosphere. Suns energy is absorbed

What type of radiation does the ground emit? What happens to the emitted radiation?

Infrared Rays. The sun emits the radiation because it is extremely hot and gives of a lot of energy.

Use the information in the diagram to explain what the greenhouse effect is?

Why is the greenhouse effect a cause for concern in our times?

It affects global warming, causing heavy rainfall or draught in some areas.

If the average temperature of our planet is said to rise by 2ºC. Some might argue that this is a small rise and so, there is no reason to 'panic' and make a big deal of it! Do you agree? Discuss it in your groups.

Discuss the difference between global warming and ozone depletion.

Is the phenomenon wherein heat is trapped within the earths Atmosphere due to greenhouse gases whereas ozone depletion is the thinning of the Earths Ozone.

WORKSHEET 1a

Name: _____ Grade: _____

Physical Sciences

Marks:

Mineral Resources in South Africa

Read the passage below and answer the questions that follow

> South Africa is rich in coal reserves so it is relatively cheap to mine and burn large amounts of coal at power plants. However, the pollutants produced have a major negative impact on the life of humans and other living organisms.

Question One

1.1 Describe how the burning of fossil fuels may lead to climate change

It decreases the temperature which would result in negative impacts to life on Earth. They trap more of the sun's radiant energy in the Earths Atmosphere, increasing Carbon Dioxide to the air. Which results in an increase in the Earths temperature. (4)

1.2 Carbon dioxide is one major gas released into the atmosphere

1.2.1 Write down a chemical equation to show the formation of carbon dioxide from burning fossil fuels.

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) + energy$ (3)

1.2.2 Coal also contains sulphur, nitrogen compounds, heavy metals and radioactive elements Oxides of sulphur and nitrogen , soot fumes and a poisonous gas form when coal is burned. The oxides of sulphur, nitrogen and carbon react in rain water to give acids collectively called acid rain.

1.2.2.1 Give the NAME and FORMULA of the poisonous gas formed.

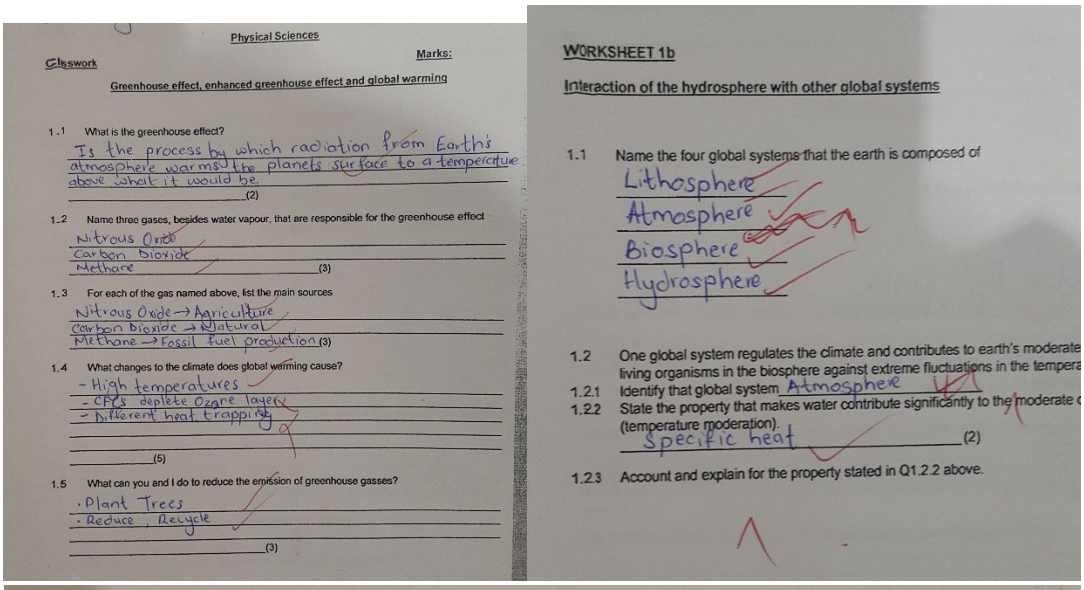
CO

Carbon Monoxide (2)

1.2.2.2 Write down one of the possible reaction equation to show formation of acid rain.

$CaCO_3(s) + H_2SO_4(g) \rightarrow CO_2(g) + H_2O(l) + Ca(NO)_3(aq)$

Marble and Limestone (3)



Physical Sciences

Classwork

Marks:

Greenhouse effect, enhanced greenhouse effect and global warming

1.1 What is the greenhouse effect?

Is the process by which radiation from Earth's atmosphere warms the planets surface to a temperature above what it would be. (2)

1.2 Name three gases, besides water vapour, that are responsible for the greenhouse effect

Nitrous Oxide
Carbon Dioxide
Methane (3)

1.3 For each of the gas named above, list the main sources

Nitrous Oxide → Agriculture
Carbon Dioxide → Natural
Methane → Fossil fuel production (3)

1.4 What changes to the climate does global warming cause?

- High temperatures
- CFCs deplete Ozone layer
- Different heat trapping

(5)

1.5 What can you and I do to reduce the emission of greenhouse gasses?

- Plant Trees
- Reduce, Recycle

(3)

WORKSHEET 1b

Interaction of the hydrosphere with other global systems

1.1 Name the four global systems that the earth is composed of

Lithosphere
Atmosphere
Biosphere
Hydrosphere

1.2 One global system regulates the climate and contributes to earth's moderate
living organisms in the biosphere against extreme fluctuations in the tempera

1.2.1 Identify that global system Atmosphere

1.2.2 State the property that makes water contribute significantly to the moderate
(temperature moderation).
Specific heat (2)

1.2.3 Account and explain for the property stated in Q1.2.2 above.

What happens to the radiation of the sun that reaches the ground?

The ground absorbs short wave radiation and sends it back as long wave radiation. reflect

What type of radiation does the ground emit? What happens to the emitted radiation?

Short wave radiation. Some waves get sent back as long wave radiation and some gets reflect back to the atmosphere

Use the information in the diagram to explain what the greenhouse effect is?

Gases such as H_2O, CH_4 and CO_2 absorb the infrared energy radiated by the earth. This heats up the atmosphere and keeps the earth warm enough to support life

Why is the greenhouse effect a cause for concern in our times?

Because ear the temperature is increasing due to greenhouse effect and this may lead to enhanced greenhouse effect

If the average temperature of our planet is said to rise by 2°C. Some might argue that this is a small rise and so, there is no reason to 'panic' and make a big deal of it! Do you agree? Discuss it in your groups.

With the rate of more CO_2, the to 2°C may starting rising fast and it may increase so We disagree

Discuss the difference between global warming and ozone depletion.

global warming is the effect or earth temperature and ozone diplefion is the feeding of ozone layer which may leael to Infrared radiation entering the earth.

