UNIVERSITY OF THE WITWATERSRAND

Physical Science Teachers' Responses to Curriculum Challenges in South Africa – Pedagogical Content Knowledge Focused Case Studies

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DECLARATION

I declare that this thesis is my own, unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

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ABSTRACT

A critical question which continues to dominate debates in the field of science education is why curriculum reform innovations do not effect change and raise the quality of inputs in most teachers' classroom practices. In this study, I worked with two teams of teachers in two different settings constituting two case studies to try to understand how teachers handle change in complex situations, with the aim of identifying appropriate strategies which can be effective in responding to their immediate professional needs in the classroom.

A multiple case study approach was adopted, with the first case referred to as a minor case study and the second as a major case study. Within the major case study, the four participating teachers also constituted sub-cases on their own. Data were analysed using pedagogical content knowledge (PCK) as a conceptual framework and interpretive analysis grounded in hermeneutic phenomenology to show how the teachers' knowledge base for teaching was shifting as they engaged individually and collectively on systematic-experiential cycles of reflecting on and in actions of planning for and teaching a new topic in their classrooms, as well as how their beliefs about learners and learning interfaced with their classroom practices.

Even though this study targeted the teachers' intrinsic resources and how these can be developed and mobilized to enhance the teachers' efforts to enact change, contextual issues emerged very strongly in the minor case study. Hence through the minor case study, I show why stabilizing the dynamics in the wider school context, should take precedence over site-based subject-specific professional development. I show how factors in the enveloping school environment can either enhance or undermine any efforts aimed at effecting changes in the subject-specific teacher classroom practices, and why school collegiality is a prerequisite.

With the major case study, I supervised the four participating teachers who undertook self-studies to learn how to teach a new topic in the science curriculum, as part of their BSc honours projects. Within this project, they explored the use of pedagogic research-based strategies and tools such as the *concept representation* (*CoRe)*, *structured, systematic journaling cycle* and the *5Es constructivist lesson sequencing strategy* to address chemical systems topics in grades 10, 11 and 12. I showed how the four teachers' PCK, their notions, conceptions, perspectives and knowledge about the learning and teaching of science,

planning for its teaching, the act of teaching it, and the related meta-cognition affected, as they engaged with the process.

One of the evolving contributions of this thesis which served as a framework to guide the study, is the *learning for teaching through participation* (LTtP) model. The LTtP offers a useful framework that provides a mechanism through which the PCK of science teachers can be developed. I used this model to map three of the teachers' individual growth patterns. It emerged that teacher growth patterns are idiosyncratic, topic-specific and shifting because teacher change is bound to time, place and person. This finding demonstrated the capacity of LTtP to serve as a useful tool for understanding and interpreting teacher learning in innovation environments.

Methodologically I show that even though the potential of the CoRe as a research, planning, meta-cognition developing tool was not fully explored, it served as a great tool to initiate and support the development of the participating teachers' topic specific subject matter knowledge (SMK), as well as related meta-cognitive skills. Ingenuity and authenticity of PCK-focused self-studies, in capturing and addressing curriculum innovation challenges, was demonstrated by the varied levels and complexity of cognitive, meta-cognitive, affective as well as pedagogic learning the teachers were able to amass within the limited period.

KEY WORDS

Teacher learning environments, science learning and teaching, curriculum innovation, pedagogic content knowledge and metacognition

DEDICATION

I would like to dedicate this work to my late father, Cornelius Christopher Khunou who while still in this life, understood the importance of educating girls and women, and encouraged me to aspire to the greatest heights and ideals in Education. May his precious soul continue to advance in all the spiritual Worlds of God. Dedications also go to my beloved mother, Pauline Letlhogonolo Khunou, for the moral support and the endless prayers that sustained this process.

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(* pseudonyms used for confidentiality)

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LIST OF ABBREVIATIONS

ACE	Advanced Certificate in Education
BASSSQ	Beliefs about Science and School science Questionnaire
CoRe	Content Representation
DoE	Department of Education
5E's	Engage – Explore – Explain – Elaborate - Evaluate (a Constructivist aligned Instructional Strategy)
FDE	Further Diploma in Education
GET	General Education and Training
IAB	Interview about Beliefs
LTtP	Learning for Teaching through Participation
LO3	Learning Outcome Three
NCS	National Curriculum Statements
NOS	Nature of Science
NRF	National Research Foundation
NS	Natural Science
NSC	National Senior Certificate
PaP-eRs	Pedagogical and Professional experience Repertoires
PCK	Pedagogical Content Knowledge
RADMASTE	Research and Development in Mathematics and Science Technology Education
RDP	Reconstruction and Development Programme
SMK	Subject Matter Knowledge
STS	Science Technology in Society
VNOS	Views about Nature of Science
LTSM	Learning and Teaching Support Materials

CHAPTER 1
INTRODUCTION AND ORIENTATION TO THE STUDY

1.1 Introduction

The quality of science and mathematics education is constantly under scrutiny because of the critical role played by these two learning areas in the economic and technological development of any country. In this chapter, I set the scene for my whole thesis by articulating my initial perceptions and conceptions of where my study is located, in the science teacher development and curriculum innovation debates, as well as the type of knowledge gap it aims to address. To put this study into context, I begin with a brief exploration of the socio-political context in which the South African schooling system is embedded and then move on to discuss the broader changes that impact the post-apartheid education system, with a particular focus on the science curriculum.

1.2 South African Socio-political and Economic Context

Worldwide, countries are propelled by social forces to engage in changing their education systems. The National Committee on Further Education (1997) correctly points out that the system of education and training in the country failed the majority of the South African population. Therefore, for the past 18 years what has been at the centre of the challenges of South Africa's new democracy, are issues of redress, as the country undergoes major socio-political transformation, with its education system being targeted as a means of redressing the gross imbalances created by the apartheid regime.