10c: Pictorial evidence

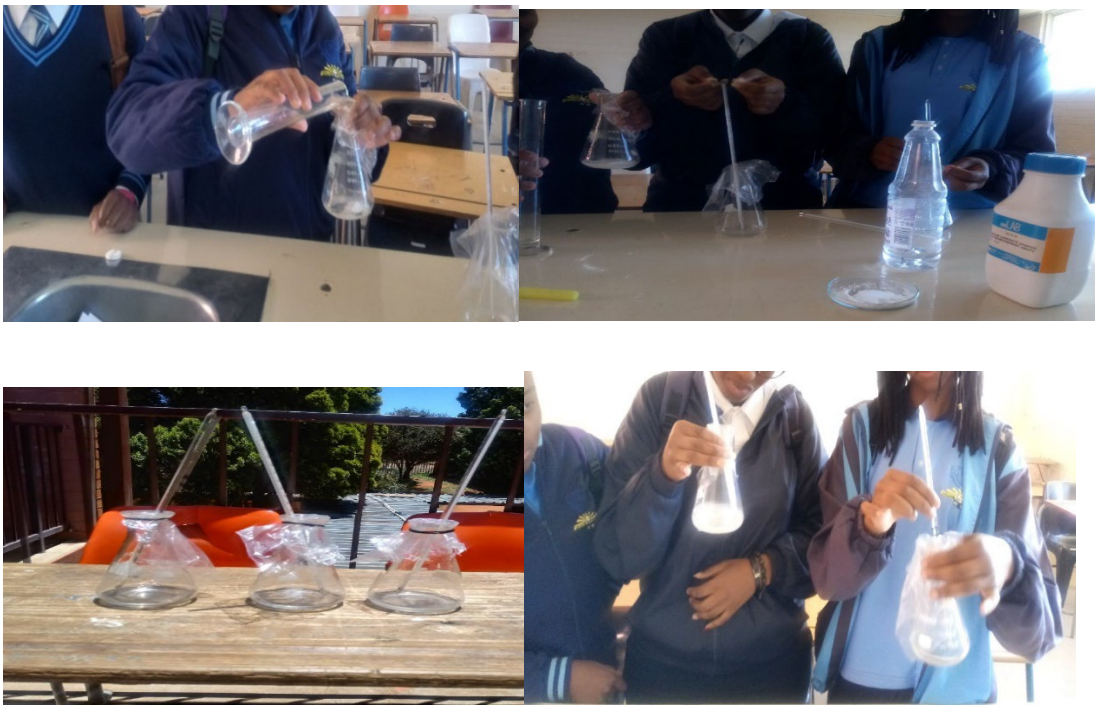


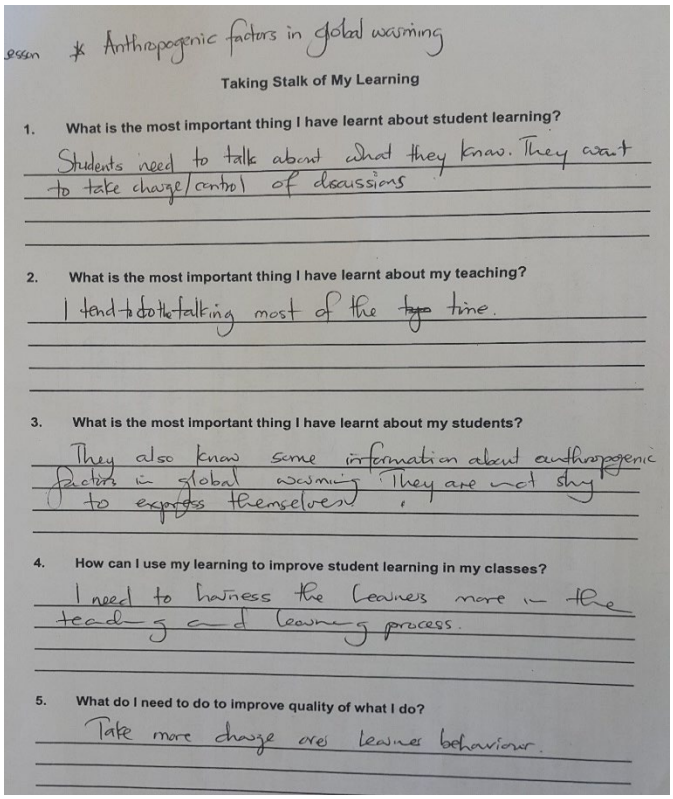
Figure 4: Learners trying to simulate greenhouse effect.

Appendix 11: Samples of my teaching & learning reflective journals

11a) **A Reflective Journal Template (pre- lesson)**

Reflective Journal Entry Form			
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?**
Term 2 May-June 2017 I constructed my pre-teaching concept map. I used the knowledge I had form my previous experience with the topic. I managed to find some Chemistry aspects and I highlighted them. This is my focus for now.	The topic looks broad! (I had forgotten and am wondering how I am going to go about it and whether I will look at all these aspects) It is however exciting that there is some Chemistry in there and I still remember quite a bunch of it. (there is still room for my research)	This was a task that needed me to think deeply about what I was doing. In all the planning to teach, that we do, we are guided by certain set standards which we are required to stick to.	I could embark on a topic that is not so broad. There is need to set my limits before I even start.
June 2017 holiday. I had no rest because of compulsory extra classes at school. Nevertheless, I managed to do some more research on the	I must plan around my hectic timetable. My workload is just burdening.	When planning for any project, I must always leave room for uncertainties.	I must make sure that I satisfy my work and school demands equally. Improve on time management no

topic. I read some texts on the topic. The Education department has granted me permission to do research, provided that I do not step outside the allocated times. I managed to tweak my research proposal. The most difficult thing is realizing that I must now use the syllabus as a guide, when I do my planning. It seems to limit me to look at the effects of mining. July My lesson planning is coinciding with the lesson preps at school since both are needed at the same time. I shift my focus to 'pollution as caused by mining activities'. This is also part of burning of fossil fuels.	Quite frustrating but I respect their territory and protocol pertaining to research. I feel overwhelmed but I am managing. I hope my planning is satisfactory. I feel that what I have down is too little. The syllabus limits me here. It is exciting that I can focus on a smaller section. (But will it make this study worthwhile?)	The focus of the study is not broad, after all!	matter the circumstances.



esson * Anthropogenic factors in global warming

Taking Stalk of My Learning

1. **What is the most important thing I have learnt about student learning?**

Students need to talk about what they know. They want to take charge/control of discussions

2. **What is the most important thing I have learnt about my teaching?**

I tend to do the talking most of the ~~typo~~ time.

3. **What is the most important thing I have learnt about my students?**

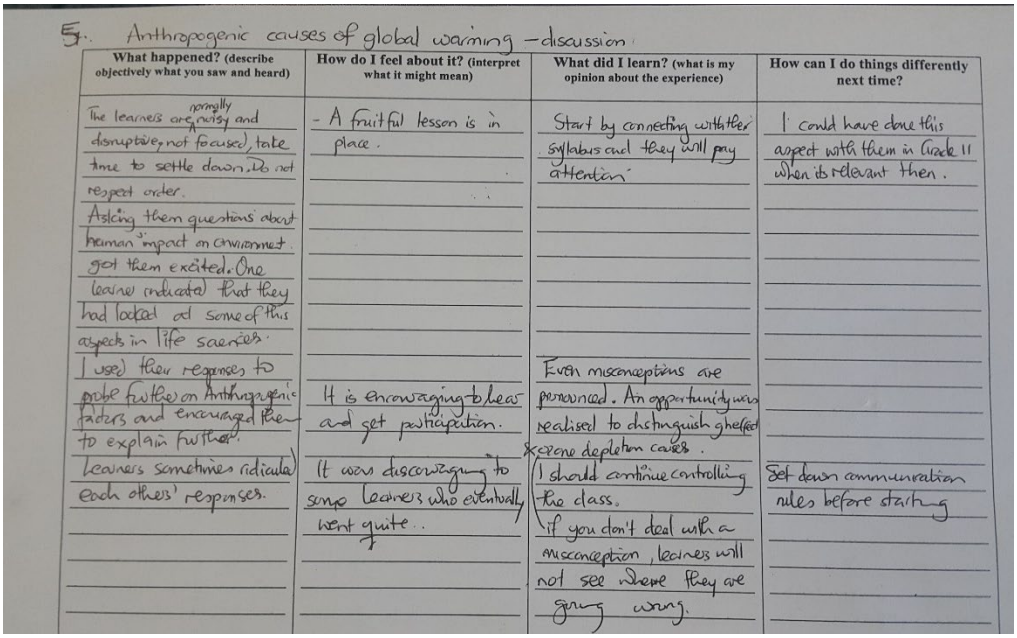
They also know some information about anthropogenic factors in global warming. They are not shy to express themselves.

4. **How can I use my learning to improve student learning in my classes?**

I need to harness the learners more in the teaching and learning process.

5. **What do I need to do to improve quality of what I do?**

Take more charge over learner behaviour.



5. Anthropogenic causes of global warming – discussion

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 learners are normally noisy and disruptive, not focused, take time to settle down. Do not respect order. Asking them questions about human impact on environment got them excited. One learner indicated that they had looked at some of this aspects in life sciences. I used their responses to probe further on Anthropogenic factors and encouraged them to explain further. Learners sometimes ridicule each others' responses.	- A fruitful lesson is in place.	Start by connecting with the syllabus and they will pay attention.	I could have done this aspect with them in Grade 11 when its relevant then.
	It is encouraging to hear and get participation.	Even misconceptions are pronounced. An opportunity was realised to distinguish the effect of ozone depletion cases.	
	It was discouraging to some learners who eventually went quite.	I should continue controlling the class. If you don't deal with a misconception, learners will not see where they are going wrong.	Set down communication rules before starting

11b) Sample of a Reflective Journal Template (post- lesson)

Appendix 12: Transcripts

Transcript for Anthropogenic causes of Climate Change

Voice_004 Anthropogenic cause of global warming

T: This part is very important to us coz we are required in our syllabus to connect the occurrences that are causing climate change to what we learn in class. Ok. Alright. You are going to look at mining in Grade 11 and under mining you study coal mining and gold mining.

Coal mining is one of the industrial activities that causes huge amounts of Carbon in the form of carbon dioxide to be released into the atmosphere. And also carbon is released (out).

Another example which we can look at and which we will be talking about is the anthropogenic activities. Anthropogenic, remember, I said these are activities in which humans take part and causes changes in the climate.

Think about the growing number of cars we have on the road….planes in our skies in our skies. Generate electricity. They release emissions which we are greenhouse gases. Think about others. What other activities are also anthropogenic? Besides the ones that I just gave to you.

L: Perfumes

Hold it there

Transportation (teacher writes them down), number of vehicles we have on our roads.

Burning of fuels

Burning of fossil fuels

Deforestation...

When I look at deforestation, how do you think ….it causes an increase in carbon dioxide?

Ma'am can I answer that.

ILife Sciences?

Yes, my girl.

When we cut down the trees, the carbon dioxide that the trees contain will be released…….

Nooo. (Noise)

One person please

Isn't it we give out carbon dioxide? Trees absorb carbon dioxide, so if more trees are cut, then humans breathe out carbon dioxide and it will go up.

Let's put people here (drawing illustration on the board). People here, what do they give out?

Carbon dioxide

The trees uptake the carbon dioxide. If we cut these trees here? What will happen now?

We have a carbon dioxide increase (shouting)

Burning of fossil fuels, we mentioned it already, anything else. Let's go back to Nelushi's point.

Nelushi, can you repeat it.

Perfumes and other aerosols….

Ok. So you think they increase in the amount of carbon dioxide.

(Laughter)

Ma'am, in class u told us that when we spray perfumes and stuff, we are damaging the ozone layer. You are damaging the ozone layer.

Ok. Damaging the ozone layer. It's very important that you separate the greenhouse effect and the ozone depletion. Why I put your point on the side. Does it cause an increase in carbon dioxide? No.

In aerosols, perfumes and other stuff, we've got what we call CFCs, chlorofluorocarbons (some learners finish off and laugh). Those are the ones that lead to the damage or the depletion of the ozone layer. In large amounts not just a few of them. You with your one perfume. It's not much to say. Much of it and the other aerosols from other sources can cause ozone depletion. Ozone depletion and other anthropogenic activities that release carbon dioxide into the atmosphere, just separate it a bit.

The only thing that is not listed here is deforestation.

Burning of fuels, fossil fuel.

Transportation and we can talk about deforestation

And methane, Madam.

And factories

What do they emit?

Carbon, carbon monoxide, dioxide.

Let's get back to you. You were talking of methane. CH4. You said you saw it in a book. What was it talking about? Ahh, Mama I don't know. In the book I was looking at, Methane was there and I don't know where it was coming from.

Yes

Do you know organic manure?

From cow dung

Yeah, we know.

Organic compounds, because they are found in organisms, living or dead, release some methane when they decay. …..Production of methane. Ice in the Polar Regions will have methane. Because of organisms there…That ice will have methane. Methane is CH4. Different from Carbon dioxide CO2.

Can we move on to other greenhouse gases, but can include others also. Carbon dioxide, (writing), methane, nitrous oxides, sulphur hexafluoride (writes it down), hexa is six. Perfluorocarbons, HFCs. When these greenhouse gases get trapped, what happens? Global warming.

Now, focus on the picture that I gave you there, take a look at it. How global warming happens.

Study it carefully, I'm gonna come back to you.

(Gives activity out…..)

Transcript 2 for Anthropogenic causes of Climate Change

T: The lesson for today I want us to look at how human activities affect climate change or contribute to climate change

We might have mentioned some of the activities before and remember the activity that I gave you and you were writing about sources of greenhouse gases

Where we get them mainly

When we talk of greenhouse gases we are talking mainly of carbon dioxide, methane and water vapour

The first human activity that we can talk about is one that contributes to the increase of carbon dioxide in the atmosphere, ok.

You are well aware of the burning of fossil fuels. When we burn fossil fuels for purposes of generation of electricity, powering of vehicles and in industrial processes, what happens is that carbon-rich fuels such as coal or even plants that are rich in carbon, for example wood that we collect from trees, they release carbon that is stored in them as carbon dioxide.

I was looking at one particular equation that we gave you in the last lesson of CH_4 plus O_2 to give you carbon dioxide and water…

L: yes

T: when we look at that now, we are saying, if coal and wood contain carbon. It's not just carbon like that. Its carbon as hydrocarbon. I can give an example of CH_4 plus oxygen will cause the release of carbon dioxide and water vapour. And these two being greenhouse gases, you find that they contribute to the enhanced greenhouse effect because we now have more of them from the burning of fossil fuels.

We have another activity besides the burning of fossil fuels, deforestation not deforestation

Deforestation, we are saying, people are going out, and companies are going out and cutting down trees

What is the important role of trees out there or plants in general, in forests? They act by….

L: giving us oxygen….

L: they also take carbon dioxide

T: we respire out carbon dioxide, they take it in, it's like they breathe in and use it for some cycle in their processes, for the manufacture of fruits, leaves and everything else concerning trees and they in turn give out oxygen

We depend on trees, we depend on plants for our oxygen and they in turn depend on us for carbon dioxide. But if we reduce the number of trees the number of plants that take in the carbon dioxide, what we are doing now, we are contributing to an increased level of carbon dioxide in the atmosphere. That's why we advocate for people to… when they deforestate they must plant again new trees maybe in another area and come back to this area once they have finished with that area….

Deforestation must be followed by afforestation. You learnt that in life Science whenever you cut down trees that are mature enough to provide us with wood you also need to grow more trees

For every tree that you cut, you must plant more. More than one. Remember they take years to mature

So, these two contribute to an increased amount of carbon dioxide in the atmosphere. Which two am I talking about, the process of burning fossil fuels and the process of deforestation?

Another greenhouse gas that I talked about besides carbon dioxide is methane CH4. It's a greenhouse gas but where does it come from?

Number 1 we have got livestock

You have heard about cows having a setup of its stomach which allows it to produce methane when it dies, you might have seen adverts or cartoons or some readings in your books and your teachers might have talked about that in Natural Sciences. They are talking about cows being ruminants. You remember that?

L: Yes…

T: you do!

L: Yes…

L

L: No…

T: Their stomach set-up allows for them to burp up or release methane in small amounts

That's one source of methane though as small it maybe but if we have a large number of livestock like that then the production can also be significant.

And then we have the mining of coal. Coal in the last contextual questions that I gave you I told you the components of coal .We can find sulfur and also methane there and when we burn coal we have the release of oxides of sulfur ,nitrogen carbon dioxide and water vapour being produced .We also have methane being stored up in coal itself as a hydrocarbon. Ok?

And then we have the increased number of landfills .We have one landfill on our way to Lenz onto your left just after…..

L: Lenmed. Daxina

T: Daxina. You see them pilling up rubbish, soil and coming up with some kid of landforms, like small hills and then they cover it up.

L: yes

T: you see that other part where they are growing vegetables there. That is an example of a landfill where they put in rubbish and cover it up and then in the long run we have the decomposition of that rubbish.

As long as we have biodegradable material there, you will find out that it will come up to be a landform eventually. When you have organic matter and biodegradable rubbish decaying, there is release of methane….

Methane can be found in the in the landfills, the livestock and coal also.