As in many parts of the developing world, the South African socio-economic situation is in a dire state. Various studies (Data First, 2002; UNDP, 2003; Ali-Dinar, 2004) have confirmed that between 20 and 28 million of the country's population is experiencing ongoing and dehumanizing deprivation. Among other factors is the devastating impact and the impoverishing effect of HIV/AIDS on affected households, leading to a full-scale socio-economic crisis (Kotzé, 2003). The reports reflect that the inequality gap between the rich and the poor is deepening. The South African Gini coefficient, which is a measure of income inequality, ranging from 0 (perfect equality) to 1 (perfect inequality), continues to be among the highest (Ali-Dinar, 2004).

The legacy left by apartheid policies, which were meant to ensure that different races developed separately and unequally, continues to haunt most developmental processes. The main legacy of the apartheid regime, which continues to threaten the schooling system, is that semi-literate masses are caught up in a cycle of dysfunctional life styles, and are therefore impotent to contribute in any meaningful way to the economic solutions of the country. Omond (1986) revealed that per capita expenditure on education during the apartheid era (1983-4) was R1, 654 for a white, R569 for a coloured, R1 088 for an Indian and R234 for an African learner in white areas. It is against this background that the present curriculum reform emerged.

One of the ongoing challenging realities inherited by the present regime is the grave inequality in the standards of inputs made in its various schools. A case in point is that the current challenges enveloping curriculum development and changes in South Africa, take their character and course from the gross variations in the quality of schools. This comes as a result of having inherited schooling systems from multiple departments which were divided according to race and tribe, and therefore treated differently by the previous regime.

Given this background, one needs to appreciate that, before considering the complexities of addressing the learning and teaching of science in the classroom, the complex realities of the South African schooling system, are mired in socio-economic realities which cannot be ignored. Another reality is that there are huge disparities across schools in terms of infrastructure, management and ecology, teacher qualifications, class sizes, access to curriculum resources and learner performance which impact the quality of teaching and learning in the classrooms (Bergman, Bergman, & Gravett, 2011; CEPD, 2000; Harber & Muthukrishna, 2000).

Still today, most South African schools remain chronically under-resourced, with dire conditions in most rural schools (CEPD, 2000; Howie, 2003; NIEMS, 2009; Bergman et al., 2011). In a recent study done on schools' capacity to support innovation, Gallie (2007) classified most schools as either low-functioning or dysfunctional, and this concurs with the Institute for Justice and Reconciliation's declaring over 80% of South African schools as dysfunctional (Taylor, 2006:65). For most township schools, the main priority for bringing normality in terms of effective teaching and learning environments is such basic issues as ensuring safety for the school community. Besides the plight of the HIV scourge and child-headed homes, the issues of school governance run deep, with a report by the Department of

Basic Education (DoBE, 2007/2008) revealing that in 2007, 49 636 learners (with approximately 70% being in Grade 9 or below) were reported pregnant.

In terms of school infrastructure and access to resources, the situation is desperate in most poor schools. Besides issues of overcrowding with average class sizes of over 60, a report by the National Educational Infrastructure Management Systems (NEIMS, 2009) revealed that 2,444 public schools have no water supply, with 3,600 having no electricity; 11,231 using pit-latrine toilets and only 21% having a library.

When it comes to performance, the picture is also underpinned by layers of complexities. Regarding international performance evaluations in both science and mathematics, South African learners ranked at the bottom of the performance ladder as compared to their peers in Africa and across the Globe (EFA, 2006; Reddy, 2006). While international studies reveal that South African learners are underperforming, there are previously advantaged white and Indian schools, which are catering for about 20% of the country's learner population, and are producing good results comparable to their peers elsewhere.

The waste of human potential can be inferred from several studies on the implementation of the outcomes based curriculum in South Africa (Rogan & Grayson, 2003; Taylor, Muller, & Vinjevold, 2003; Taylor & Vinjevold, 1999). According to Rogan (2004b), the level of achievement of the Grade 9 learners observed during case studies of secondary schools in Mpumalanga, is only at about Grade 4 level. A serious challenge faced by the South African education system, with the advent of the new curriculum, is that the quality of learning and teaching in most classrooms has deteriorated. Part of the problem is that there have been strings of reviews of the curriculum injecting more confusion into the schooling system. At the time of writing this thesis, the new curriculum was the National Curriculum Statements (NCS) which were introduced in 2006, while the old curriculum was the NATED 550 (apartheid curriculum). The NCS policy has since been superseded by the Curriculum Assessment Policy Statement (CAPS).

At the time of the study, even though matriculation results had started showing steady improvement, the reality was that teachers in general, and more specifically, science and maths teachers were not coping with the complex intellectual demands, placed by the prevailing reform based NCS curriculum on their classroom practices. This reality continued to unleash sporadic interventions from the government, which exacerbated the situation

further, mostly sending the schooling system into even deeper levels of confusion. Central to this problem was the lack of appreciation in most teacher support and development strategies, that the philosophy underpinning the NCS is different, and necessitates a total shift in paradigm from how most teachers were trained, as well as their present outlook on practice. The NCS was a constructivist, outcomes drive curriculum with the physical sciences in sync with the nature of science by promoting open inquiry and STS approaches through its three learning outcomes.

In science and mathematics, one of the most challenging issues which continued to undermine the process of bridging the gaps between the intended and the implemented curriculum, is the weak content knowledge of many teachers. In the science NCS, this situation was further exacerbated by the introduction of the new topics, some of which used to form part of first year university curricula, as well as the complexity of three science learning outcomes (LOs), which are very far removed from how most of the teachers were trained, and hence their current classroom practices. The first science LO is about the skills underpinning the 'doing of science' while the second focuses on the content and the third on relevance and interrelationship between science, society and the environment. In trying to get to the heart of this gap, this thesis explores how two teams of science teachers respond to the challenges posed by the NCS on their practices, and their content knowledge for teaching.