Most of them are not natural, there is a human hand in these activities. So we can say that Human activities contribute to climate change. By mistake or virtue of trying to get some money out of it. They ensure that there is a high level of methane, water vapour, mostly carbon dioxide in the atmosphere, mostly carbon dioxide and methane. Then the solution on climate change. We know how to solve such problems. We are part of it.

Such as burning of fossil fuels. When we discuss such activities, we call them anthropogenic activities. Anthro- means it's caused by humans.

Mining of coal. We need those landfills. But then if we have more of them, we are also contributing to the high levels of methane….mining and processing of coal.

Any question so far on these anthropogenic activities…

L: Madam, is this science?

L: (laughter)

T: Yes, my dear. What did you think it was?

L: I was just asking

L: Geography

T: and what else

T: In Natural Sciences you did this...

Its ability to absorb infrared radiation.

In the other lesson we were talking about why carbon dioxide.

If we have more of the carbon dioxide

A rise in temperature.

An increase in temperature around the earth's surface

Close to the earth's surface.

An increase in temperature around the earth's surface

Number 1….It leads to more evaporation of water. If there is an increase in the average temperatures around the earth's surface...

And this can lead to flooding. Now we are linking global warming to flooding.

Then we have a high chance of precipitation of flooding….which may lead to flooding.

Flooding is more water than necessary on the earth's surface.

Number 2….An increase in temperature can cause a rise in the melting of ice sheets.

Where do we find landforms made of ice?

L: Antarctica

T: Ok!

L: And Arctic

That region up in the North there

L: Antarctica

North Pole not south…south is down here

L: yes….

T: There is an ice sheet the size of an African country which is melting now and drifting away….

L: huh!

T: As it is melting it increases the sea water level.

Ice Age 1, 2 and 3 makes it dramatic. The movie

L: ohm…

T: yes. Really that is what is happening.

L: and the animals Ma'am!

T: Some of the animals are factious obviously…..but that is what is happening... put people inside there, imagine what will happen and the consequences are just big…

If you have melting ice and the rising sea levels, in the low-lying areas we are likely to have more flooding than in the high regions. Ok?

L: yah

T: We have experienced these things over the few hundreds of years that we are in now and we can't say it's just nature taking over here. The contribution of an increased amount of carbon dioxide and methane plays a part. Ok.

It's causing an increase in the average temperatures around the world and then we have flooding occurring here. Increase in temperatures can also lead to wild fires. We have temperatures which are higher than what we used to have… in Western Cape

We have had reports of wildfires recently in….

L: Lesotho …

T: Coastal places…But Lesotho is inland here…

Wild fires occurring in the coastal regions

L: Coz of cigars…

T: It's not as a result of someone dropping a cigar….eventually we have a fire spreading all over…Something is going on and we can safely attribute it to

An increase in

Another cause….if vegetation is destroyed due to wildfires

We are messing up species with we can have desertification

Then we have bare lands….

Increased droughts in some areas

Undesired movement of people.

Those disturbances

Can be caused by anthropogenic causes

And in the long run to reduce Climate Change itself.

L: stop pollution

T: Do you want to expand on that…

L: Stop dumping things...

T: You can try to add something to what you have said…mere dumping, mere pollution might not lead to climate change.

I can leave you to think about it.…

L: Why don't us built-up on the forest.

T: In this country do we have a National tree plant

L: Yes

L: Spring day, Arbor Day….

L: Why must we only plant one day…We must plant

T: Any other change that could make a difference…You only talked about planting trees

L: They should talk about global warming.

T: When often do you hear talk about global warming….

Or they can say it's a 'Sandton' problem

We need to talk more about it. Understand that the aspects on climate change are covered in three learning areas….life sciences, geography and physical sciences and appreciate that.

Ok thank you guys.

Transcript-Voice 170302.3gp(radiation and greenhouse gases)

T :We need to talk about firstly greenhouse gasses ,so on this question that I have for you is ,what is a greenhouse gas .You have studied greenhouse gasses before right

S: Yes

T : Like what

S : Carbon dioxide, oxygen, methane, nitrogen, nitrous oxide,

T: So these greenhouse gasses we said they have an effect on the absorption of radiation on the earth itself. What do you know about the greenhouse effect probably know that we need it but what if its enhanced greenhouse effect .Enhanced greenhouse effect we are saying that the earth is more heated than what's it was before. We have gasses that are blocking the filtration of radiation through them so effectively you are saying there is an area we have a layer of gasses on the earth and part of it are these gasses .When the sun gives out its radiation it goes onto the earth and then it can come out but not all of it so its selectively absorbed into the atmosphere., some of it.

So if we now have certain gasses in this whole film around the earth ,they will allow some gasses to pass through but some of the times they won't allow .If we have more of this carbon dioxide, methane and all that they will trap the heat that is radiated from the earth and going back. So an increase in the amount of these gasses on the earth surface itself will ensure that more heat is found in this region and we will end up having a warming effect around the earth, an enhanced greenhouse effect. And that will lead to what we call global warming

The average temperatures around the earth itself increase and what does that lead to in real life .If we have average temperatures changing, there is likely to have more rainfall in wrong places and no rainfall in the wrong places also. That's a change in the weather patterns and within five years or more will have a climate change in a particular area because average temperatures have changed average rainfall has been affected also because of cloud formation in the different areas. And the average weathers have been changed.

So climate change is within the regions and we have diverse effects like droughts, floods, tropical cyclones .Were you aware of these facts that the enhanced greenhouse effect is the one that leads to global warming and then we have climate change. Tell me what you know about climate change

S: When we have a climate change we have changes in seasons

T: We can't say changes in seasons as such, we have the same season but we are expecting low temperatures but we have high temperatures because of the increase in the average temperatures in the region. This process is gradual .We are putting it to you guys to make other people aware there are climate changes really occurring. In South Africa the recent wild fires, the floods and the cyclones .What is causing that shift in the temperatures .Loss of plants due to droughts and floods. What other effects do you know .We are talking about human impact on climate change .So do we know the greenhouse effect

When we talk about the greenhouse effect its actually helpful to plants and anything that is on the earth. We need that layer of gasses so that it is a conducive environment for organisms to survive on or close to the earth, but now if we have more of these gasses, forming that layer now it is a problem, it becomes an enhanced greenhouse effect. It's more than what we need. And this enhanced greenhouse effect is what causes rise in average temperatures around the earth and effectively global warming and eventually climate change

So this one now is a bad idea, so when we talk about the greenhouse effect know that the greenhouse effect is actually essential for organisms to survive near the earth or on the earth's surface and then the enhanced greenhouse effect is the one that has a bad effect. It causes a rise in average temperatures on the earth and it leads to global warming which leads to climate change. And then what does this have to do with us physical science learners we need to know that we have gasses, carbon dioxide, methane and NOx.

Another greenhouse effect we left is water. And H_2O is the most abundant greenhouse gas that you can have. So these greenhouse gasses that we have listed please also know that water is amongst them. So because of this abundance in the atmosphere and close to the earth's surface we see now that it causes so much shifts in the temperatures because it's readily available in the gas. What causes these gasses to cause increase in temperature. The gasses themselves have carbon dioxide and we can talk of methane. The bonds here, these bonds have special properties that allow for interaction with radiation and in the end an increase in temperature, so wherever they are, these bonds will move or vibrate and cause a change in temperature. So because of these bonds which is what we know as physical science learners, you know there are bonds here. Because of the bond there is an interaction between the bonds and the radiation that is provided by the sun itself and that interaction increases with the amount of carbon dioxide, water and the methane. So that's where physical sciences come in. When we learn about bonds ,we need to link it with why these molecules cause an increase in temperature

When the bonds interact with radiation the whole system has more energy than what it had beforehand then we will have an increase in temperature.in the system .As physical science learners we need to

Transcript-Voice 008 Enhanced greenhouse effect

T: Alright we are carrying on from yesterday's discussion on climate change .I want to explain more on the greenhouse effect or the enhanced greenhouse effect which leads to global warming.