1.3 Background of the Problem

The diversity in both content and focus of studies related to curriculum reform, bears witness to the complexity of issues surrounding curriculum reform, both in developed and developing countries. Among other factors, the problems in the South African reform process seem to emanate from the emphasis by teacher development programs on innovative teaching and learning strategies, at the expense of content knowledge. Teachers were expected to take forward a complex curriculum with very high ideals from a very shaky science content knowledge base. The main criticism levelled against the outcomes based curriculum is that it underplays content and focuses on skills and collaboration which in their nature require teachers with highly sophisticated content knowledge for them to be able to work productively with it. As echoed by some expert teacher educationists (Adler, Slonimsky, & Reed, 2002), teacher education faces critical challenges in rethinking what constitutes teachers' conceptual knowledge in-practice, and how this can be developed and acquired through pre-service and in-service education programmes.

Even though progressive, nevertheless the ideals of the NCS placed complex intellectual demands on teachers. The South African Norms and Standards for Educators (DoE, 1998), calls for reflective practitioners. Research on reflective practice (Roth, 2007; Schön, 1990) argues that teacher reflection should form a central and critical part of professional educator responsibility, as it provides a continuous avenue for the teachers to consider many factors which should inform the decision on how to act in particular and varied situations. Loughran, Berry & Mulhall (2006) assert that, for teachers, thinking about teaching is a complex task and that it is important to promote ways of sharing teachers' professional knowledge of teaching, to further enhance understanding of teaching and learning in science.

Some studies (Powell & Anderson, 2002; Haney, Czerniak, & Lumpe, 1996; Pajares, 1992; Fullan & Hargreaves, 1991) take the complexity of teacher development to even deeper levels, by highlighting the centrality of the behaviour and belief of teachers on how the curriculum is put into action. The argument is that beliefs teachers hold about learning and teaching are at the core of their practice. The studies cited above highlight how previous reform efforts fell short of success because they largely ignored the influential nature of teacher beliefs on changes in teaching practice.

Magnusson, Krajcik, & Borko (1999) describe beliefs as having both affective and evaluative functions, by acting as information filters and thus impacting on how knowledge is organised, retrieved and utilised. They further highlight the distinction between orientation of strategies used frequently by majority of teachers, and those which are used less. They point out that the less frequently used strategies have content specific orientation while those used frequently are pedagogically more generic – a finding which they argue might be linked to teachers' lack of confidence in their content knowledge. This might also serve to explain the gap addressed in this present study.

Given this background, one can argue that research on teacher development needs to grapple with and be embedded in teachers' real contexts, in ways that are supportive and empowering to the teacher's role in the classroom. There is an urgent need to model effective and practical teacher professional development strategies that put the science teachers' real context at the centre, and employ it to engage them in modes that will mobilize them for change and professional growth.

1.4 Problem Statement

As stated above, the situation in most South African schools is in great need of improvement. One of the causes of this situation is the quest for a quick fix for complex situations which requires focused research-based strategies to identify ways to turn it around. The quality of science and mathematics education, as the gatekeeper to socio-economic prosperity, is the key to unlocking the fortunes of this country. High quality teacher education programmes that integrate ethical and scientific orientations are crucial. In my opinion, what the process requires is a critical reflection on what brought us to this stage, and, more importantly, the courage to pilot radically different, skills-based support interventions with immediate on-site relevance in schools.

In the light of this background, this study was aimed at engaging the real complexities of the evolving setting of the South African schooling system, with both an inquiry as well as an emancipatory agenda. The strategy employed in this study was to study teacher responses to practices which inspire teachers for change. The overall aim of this study is to explore the types of resource systems and learning environments that can be useful to support senior/FET science teachers, as they grapple with the challenges of implementing the new curriculum in their classrooms.

The research process in this study is guided by a multi-paradigm perspective, which draws heavily on qualitative, interpretive, social constructivist and a situated cognition orientation. The study was attached to two different teacher development programmes, which focused on enhancing the science teachers' pedagogical content knowledge (PCK) through the use of action research techniques. The programmes employed research-based strategies to assist the teachers to systematise their learning and teaching efforts, as well as deepen their understanding of specific science concepts.

1.5 Aims of the Study and Research Questions

This study was driven by two main aims. The first was to foster the development of senior/FET phase science teachers' professional and pedagogical content knowledge in the context of South Africa's NCS. The second was to find out how these teachers handle change by exploring the nature of collaborative inquiry that emerges, and its influence on the development of their pedagogical content knowledge and meta-cognitive skills, as they

endeavour to implement the NCS in their classrooms. To be more specific, the unit of analysis of this study is teacher learning in the teaching environment.

This is an action learning project which focuses on understanding how teachers handle change in complex situations, in order to identify appropriate strategies which can be effective in responding to their continuing needs in the classrooms. The main question this study is addressing is: how do teachers respond to the challenges of implementing a new curriculum in their classrooms and how best they can be supported in their endeavours?

The study is guided by the following two key questions with their sub-questions:

Question 1

What professional and pedagogical content knowledge base do participating teachers need to sustain their efforts of implementing change in their classrooms?

1.1. What knowledge base do the participating science FET teachers have concerning the new curriculum and the topic of chemical change/chemical systems?

1.2. Are there any relationships between their beliefs about the learning and teaching of science and their actual classroom practices?

1.3. How is their knowledge base for teaching science within the new curriculum framework shifting as they plan, design, teach and reflect on their practices?

1.4. How are their meta-cognitive capacities evolving as they plan, design, teach and reflect on their practice?

Question 2

What is the nature of support needed to inspire the participating teachers to initiate and sustain curriculum aligned change efforts in their practice?

2.1. What are the key strategies and tools that played a valuable supportive role in the transformation of the teachers' PCK as they participate in these settings?

2.2. What dynamics serve to afford or constrain teachers' efforts in effecting curriculum aligned changes in their practice?

1.6 The rationale and the significance of the study

The urge to pursue this study stems from my reflections on various experiences I had during my five years of coordinating the Further Diploma in Education (FDE)/Advanced Certificate in Education (ACE)[1] maths and science programmes at the RADMASTE centre (Centre for

[1] The Advanced Certificate in Education (ACE) is an intermediary professional qualification between a junior degree and honours qualification which was intended to replace the Further Diploma in Education (FDE) and the Higher Diploma in Education (HDE) and could be used by teachers for up-grading or further training in a subject specialisation or for re-training into a new subject specialisation.

Research and Development in Mathematics, Science and Technology Education). These programmes, which integrated academic with school based support programmes, were funded externally, and mainly attracted teachers from disadvantaged communities. What became apparent during my interactions with the teachers, their schools and classrooms was that the present waves of reforms in the South African education systems have thrown teaching and learning in most schools and classrooms out of balance. Some of the tensions that came to the fore as we strived to organise the courses in the most relevant and effective ways, were due to issues of upholding high academic standards versus issues of support, relevance and retention, as well as issues of enrolments versus teacher professional image and autonomy.

One of the two distinct tensions which I hope to elucidate in this study, is how to ensure that the theory promoted in academic programmes is translated into practice. On my few visits to the participating schools, I was concerned that most schools failed to create empowering environments for effective learning. What was even more disconcerting was, that this was not due to teachers being lazy or de-motivated or due to lack of resources. In those science classrooms, the teachers engaged learners in many activities and involved them throughout the lesson. These teachers' efforts to promote learning in their classrooms were sadly undermined by the quality of their questioning techniques and types of learning and teaching strategies. As Shulman (1986) would put it, these teachers were failing to transform and package content knowledge into accessible forms for effective learning. Shulman has termed the required knowledge as PCK, and implies that effective teaching and learning is a product of tacit skills based on a combination of acquired teaching experience, as well as secure subject matter knowledge.

The second dilemma which this study hopes to address, is how to establish programmes which really address the challenges of teachers' science/maths competencies, while, at the same time, empowering them to create sustainable environments and structures, on which they can continue to base their professional growth, long after the in-service programme has come to an end.

It is hoped that the theoretical contribution of this study will offer a practical framework which draws from relevant research-based strategies, and available teaching and learning resources, to create and frame rich, collaborative and sustainable environments that can support development of science teachers' PCK, as they endeavour to implement the new curriculum within their typical working contexts.

1.7 Context of the Study

This study was attached to two types of development programmes that focussed on enhancing science teachers' pedagogical content knowledge through the use of action learning methodologies. The programmes constitute case studies, and the key teachers, in each of the programmes, also constitute sub-cases.

The first case which is referred to as the *minor case study* was conceptualised as an informal, school-based, collaborative action research. This involved working with nine science teachers in a neighbouring high school and primary school in a newly established formal settlement (RDP[2] houses) 74 km south west of Johannesburg. Since the programme aimed at promoting both development and research agendas of entrenching a new culture of practice, inputs by the researcher had to be intensive, requiring a lot of dedication and commitment from the participating teachers. This programme did not take off and was aborted at the beginning of its second cycle. The core of this initiative, which was the building of a school-based community of practice, was undermined as the process was arrested through technical and contextual issues. Due to dynamics discussed in detail in chapter 4, the commitment and participation level of the nine teachers in the programme varied greatly. Research data which could be collected also varied.

In the second case which is the *major case study*, four teachers undertook self-studies on learning and teaching *chemical systems* as part of projects in a formal programme of study. The four teachers (two females and two males), with varying backgrounds, were from four very different high schools where they taught physical science at three different grades (10, 11 and 12). Two of the teachers were teaching in high schools in East Rand[3] (one school being on the premises of an old technical school). Another teacher was teaching in a township school south of Johannesburg, and the fourth at all-girls, former model C school east of Johannesburg. Former model C schools are government schools which used to be all white schools during the apartheid era, and now have a predominance of black students. The projects were built within the framework of this PhD study, to explore useful resource systems to support FET teachers as they grapple with the challenges of implementing a new topic in their classroom. *Chemical Systems* is a theme consisting of new topics in the

[2] Reconstruction and Development Programme(RDP) is a South African socio-economic policy framework implemented by the new government.
[3] The name for the urban Eastern part of Johannesburg.

curriculum, and therefore unfamiliar to many teachers. The project drew from research-based strategies, and teaching and learning resources, to create a rich environment to support them.

1.8 Researcher Positionality Statement

This study is within the qualitative interpretive paradigm, and several qualitative researchers (Carter, 1993; Tobin & Begley, 2004; Henning, 2004) argue for a clear account of who the researcher is, so as to make it possible for readers to make judgments about the biases she or he brings into the study. Two things I will elaborate on which have influenced my outlook on life and the role of education profoundly, are my educational and religious backgrounds and experiences. My multiple role in the first case study, as a mentor and science teacher developer in both primary and secondary schools, and as a researcher working towards a higher degree, as well as the dual role of a supervisor and the researcher in the second case study, requires that I should give my professional background in science education, especially in teacher development of primary and secondary school science teachers.

I am a black woman, who was born and bred in a small village of Bafokeng near Rustenburg in South Africa. My parents were among the first few South Africans to embrace the Bahá'í faith in the early 1950's, so I was brought up as a Bahá'í which profoundly influenced who I am. I completed my matric at an all girls' Catholic boarding school near Boshoek, close to Rustenburg. I then did my BSc Ed with the former University of Bophuthatswana (now North West University) which I completed in 1991. After my first degree, I joined JM Ntsime High school, teaching science at Grades 8 and 9 for two years. In 1993, I joined Marapyane College of Education as a science lecturer for three years. I taught first year Chemistry and first, second and third year Primary Science courses to teacher trainees at this college.