We were talking about the presence of greenhouse gases, some of them .One example being water vapour. And I said to you that do you know that water vapour is one of the most important greenhouse gasses. Some of you didn't know that, some of you said ummh like they knew but they had forgotten.Andd then the other one was carbon dioxide and then you mentioned several other ones.

The most important ones to us are carbon dioxide, water vapour, nitrogen, oxygen, argon and then what else methane. Methane is CH_4. When you were looking at mining activities in your senior phase you talked about methane being found in fossil fuels. And besides methane you can talk about other organic compounds being found in fossil fuels, hydrocarbons containing carbon and hydrogen okay remember those discussions

So we can talk about methane being the simplest hydrocarbon which is CH_4 okay:

Coming from the greenhouse gas now we are saying these greenhouse gases contribute to enhanced greenhouse effect .How?

From a science point of view we want to find out what goes on and what causes that okay:

The first thing that we need to realise is the role of the greenhouse gasses .What role do they play around the earth? If we find them in the atmosphere they play the role of keeping the earth warm, okay but not hot

Right, so they should be there. The greenhouse effect is beneficial for the organisms that are on planet earth but if we have an increased amount of these greenhouse gasses now there comes a problem

How is it a problem? Is it because we have a high concentration of the carbon dioxide and the water vapour then we have temperatures rising. What is it that goes on, okay?

My first point on that these gasses they allow radiation from the sun okay, to come in, talking about solar radiation. This is radiation from the sun okay, sun's rays directed to the earth and heating the objects on the earth

And do you realise once your body or anything on earth is heated it can emit radiation outside also .Do you know that? Okay, you should know that now. Bodies on earth they can receive radiation and they can emit some radiation also .When I talk of bodies I'm not talking about dead bodies I'm talking about dead bodies I am talking about anything that you can find from the surface of the earth

Can be a water body, solid body can be a structure, can be a human being, can be an organism, It can be trees. Okay. So if they receive the radiation now it comes in through what. Those greenhouse gasses are around the earth the earth is here and the greenhouse gas is here .They allow radiation from the sun to come in through them, they allow that but then that radiation can go to the earth fine and then go on the bodies and then the bodies on the earth or on the surface of the earth can emit some of the radiation.

When that radiation is now emitted .The greenhouses again selectively allow some radiation to go through them okay so what happens now? Earth layer of greenhouse gasses here the sun is there .Sun's rays go through in are allowed to pass through the layer of the gasses go to the earth, bodies of the earth are heated up and they emit some of the radiation back and the same layer of gasses can come into contact with the radiation put it back on earth, come into contact and put it back on earth and allow a bit to go back out into the space. Do you get the picture now?

If that happens now between the earth and the layer of the greenhouse gas, what is going to happen inside there? We have temperatures rising but because there is selective entrance and exit of the radiation the temperature is well managed okay, but then if you have an increase in some of the gasses now like carbon dioxide and water, if you have more of these occurring on that band or the layer of the greenhouse gasses you find that the temperature will increase rapidly an then will end up with what enhanced greenhouse effect an then we have global warming and an increase in the average temperatures around the earth's surface

What is it that is in the carbon dioxide and the H_2O that causes temperatures to rise above the normal that we want okay? Greenhouse gasses are beneficial but if we have an increase in the carbon dioxide, H_2O and other greenhouse gasses then we are having a problem

Number 1 you need to take note of this:

Air on its own being made up of the nitrogen, oxygen, the carbon dioxide ,the methane and whatsoever components that we have can allow ultraviolet rays to pass through and allow the visible rays to pass through which allows us to see because of the visible rays okay. It allows it to pass. Fine, that's good for us .But we have things like nitrogen and oxygen now .These ones because of their nature ,you did natural sciences and you are well aware of how nitrogen is like .N atom here ,N atom here sharing electrons in the bond .We used to draw that nitrogen N_2.

Hello.....

L: Yes.....

T: Okay, if I am talking to you say yes or say you remember, if you don't remember you say you don't clearly remember, Okay what I am taking about is the nitrogen and another nitrogen there like that. And then for the carbon dioxide you write them like this .And drawing the bonds.

So the electrons are familiar.....

L: Yes.....

T: These 2 now oxygen is how many bonds here....

L: Two.....

T: If you are drawing the structure of oxygen you understand that it's O_2.How many electrons around an oxygen atom?

(1 ,2 ,3,4,5,6) ,(,2,3,4,5,6) and when you pair them up so that we have 8 around each .Put these 2 and these 2 that will be 1 ,2,3,4.Take these out 4,567,8 and it's like this .2 double bonds and 2 non pairs of electrons here and 1 double bond there. You remember this structuring from grade 9 .If you don't then you will remember this, how you would write them out .And how would you call out these elements. Diatomic elements, these two because they have 2 atoms or atoms of the same element but they have 2, atoms of different elements but they are 2, diatomic!

Right,O_2 and N_2 .Now these 2 here oxygen and nitrogen are important to us .I'm going to draw out another one and use it later on .H_2o ,you also remember this neh! This is for water. Their linear structures, if you don't put these single lines you remember putting electrons there. You drew it out in the chemistry portion of natural sciences. Okay, if you don't remember this please try to remember, you will need it for your grade 10 also.

These, you write down they are formulae, oxygen, nitrogen, carbon dioxide and H20 which is water.

Someone does remember at least remembers ,Okay let's start with oxygen and nitrogen .Those 2 we say they are symmetric ,if I am to put a mirror here it will bring me the other oxygen .If I am to divide here this part and that part are the same. And when you talk about this one this is a bit bent .We can't say its symmetrical at all .We can't come and divide along this line no.

But when you look at these 2 they are diatomic and they are symmetrical. In chemistry okay, when it comes to such arrangements it affects even the way the particles behave in nature .Now these 2 because they are symmetrical they do not absorb radiation.

Which type of radiation am I going to talk about there: Infrared radiation?

So we gonna use that criteria and say which ones absorb infrared radiation, which ones do not absorb infra radiation. That is the biggest explanation we can give as to why carbon dioxide and water vapour causes an enhanced greenhouse effect. The ability of the molecules themselves to absorb infra-red radiation.

If we have things that are symmetrical they will not absorb infrared radiation like here. They will allow it to go back to the earth .Alright, put this into the mind. The earth here, the layer of greenhouse gasses and then the sun here and this goes to the earth and it can allow some of the gasses pass through and some of them not to pass through like that.

So which gasses are absorbing ,which gasses are reflecting back the infrared and which one are allowing the infrared to pass through .What infrared ?The radiation from the bodies on the earth when it is now being emitted back onto the space we call it infrared .Let's move on

So oxygen and nitrogen are not going to be absorbing infrared and then when it comes to argon it, we never mentioned it before but I gave it to you as part of the list of the greenhouse gasses .Argon atoms exists as free atoms. In which group do you find this .Which group do you find argon in the periodic table?

L Non-metal...

T Which group in particular 1, 2, 3, or 13,14,15,16 .Allow me to conclude this

Right, the noble gasses okay, what we normally term the unreactive but it has

Been found that they react with other compounds but we generally term them

Unreactive. And when you look at that they are just free atoms .There are no

Bonds there at all. So when we talk about any absorption of radiation they won't

Absorb radiation.

So this one wont, this one will not absorb, what else are we

Left with? We are left with, not part of the bonding there but clouds themselves.

When clouds interact with radiation what would happen, because there is solid

Particles in there we don't expect absorption, scattering, reflection will occur.

This light will not pass here.it goes there in any direction it's scattered because?

There is solid particles .If there is space it can pass through, mostly there is

Solids so it's going to be scattered not absorbed and then the last one, the

Most important ones like carbon dioxide and H_2O.Carbon dioxide and H_2O

Tend to absorb the infrared radiation .That's important to ask, If it does absorb

What does it mean to us now .If they can absorb the infrared radiation and we have more of them in that layer around the earth that will cause an enhanced greenhouse effect. And temperatures close to the earth themselves is going to increase.

In the end we have global warming okay, this is where the chemistry fits in, this Layout some of you say they remember some say they don't, you are going to Be studying this in grade 11 but these names in grade 10 .Are we clear on that?