In 1996, I enrolled in the BSc honours in Science Education full time at Wits University and completed it that year. I then joined RADMASTE in 1997, as a Research and Development Officer until the present time. While at RADMASTE, I did my MSc part time and completed that in 2003. My main roles at RADMSTE involved development of research-based science learning and teaching materials, as well as running teacher development programmes to support the implementation of the new curriculum in schools. This experience deepened my understanding of the school science curriculum, and afforded me an opportunity to study and reflect on issues related to constructive approaches, for effective teaching and learning of science.

For my MSc, I was involved in the development of a Primary school micro-science kit. As part of this programme, I interfaced with education ministries in countries such as Rwanda, Cameroon and Mauritius, to train their delegates on the implementation strategies of the programme in their primary schools. This process broadened my horizons, and gave me a high level of exposure to science education programmes, and the types of issues faced by these countries. This work also attracted the National Department of Education (NDE) and funders, such as National Business Initiative (NBI) and Zenex Foundation, to sponsor programmes for schools which I coordinated in different provinces.

I also coordinated science and maths FDE/ACE programmes for several years, as well as developing modules, and taught science General Education and Training (GET) courses within these programmes. At the beginning of 2006, I went on study leave from RADMASTE for three years and joined the Marang Centre for Maths and Science at Wits school as a PhD fellow. As part of this position, I was involved in my own PhD research, as well as teaching and supervising students in honours' and masters' science education courses.

On matters of faith, even though I was brought up a Motswana in a small village, being amongst the first Bahá'í families in the whole of South Africa meant being opened up to an ever changing world of diverse human relations, as well as being constantly thrown out of one's comfort zone. The Bahá'í faith is quite revolutionary, in the sense that it has as its agenda, the unification and spiritualization of the whole planet. I developed a pioneering spirit and a paradoxical sense of belonging, as well as not belonging to any one place or any one racial group. I always have this profound longing to relate to people only on a spiritual level, irrespective of racial background. I also developed a critical eye on my own cultural practices, seeing cultures as potential resources for those who do not belong to them, and potential enemies for those who do.

The Bahá'í educational perspective is that all human beings have been created noble, with latent capacities which education alone can bring to bear, to ensure honour, prosperity, independence and freedom of peoples and their governments. Bahá'ís believe that every human being has been created to fulfil the dual purpose of their lives: to participate in their own individual transformation through participation in societal transformation. We also believe that the three capacities with which God has imbued the human soul, and which should therefore be the target of educational goals, are: the capacities of the heart (love), of the intellect (power) and of the will (justice).

Universal education, which must begin at infancy, is therefore a basic tenet of the Bahá'í faith. We believe that all humankind must be trained in spiritual and moral laws, as well as in both the arts and the sciences. Bahá'u'lláh, the prophet founder of the Bahá'í faith asserts that the real task of education is the pursuit of excellence and the aspiration to spiritual distinction, sincerity, loyalty, service to humanity, love, justice, peace, unity and the fostering of learning. The following quotation from the Bahá'í holy writings captures the essence of its perspective on education and the nobility of the human spirit:

> *Man is the supreme Talisman. Lack of a proper education hath, however, deprived him of that which he doth inherently possess. Through a word proceeding out of the mouth of God he was called into being; by one word more he was guided to recognize the Source of his education; by yet another word his station and destiny were safeguarded. . . . Regard man as a mine rich in gems of inestimable value. Education can, alone, cause it to reveal its treasures, and enable mankind to benefit therefrom". ("Gleanings from the Writings of Bahá'u'lláh", Sec. 122, pp. 259-60)*

1.9 An Overview of the Chapters

Chapter 2 Review of Literature

Chapter 2 is review of literature on the state of curriculum change in South Africa, and moves on to examine the broad literature on issues related to the kinds of challenges teachers face during times of curriculum reform, and the models of effective and innovative strategies employed in various science and mathematics teacher development programmes, as a support base for teachers during those times of change. The thesis does not only work with reflexive aspects, but also practical, conceptual and procedural aspects, critical for competent science curriculum implementation. The review of literature related to the new science curriculum also touches on the critical role played by beliefs and understanding of nature of science (NOS) in the effective implementation of this new curriculum. The thesis draws from cognitive, social constructivism, situated and socio-cultural perspective to foreground the focus on 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, as an effective response to challenges of teacher support during curriculum change. The role of misconceptions, with particular reference to fundamental concepts in learning and teaching chemistry, as well as the concept of chemical systems within the FET curriculum, is reviewed.

Chapter 3 Methodology and Conception of a Framework

This chapter provides an explanation of the research design and methods employed in this study, as well as the description of the processes followed and techniques used to collect data and ensure ethics compliance for the study. There follows a detailed discussion of how the *Learning for Teaching through participation* (LTtP) model which is an analytical framework used in this study, was conceptualised. The chapter ends by explaining how data in each of the case studies is analysed using the LTtP framework.

Chapter 4 Underlying the Journeys of the Heroines and Heroes

Any type of change will be embedded in a unique and complex context. Even though the main focus of this study is on how development of teachers' knowledge can be supported, contextual issues surrounding teachers' practice emerged strongly in the minor case study. In this chapter the aspect of the LTtP model, referred to as the *enveloping change environment* is used to capture and analyse the dynamics inherent in the unique settings surrounding the participating key teachers' practice. All the findings of the first case study which involved an aborted school-based action research programme, are presented with its analysis focussing mainly on the three most consistent participating teachers. The focus of analysis is both on the issues emerging from the programme implementation process, as well as those personal, academic and practice related challenges experienced by the teachers during the research process.