L Yes

T Basically that's the explanation behind why we have enhanced greenhouse Effect as a result of the increase in carbon dioxide and water. They are the ones That have bonds which allow the absorption of infrared radiation. And cause the General increase of the temperature around the earth surface. Go home thinking About these words because it's part of the syllabus

Transcript: voice 1My presentation to peers on CoRe

A very good afternoon to you ,Thank you for giving me your time and coming to this meeting I hope we will all benefit from this meeting. You will find few pieces of work that I'm presenting today, First on the agenda is my content plan and workshop plan and we have my presentation the first one written 1A.If you don't have anything you are free to share

My first point of call is I`m doing research together with my supervisor, Doctor Nakedi on using climate change as a context to teach chemistry topics in my physical sciences classrooms. I am going to be looking at how I use different teaching approaches and ensure that learners understand climate change from physical sciences and I will be looking at what other opportunities are there in the syllabus about climate change. Your help that you give me as a geography teacher, biology and physics teacher is for us to come together and come up with something that helps the learners understand the aspect of climate change in physical science from your point of view according to what you know. Basically that is what my research is about

There is a concept map that is right in front of you. The one written pre-teaching concepts name, Take a look at it, this one is my starting point at looking at what areas are found in the teaching of climate change where I can fit in chemistry itself. So if you look at that concept map, right on top where it says my teaching concept atmospheric chemistry, climate change .I'm looking at two regions that are specified or thought to be they are kind of related .There is something that is missing between the two .So this is my display of the knowledge that I currently hold pertaining to climate change in the physical sciences. If you look from the right hand side that's where the sun is and then we have UV from the sun going on to the CFCs .CFCs in the presence of UV trap heat and cause global warming that is my thought and then goes to radical formation of carbon radicals plus ozone depletion.

And then from there we were talking about the ozone layer which is already present and we were saying that the formation of ozone layer causes harmless gasses to be trapped, and then it blocks shortwave radiation from coming onto the surface of the earth .Those are my thoughts of what happens in the atmosphere as from May 2016.Also,I didn't know where to put what happens in the spheres to protect the layers of the earth itself .Taking about troposphere ,the other spheres that we can talk about in the atmosphere We go to the left hand side region ,we have dashed lines where there is greenhouse those that emit radiation into space, conservation of radiation and raising of average temperature in the earth.

If you look at that portion I put those 4 things as related to each other and amounting to what we call global warming. That is what my knowledge was telling me at that point. I managed to identify some greenhouse gases, carbon dioxide, nitrogen oxides, water and argon and then after that I think they form a blanket in the atmosphere but in which layer. I remember it prevents the loss of reflected radiation into space reflected onto the earth itself. And what does that lead to, some conservation of radiation close to the earth surface and this causes a raise in the average temperatures near the earth. We are talking about the global temperatures. Near the earth, that is what I know. So all the things that are in the dashed lines this is what we call global warming.

And then we go to just outside that layer, the results in climate change which leads to drought and that lead also to loss of plant biodiversity. I stopped there with my knowledge of chemistry and then I said this is outside what I know. And then I go to climate change again onto the right hand side onto the bottom, the average weather patterns rainfall plus temperature fall over a five year period that is the definition that I know of climate .All these are the concepts that I heard before having contact with any literature. It is what I had in mind pertaining to the concept of climate change. I sat down and developed a very important document which I was taught during my undergrad which is the content representation

The content representation, this is the first one that I made ,Initially I could only manage to identify two things but if you look at the dates I have here it was after so much consultation and looking at resources ,I am talking about literature. I came up with what we call big ideas .The big ideas basically we are trying to link it basically with what you guys teach. What are the principles that you consider to be more important when it comes to teaching climate change so it came from all of this. When I look at those principles I want to highlight. On the big ideas the first one climate is regulated by complex interactions between components of the earth's system which are the sun, ocean and the atmosphere

This is one big idea I realised that climate is controlled and exists because of interactions between the sun as a source of heat and the ocean as a water body, and the atmosphere where you can have the interaction. The second big idea is energy existing systems in various forms and its transformation and conservation occurring in processes that are predictable and measurable. The second part which is processes that are predictable and measurable it makes the whole process scientific aspect but the second big idea comes in now .There is energy in the earths system where we have the sun, earth and the atmosphere

And the energy allows for that interaction between those components themselves .Energy transfer but is not lost in the whole system we consider it as a closed system if we look at physical

sciences. The next one which is number 3 water is unique and special properties that contribute to nature through the water cycle.

Looking at the system as a whole how it affects climate and then going deeper to what is it that connects the things that are in the system, the energy ad going to the particular thing that causes the interactions to exists., the water itself, we look at the hydrological cycle. How come water is important in the earth system in regulating temperature .We are going to break own the big idea and find out how we can help learners find the link between the sun, ocean and the atmosphere using water.

The 4th big idea, which is the chemistry of the atmosphere, has a role in climate change. So in the big fourth idea we are trying to identify this, in the atmosphere which is the region we have all the interaction is taking place., not the whole interaction but most of the interaction, so I chose the atmosphere itself as the main player in climate change. Where some interactions which is very useful for learners to understand what is going on takes place.

Then the last one, human activities impact on the climate change through mining activities. This is important especially when it comes to physical sciences. Its one aspect that you cannot ignore you will see by the example of coal mining. In geography and life sciences we also look at other human activities

This core is a tool for looking at the knowledge that you will give to the learners and what is available in those resources, what you are going to teach. Number one, on the big idea we have what we call prompts ,,On the left hand side of your document that you have, what you expect learners to know about this idea .We basically know this as background knowledge .You write down what you think these learners might know from their previous grade or taken from home. I make a list of those things that I expect learners to know the idea. I'm talking about learners in grade 10 and you can also go to learners in grade 11 depending on what they should cover. So I can pick an example of the first aspect about climate is regulated by complex interactions amongst components of the earth's system, the sun, the ocean and the atmosphere

I expect them to know that the sun, water and the atmosphere are interconnected in determining the weather in a particular area. I don't expect them to know from physical sciences but from other subjects as well. Remember they have progress from previous grades and have passed, so they should be knowing this .And if I go down with that one example

Number 2 what you intend students to learn about this idea ,what is it I want the students to learn about this idea .So number 1 they need to know that the sun is a primary source of energy for the earth's climate system. This particular point can come as a big idea also but I took it from the big ideas I didn't want to look at the sun only but link the sun with the other objects in the system, which is the sun, ocean and the atmosphere

So when we look at that the sun is a primary source of energy for the earth's climate system. Heat from the sunlight can heat the land, ocean and the atmosphere .The ocean acts a reservoir for hot temperature. They should be able to know this .They also need to know about climate and the earth system itself .The amount of solar radiated by the earth, modulated or controlled by the atmosphere and composition of the atmosphere. We could find this also under the atmosphere but we can't ignore it as stated down

Why is important for students to know this .You are now trying to fulfil your objectives .You said out the big idea and you are saying I need them to know about this big idea that climate regulates the interaction between the sun ,the earth, the ocean and the atmosphere. Why is important for them to know, so that they link climate to earth activates and atmospheric activities .Whatever happens on the earth surface and whatever happens in the atmosphere itself. They can think to what happens to change in weather patterns and the resulting climate change .They will be able to do that .They go through the activities for this particular big idea.

Then on number 4 if you look at that it says that other factors that cause climate change and what else do you know about these ideas which you do not intend your learners to know yet. Right, on other factors that cause climate change besides human factors there are also natural causes that are there but I don't want to highlight it yet because it will overshadow the real point I want to talk about which is there is this interaction but I can talk about this later on not at this point. And then there is a science behind the relationship between those three. Why do they act in a more complimentary way ,the earth,sun,ocean and the atmosphere to keep the system close and in balance as it is .We don't want to talk about that at this point .

Then if you look across the number 4 from the big idea number 1 up to the last one its things that you as a teacher would know about with more content or its things that you are going to be teaching later on but you are trying pave the way first before you can bring those things .So the things that you know now and don't want to bring out can be new things that are going to be learnt in another year another topic or the same topic but in different section. The difficulties related to teaching this idea .Before we can look at the end of the lesson and say I had problems because of this and that we want to look at ,other people have looked at this topic ,How do they find it .Where were they facing problems ,difficulties like if you look at the first one other factors are

discussed pertaining to their syllabus .If I really want to know more about this and don't have that content which means I must approach someone with that content in geography or look out for resources .But when you enter into a class of physical sciences you don't expect your learners to be interacting with geography based resources .You are the one who goes out and looks out for that information and then guide them as to what you mean in that particular aspect..

And if you go to number 5 across there are things that make topics difficult to teach. Some of them I have managed to bring them out. With more experience we have more and more that we can list here and how we can overcome them. For example in the last one where we said human activities impacting on the atmosphere .There is many things that we can talk about like can learners believe that a tiny carbon dioxide concentration causes climate change and some of them have confusion between ozone depletion and the whole topic is a difficult to comprehend .

And what is known by the science community sometimes it's not made available to the everyday person or the laymen. So you have to bring it out before you can start teaching or you have to find it out first before you can start teaching. And then number 6 we look at the knowledge about learners. Learners thinking which affect you're teaching of this idea. When I look at number 6 you have to look at what do you know about learners pertaining to the interaction between the earth's itself so that the earths system which is the sun, the ocean and the atmosphere.

When you look at the last part which I can say I more knowledgeable in that, there are misconceptions pertaining to global warming, the greenhouse effect itself and the ozone depletion. The learners also think, this is what learners think, when I'm talking about misconceptions it's a way of thinking from a particular person that you are interacting with that they think is right but may not be necessarily right, there is some fault in it or some diversion from the actual truth

So the learners on number 6, in the last aspect where we talk about, U can refer to your top part where we talk about human activities which have impact on the atmosphere through mining activities .Greenhouse effect is bad and which will lead to the eventual of organisms .However without the greenhouse effect the earth will not be warm enough to support earth life. There is another issue also of they can't differentiate between the necessary greenhouse effect and the enhanced greenhouse effect. So you should know when we talk about greenhouse effect are you talking about the same thing or you are talking about enhanced whereas they are talking about the beneficial.

And then interchanging of the words such as global warming ,climate change an ozone depletion out of not knowing the difference between those 3.And another thing which not only happens with learners which can happen to teachers as well is change in weather is climate change. You need to know under what, for how long the observation has been made for us to say this is really a climate change for a particular area.

As for me mine is five years an some of you can come up with a different view pertaining to what they know about it .On number 7,again before I continue this will be covering the whole topic and you planning for the whole topic. Number 7 you looking down at your teaching procedures and particular reasons for using this to engage an idea. Idea number 1, idea number 2, idea number 3, number 4, number 5 and write down how you are going to implement those .what approaches are you going to make pertaining to how you make the points for the particular sub topic or idea.

So these you must also find in the lesson plans you are going to be making or the particular worksheets that you are going to be making so understand that your teaching procedures must be reflected under them

Number 8, specific ways of ascertain learners understanding of confusion around the idea .How you are going to probe the learners and how you are going to make sure that they won't have confusion that they had before for a particular idea, so I have given particular examples and on the last one which is number 9.What will be the preferred assessment strategy for facilitating learning. In a conducive environment and with all the resources available these are some of the suggestions I made of which I am going to look at most of them there

So my plan is basically the content representation .How do you come up with this .You have to have some ideas to start with fine but at the of the day you need resources. If you are going to look at a topic like climate change and you are teaching in physical sciences, what does the syllabus say about that particular aspect? Then how far can you go. You might want to teach it as cause we are allowed to do so let's say combine certain topics ,let's say in state of matter ,kinetic matter of theory and then you take up the water cycle and you take another related topic let's say bonding in molecules then bring them together and come up with your plan for that. So which is basically what I am trying to do like put certain topics together and bring them out as a way of teaching climate change without saying I am going to teach climate change to physical science learners ,I am looking at what opportunities are available in the sub topics for me to be teaching climate change. I talk about the water cycle put in something about climate change, talking about bonding molecules put in something about water and how it affects the water cycle and how it affects climate in the end and other related issues.

Can you just pause a bit, comments so far before I loose direction and if you have anything that you need to write ‘I have an extra page for you to write. I think we can address some comments, additions, contributions based on the plan that I made.

P : I was suggesting that you write where it says mining include all industries not generalizing

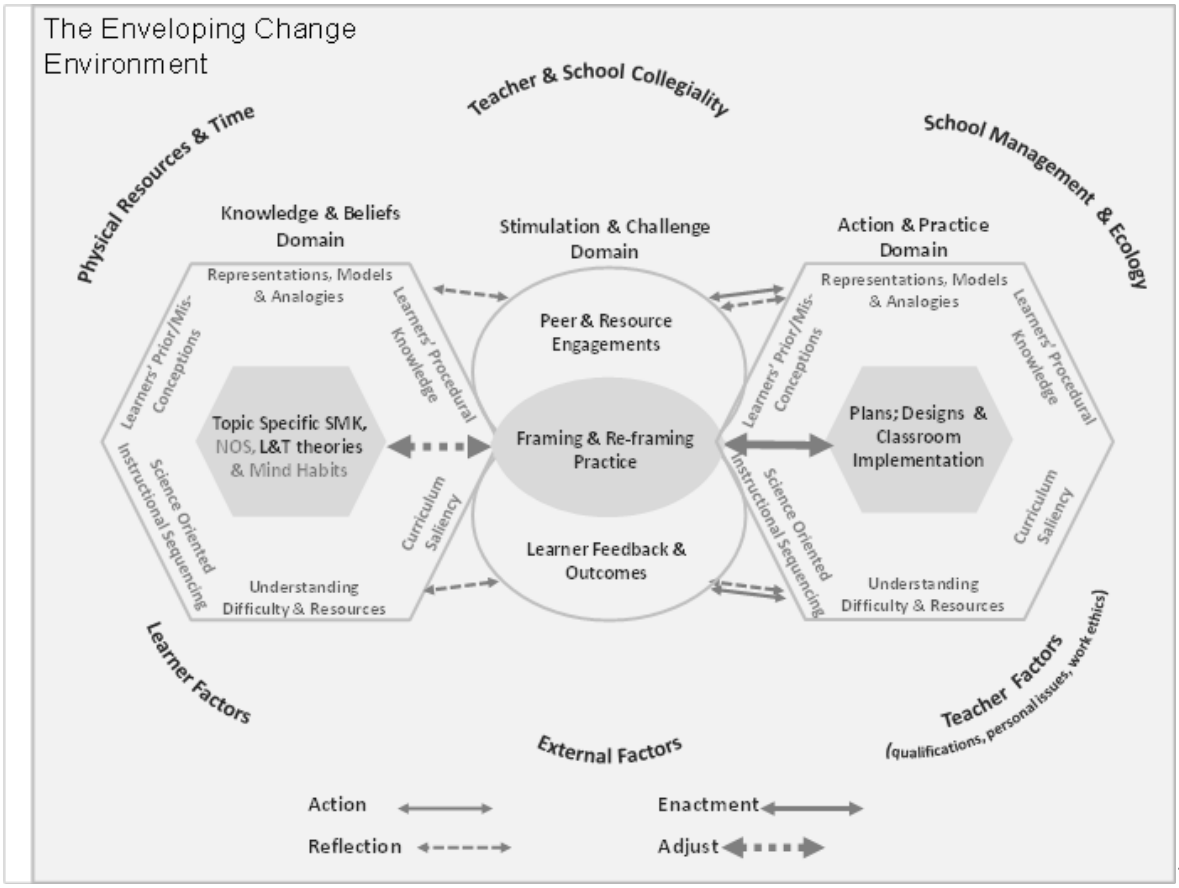
S :Just a comment we are going to interrogate this later on, we discuss but maybe to highlight the truth you have said I’m doing a self-study and to be honest I think we need to applaud you .That’s a brave stance to take and be able to about it. That’s the way we learn and move forward .The topic we are appreciating and maybe looking at the structure of the core which you have presented to us, I appreciate the structure, going deep in capturing important knowledge base about teaching as a practise .And just the forerun also to say …….