Chapter 5 Nature and Profile of Support and Dominant Change Force

Within the LTtP model, one of the three distinct domains which encompass the teacher's professional world is referred to as the *stimulation and challenge domain*. This domain captures professional activities and processes the teachers engage in to research, design as well as plan and reflect on their classroom implementations. In this chapter I present the analysis and contrasts in the designs of intervention programmes attached to the minor and major case studies. To highlight the challenges experienced and the learning accrued in this study, the Rogan & Grayson's *profile of outside support* construct was modified and used to analyse the strengths and weaknesses inherent in the modes of interventions applied in the two case studies. The programmes are contrasted with a focus on the following aspects of the *profile of outside support* (modified): first, *the purpose, the design and the extent*, second

nature of *collaborations*, *monitoring and accounting for learning*, *physical resource provisioning* as well as the *dominant force driving learning*.

Chapter 6 Planned Actions, Reflective Practice and the Shifting Knowledge Base

This chapter presents the findings of the major case study, involving the four teachers who undertook self-studies as part of their honours projects. This chapter specifically focuses on how each of the four teachers' knowledge base, on the three aspects of their PCK (science content, learners and learning and curricular saliency), shifts as they engage with the process of systematic and deliberate planning, designing and reflecting on their actions within the constraints and affordances of their working contexts. Each teacher's journey, with its independent features and processes, constitutes a unique case on its own and is therefore presented as such. The focus on this chapter is more on profiling issues of PCK and its development and therefore the LTtP framework is used to map and profile each teacher's PCK related experiences into a coherent whole.

Chapter 7 The Professed and the Practised

In this chapter, I report on the relationship of the participating teachers' beliefs about the nature of science, and about the teaching and learning of science with their classroom practices, as well as their progress towards learner-centred approaches. This chapter employs a cross-case analysis matrix to explore the consistencies and inconsistencies in the conceptions the teachers hold about the nature of science, science teaching and how learners learn with their actual classroom practices. The analytic model of this study is used to synthesise a profile of each teacher, on how their dispositions and beliefs about science relate to their classroom practices.

Chapter 8 Bringing it all Together

This chapter presents the main findings of the study by drawing the conclusions of the three preceding chapters together, discussing the patterns that emerge from them into one whole, while highlighting lessons from each of the cases. In this chapter, the main findings of the study are also linked to the literature by discussing their implications to the field of schooling, and science teacher development and training. The chapter concludes the thesis, by reflecting on the limitations of this study, as well as making recommendations and identifying future research areas.

CHAPTER 2
REVIEW OF LITERATURE

2.1 Introduction

In this chapter, I draw from both international and local research literature to critically examine issues related to implementation of the natural and physical science NCS, with the aim of trying to understand and explore how the teachers respond to these challenges, and the best strategies which could be used to support their efforts. I start this chapter by discussing the broad theoretical perspectives which underpin the framework which is used to understand the problem of this study, as well as to develop categories to analyse and interpret teacher learning during curriculum innovation. I then move on, to interrogate issues and challenges of curriculum reform in South Africa by drawing from both policy documents and local research. A review of literature on the nature of the new science curriculum, the critical role played by teachers' beliefs about science learning and the views they hold about the nature of science on the effective implementation of inquiry-based instructions, is also presented. In addition, literature on the role of misconceptions in the teaching and learning of science, as well as that with a particular focus on the topic of chemical systems at the FET phase is reviewed. I conclude the chapter by drawing from the above insights and relevant literature on innovative models of teacher support and development, which have proved to be effective in presenting the features of the framework adopted in this study.

2.2 The Theoretical Base for the Study

We have to admit that understanding a complex process, such as learning and, therefore, good teaching is a very abstract, as well as an extra-ordinary task. Lave & Wenger (1991) cater for this complexity by emphasising the importance of basing the field of education on explicit accounts of its different theoretical perspectives.

This study has a focus on the development of science teachers' PCK within the framework of the new science curriculum. As elaborated in section 1.5, the study employed action learning strategies to understand how teachers handle change in complex situations with the aim of identifying appropriate strategies to help meet their immediate classrooms challenges in implementing the new curriculum. On one hand the study seeks to develop the teachers'

competencies for curriculum implementation while evaluating their practices for curriculum compliance. Given the nature of the science curriculum and the challenges inherent in its implementation the problem of this study is embedded in four complex areas: curriculum innovation, the nature of science and its teaching, the gaps in the professional world of the science teacher and the contextual issues surrounding their working environments.

To bring a coherent and a holistic approach to the multi-dimensional aspects inherent in the problem of this study, I drew from cognitive constructivism and situated perspective to conceptualise a strategy for this study. Consequently, this study engaged teachers in self-studies, with a special focus on the development of PCK while approaching a topic which integrates the three science learning outcomes. The three physical science learning outcomes with the first having focus on the doing of science, the second on the content of science and the third on the relevance of science are quite significant to this study and are therefore discussed in depth in section 2.4.1 of this chapter.

In the two sections that follow, I justify the theoretical base of this study by showing the links between situated perspective and the action learning strategy adopted in this study as well as the link between cognitive constructivism and PCK as an adopted research construct. I also show how integration of self-study and PCK with the focus on their cognitive and metacognitive elements serves as a framework that fosters habits of praxis such as critical thinking, reflective practice thereby enculturating teachers into new norms, practices and habits of mind which are consistent with the effective implementation of the new curriculum.