Appendix 13: Participant teachers

PARTICIPANT Code	AGE group	GENDER	QUALIFICATIONS	TEACHING SUBJECTS
T	≥30	Female	Science Education honours degree,	Physical Sciences
L (Life Science)	≥30	Male	Science Education honours degree,	Life Sciences
P (Physical Sciences)	≥40	Male	Diploma in Science Education , ACE	Physical Science, Natural science
G (Geography)	≥40	Female	BSc	Geography

Table A13.1: Details of the participant Educators

Appendix 14: The Learning for Teaching through Participation (LTtP) model



The Learning for Teaching through Participation (LTtP) model (Nakedi, 2016)

The Aspects of Teachers' PCK

Data points to the centrality of the teacher's science subject matter knowledge (SMK) and its influence on other aspects of PCK to almost the same degree as the beliefs they hold about learning and teaching of science. Science SMK becomes the core of the knowledge and beliefs domain and it pertains to the knowledge of the science topic under review and whether the knowledge is deep enough to enable the teacher to be able to dissect and unpack the topic into big teaching ideas. Here, the extent of the teacher's expressions about their practice combines with their actual practice and the curriculum materials they produce to form a solid grasp of subject matter. The efficacy of this becomes apparent in the strategies they employ, to promote strongly coherent conceptual understanding of the fundamental concepts underpinning the science topic under consideration and, where relevant, by linking the observed set of phenomena with the explanatory model that assists with their understanding.

Three of the other aspects have to do with how the teacher positions the learners in learning and the type of learning culture engendered through the nature of interactions promoted between the learners and the teacher and between learners themselves to promote science specific conceptual and procedural knowledge. These are the knowledge and beliefs of teachers about learners' prior conceptions; about learners' procedural knowledge and about learners' socio-scientific reasoning (Sadler et al., 2007). The remaining three have to do with the representation forms and alternatives employed by the teacher to promote learners' conceptual understanding; the fifth is referred to as topic comprehensible difficulty & alternate teaching resources (TCD_ACR), the sixth is the teacher's curriculum saliency (CS). These six aspects of the science specific are elaborated below as ***teachers' knowledge, beliefs and practices*** *about:*

Learners' Prior/Mis-Conceptions (LP_MC)

This deals with what research says are of the types of conceptions and preconceptions learners normally have about the topics, and make the learning of that topic either difficult or easy to learn and understand. Consideration within this aspect is whether the plans the teacher puts in place, the tasks the teacher selects/develops and the instructional strategies the teacher employs, value, take cognisance of, and integrate the learners' prior conceptions and how these are further developed. Are the instructional and assessment strategies used value and engage learners' prior knowledge, as well as promote and capture the cognitive and the social dimensions of how scientific knowledge is generated as well as how shifts from one form of knowledge representations can either impede or enhance understanding.

Learners' Procedural Knowledge (LPK)

This constitutes the types of skills and knowledge inherent in how scientific knowledge is generated. They have to do with the teacher's efforts in trying to capture and portray the human nature of scientific inquiry, as an enterprise that involves challenging other scientists' ideas, as well as thinking critically about one's existing knowledge as well. Argument is a central feature of the resolution of scientific controversies and the core skills of scientific reasoning involves one's capacity to logically link evidence provided with the theories bearing on them. Procedural skills also pertain to types of tasks which involve learners in resolving scientific problems, by expecting them to draw the plan of action, carry out those plan through collection of the necessary data and then move on to organise and interpret the data, which should lead to eventual formulation and communication of conclusions. These further involves engaging learners on issues of validity where they engage with ensuring confidence in the collected data by ascertaining that tests used are fair and that sources of error were minimized by controlling variables and using repeat trials or replication. This concerns whether the types of plans, tasks, instructional and assessment strategies the teacher puts in place value, engage as well as promote the social dimensions of how scientific knowledge is generated. Are the plans, tasks, instructional and assessment strategies used promote sense of community of practice where learners are encouraged and given an opportunity to engage in social discourse and challenge each

Representations, Models, Analogies &Resources (RMAR)

The representations, Models and Analogies (RMA) sub-domain pertains to a range and forms of subject and topic specific representations, models and analogies the teacher employs to package SMK in ways that are comprehensible to the learners. They constitute a repertoire of powerful analogies, examples, illustrations and demonstrations which have proved to be effective in inducing learning and could originate from research as well as form wisdom of practice which the teacher has come to amass through experience. These would take into account the nature of science and the types of shifts scientists make between concrete and observable world of macroscopic phenomena to the microscopic world of abstractions and theoretical constructs developed to try to explain and make sense of phenomena as well as symbolic world of coding.

Topic Comprehensible Difficulty & Alternative Curriculum Resources (TCD_ACR)

Each topic has inherent comprehensible difficulty and each curriculum should have a full range of programmes designed to respond and address these at any specific grade or level and these will normally be accompanied by a range of resources and materials used to teach those particular topics. This aspect is about the teachers' knowledge of what makes the specific topic difficult to teach, learn and understand as well as a whole repertoire of alternative teaching resources available for teaching this particular topic at any grade or level, their particular strengths and weaknesses in promoting learning as well as cost effectiveness, safety, convenience and accessibility issues related to their use. It is about awareness and knowledge about alternative texts, audio visuals, simulations, soft-wares, molecular models, laboratory experiments, demonstrations etc. as well as informal learning centres and industries potential for field trips which can be pulled in to promote learners' conceptual in the topic.

Curriculum Saliency (CS)

This aspect is about the teachers' strategic curriculum knowledge, which entails informed and strategic sequencing of subject matter during teaching, as well as effective sequencing of concepts across the different levels of the curriculum. This aspect is what Shulman refers to as the lateral and vertical curriculum knowledge. It pertains to the teachers' knowledge about the sequencing of concepts underpinning a topic, about which concepts are central, which are peripheral and how are they connected and related to each other as well as foundational and advance knowledge of the topic. It is also about the teacher's knowledge of the big ideas underpinning a topic, the knowledge of what learners know prior to instruction, what they intend the learners to know as well as what they themselves know about each big idea but they do not intend their students to know yet.

Learners' Socio-scientific Reasoning (LSSR), Nakedi (2018)
This aspect pertains to learners' knowledge, values, attitudes and higher order dispositional thinking with regards to the five specific scientifically literate attributes, thought processing and practices fundamental to effective negotiation involving socio-scientific issues (SSI) which are: a) appreciation and recognition of the inherent complexity controversy of SSI and the need to exhibit multidimensional understanding of the various dilemmas inherent in an issue due to different stakeholder, interests, & opinions in considering potential solutions; b) given the potential multiple perspective tensions the appreciation and need to exhibit reflective judgement in examining the issue from all its multiple dimensions and perspectives; c) appreciation that SSI is subjected to ongoing inquiry which requires knowledge of setting inquiry based plans for collection of both scientific and social data; d) exhibition of skepticism in analysis of the claims levelled due to recognition of inherent conflicting interests, purposes and biases among various stakeholders; e) ability to select and apply appropriate chemical models from the contesting range to interpret and judge human impact on environmental systems.

OR

Science Oriented Instructional Sequencing (SoIS), Nakedi (2016)
Use of science oriented learning and teaching strategies for lessons sequencing and assessment task construction. This concerns the use of instructional and assessment strategies that value and engage learners' prior knowledge, as well as promote and capture the cognitive and the social dimensions of how scientific knowledge is generated. Science oriented instructional and assessment strategies, such as 5Es lesson sequencing which promotes centres inputs around learners' prior knowledge, such as use of cognitive dissonance which engages two competing theories and promotes plausibility, fruitfulness and defensibility of preferable theory against a competing theory; argumentation which promotes dialogue and learner-teacher and learner-learner interactions underpinned by use of evidence and logical reasoning to defend claims in classroom discourses; use of open inquiry, which engages learners in resolving scientific problems through planning course of action, carrying out that plan by collecting the necessary data, organise and interpret it as well as reach conclusions which are communicated in some for; use of a scientist case studies and role playing to interrogate a topic within the context of its historical development which allows learners to appreciate the NOS and the procedural knowledge and messiness inherent in the generation of scientific knowledge. Role playing on the other hand can allow engagement with the ethical as well as the socio political and cultural aspects of use of scientific knowledge.