2.2.1 The Cognitive Perspective

Cognitive researchers are interested in exploring representation of knowledge within human memory, and the higher mental activities involved in the process of knowledge construction by an individual (Nesher, 1987). Constructivism derives from both the history and philosophy of science, as well as from the psychology of learning. Piaget's cognitive development theory set him apart as a founding contributor in this field, whose work has inspired interest in the expansion of the constructivist theory of learning. Constructivists regard science knowledge as a social, as well as an individual construct, and recognise that learners come to instruction with prior ideas, which are often in conflict with accepted science concepts. The main emphasis is that learners build/construct their own knowledge and knowledge representations from their own experiences and thoughts, and therefore teaching should start

by considering the learners' existing conceptions (Hatano, 1996; Carr, et al., 1994; Smith, DiSessa, & Roschelle, 1993).

Student's misconceptions play a vital role in the acquisition of content knowledge. Hatano (1996) and Smith, DiSessa, & Roschelle (1993) take a critical stance on misconception research, which views students' pre-conceived ideas as mistakes that impede learning, and should therefore be confronted and replaced. They argue for a more constructivist view on the role of misconceptions in learning, where they are viewed as playing a very critical role in the learners' process of constructing their own scientific learning. They are opposed to viewing misconceptions as flawed ideas that interfere with learning, but promote a view that novice conceptions, including common misconceptions, play a productive role in the acquisition of more advanced mathematical and scientific understanding. Hatano (1996) asserts that knowledge systems, before and after restructuring, are different in organisation and that conceptual change in the history of science, and in cognitive development, are the best known illustrations of the restructuring of knowledge.

Smith, DiSessa, & Roschelle (1993) further argue for a view of learning as involving interrelationships among diverse knowledge elements, which require continuous re-organisation and refinement, rather than identification of flawed, replaceable conceptions. Nesher (1987) elevates the status of misconceptions to one that causes a series of errors, all resulting from an incorrect underlying premise, rather than sporadic, unconnected and non-systematic errors. Similarly, Hatano (1996) raises an important argument, that learners' conceptions (mathematical cognition) are robust and 'theory-like knowledge systems', and will therefore share, to some extent, the same features with all other theory-like systems, such as naïve physics.

Smith, et al., (1993) also argue that substantial conceptual change does not happen rapidly but that conceptual mastery is often preceded by a relatively stable intermediary state of understanding. Aikenhead and Jegede (1999) describe this shift from misconception to content knowledge as "border-crossing". They view misconceptions as either productive or unproductive, rather than as wrong or right, and suggest that productive and effective knowledge has its roots in, and therefore is constructed from these robust misconceptions.

Meaningful learning requires intense mental effort, and therefore demands continuous and sustained hard work from both teachers and students. Efforts to introduce such innovations

should be very carefully considered processes of enculturation of both teacher and learners, otherwise they can backfire.

2.2.2 Situated Perspective, Action Learning and Self-study

The situated perspective on knowledge generation locates learning in certain forms of social participation. This perspective to learning explores the context-embedded character of human understanding and communication. The present study explored teacher learning environments, and therefore situated learning, which brings together, learning processes with the contexts in which they occur, offered an appropriate theoretical base. Learning is viewed as a special type of social practice, associated with the kind of participation frame which is referred to as Legitimate Peripheral Participation (LPP) (Lave & Wenger, 1991).

Lave & Wenger (1991) argue that learning is the way of being in a social world, and not of coming to know about it. They see learning and acting as intertwined, with learning being a continuous, lifelong process, which comes about as a result of acting in situations. Learning is also regarded as a process of enculturation within a community of practice (CoP), which itself is intricately bound to socially constructed webs of beliefs which are essential to the understanding of its operations.

Amsel & O'Loughlin (1988), claim that people's ability to think, not only with their ideas, but about them, is the crucial step in the development of scientific thinking. Flavell (1981) argues that meta-cognition underpins all critical process skills that have to do with oral communication of information such as oral and writing comprehension, persuasion, language acquisition, attention, memorisation, problem solving, social cognition and diverse forms of self-control and self-instruction.

Situated learning promotes apprenticeship as a legitimate learning practice, because it allows for the activity of learning to simply become one aspect within the daily practice of the profession. Lave challenges the notion of schooling directly, by the following two strong criticisms: (i) it assumes that decontextualisation is a hallmark of good learning; (ii) it assumes that teaching or intentional transmission is a precondition for learning or that cases where teaching is not apparent, learning is not taking place. They argue that effective learning practices are those which break down the distinction between learning and doing, between social identity and knowledge, between education and occupation as well as between form and content.

Brown et al.'s (1989) notion of cognitive apprenticeship discussed fully in section 2.6.1, is not as revolutionary, and therefore serves as an alternative to conventional practices, to bring the ideals of situated perspective into the framework of schooling and classrooms. Cognitive apprenticeship promotes an approach that embeds learning in an activity that deliberately engages both social and physical contexts. They equate tools with knowledge, and argue against the notion that concepts are self-contained abstract entities; instead concepts are viewed as situated and progressively developed through activity. They argue that learning how to use a tool is context bound because use of that tool is framed by the way members of that community see the world and hence opportunities of using that tool only arises within the activities of that community of practice.

Another strong confirming argument is put forth by Cochran, DeRuiter, & King (1993) that understanding is situated or context-bound because social interactions are foundational and intricately bound to the development of the tools, and the understanding how they should be used. The idea of a school-based support programme is consistent with the notion raised by most social constructivists (Reid & Stone, 1991; Rogoff, 1990; Kass & McDonald, 1999), that learning is a social and context-bound exercise. Kass & McDonald (1999) argue that since learning is both a constructive and enactive process in which a person and a setting co-emerge, then the context in which learning is situated is critical to the whole picture. Hence the reason why the activities of the minor case study took place at the school and the teacher centre in the neighbourhood and the teachers in the major case study carried out self-studies on their own practices.

Studies such as Paris & Winograd, (2001), Kitchener (1983) and Flavell (1981) argue that, in order to be successful in providing an authentic instructional context, teachers must not only be reflective and analytical about their own beliefs, but must also acquire a profound understanding of both cognitive as well as motivational principles underpinning learning and teaching. Self-study is premised on the recognition that there is a disparity between one's teaching philosophy and one's actual practice, especially during the time of curriculum reform. Recognition of this living contradiction, as Whitehead (2000) refers to it, holds all the potency for any possible teacher growth. Self-study as a teacher training strategy and research methodology offers a framework to assist teachers to recognise and engage with this critical focal point for growth, by adopting a reflective and evaluative approach to their own teaching.

Bray, Lee, Smith, & Yorks (2000) define collaborative inquiry as a process which involves repeated episodes of reflection and action, through which a group of peers endeavor to answer a question which they all deem important. As reiterated in most studies (Kelly & Lesh, 2000; Dick, 1993; Schön, 1990; Kolb, 1984), the cycle of problem identification, action and reflection encourages changes in teachers' beliefs and in their classrooms. In this study, action learning was employed as an in-service training strategy that sought to equip the participating teachers with new skills and methods, aimed at sharpening their analytical powers as well as heightening their self-awareness. As Cohen, Manion, & Morrison (2007) puts it, action learning was also employed to inject innovative approaches to teaching and learning, into an ongoing system which is normally inhibits change and innovation. Most research (e.g. Roth, 2007; Schön, 1983) alludes to the fact that teacher reflection should form a central and critical part of professional educator responsibility, as it provides a continuous avenue for the teacher to consider many factors which should inform the decision on how to act in particular and varied situations.

Self-study is a research methodology which has in roots in teacher inquiry, action research and reflective practice (Samaras & Freese, 2006). A self-study is a self-initiated personal pedagogical strategy, which requires teachers to engage in a close monitoring and continuous justification of strategies they adopt through reflective practice within a collaborative forum. Methods employed in a self-study should therefore be interactive and responsive to what those who teach do, as well as capture the complexity of their work as practising teachers. PCK is a research construct that integrates practice and teacher knowledge and hence ensures that teachers' subject matter knowledge is not only referred to but actually takes the centre stage in teacher professional development.

Inevitably, self-study and action research share a lot in purposes and practices, but what differentiates the two is that, while action research has its focus on action and the development of a plan of action, self-study has a focus on the self and the development of the self, on both the personal and professional level.

Action research as seen in this study is a process by which change and understanding can be pursued simultaneously (Dick, 1993). There are various definitions for action research found in the literature (Cochran-Smith & Lytle, 1993; Dick, 1993; Kolb, 1984; McNiff, 2002). There have also been attempts by various authors (Calhoun, 1993; Cochran-Smith & Lytle, 1993; McKernan, 1988; Rearick & Feldman, 1999) to develop classification schemes by

comparing and contrasting, as well as tracing the development of various models of action research. McKernan (1988) identified three categories of action research, based on an ideological perspective. The first category is *traditional AR*, which seeks resolution within the system and is based on the premise that participants have common interests and share consensus in problem resolution. The second is *collaborative AR*, which stresses school reform and has as its goal the reformation of curriculum and the development of teachers' research skills. The third category referred to as *critical emancipatory AR* is rooted in critical theory; it is critical of the status quo and it therefore seeks to reform the wider social structure.

Based on McKernan's (1988) classification scheme, this study can be categorized as *collaborative AR*. The definition of action research below by (O'Brien, 1998) captures the essence of this study which:

> *… aims to contribute both to the practical concerns of people in an immediate problematic situation and to further the goals of social science simultaneously. Thus, there is a dual commitment in action research to study a system and concurrently to collaborate with members of the system in changing it in what is together regarded as a desirable direction. Accomplishing this twin goal requires the active collaboration of researcher and client, and thus it stresses the importance of co-learning as a primary aspect of the research process.*

As explained by Cohen, Manion, & Morrison, (2007), in action research two professional bodies, like researchers and a group of teachers, each with their own objectives and values, are brought together to work collaboratively. They argue that, even though both parties could share the same interest in an educational problem, their approaches would differ in that what is important for researchers is precision, control, replication, with the aim of being able to generalize from specific events, while teaching, on the other hand, is concerned with translating generalizations into specific acts. They see this incompatibility between action and research as constituting the source of a problem. What has emerged in reviews of a number of American community action programmes is that the principles of action and experiences research differ so much, often being also mutually exclusive, that attempts to link the two into a single process, are likely to produce internal conflict and the subordination of one element to another (Marris & Rein, 1972).

Bodner (2004) explains action research as a cyclic process where changes are made, their effects are studies and modifications are effected with the aim of continuously increasing the positive effects and minimizing any negative effects on the target population. Unlike in quantitative approaches to research or program evaluation, where innovation is withheld from

half of the population, with the hope that statistical evidence of its efficacy will arise during the course of the study, action research begins by assuming that the innovation will have an effect, and tries to maximize its benefits and minimize its disadvantages (Bodner, 2004).

Bray, Lee, Smith, & Yorks (2000) define collaborative inquiry as a process which involves repeated episodes of reflection and action, through which a group of peers strives to answer a question which is of importance to it. As reiterated in most studies (Kelly & Lesh, 2000; Dick, 1993; Schön, 1990; Kolb, 1984), the cycle of problem identification, action and reflection encourages changes in teachers' beliefs and in their classrooms. In this study, action learning as a strategy was employed as a means of in-service training to equip the participating teachers with new skills and methods, to sharpen their analytical powers and to heighten their self-awareness. As Cohen, Manion, & Morrison (2007) expound, it was also employed as a means of injecting innovatory approaches to teaching and learning, into an ongoing system which normally inhibits innovation and change. Most research (e.g. Roth, 2007; Schön, 1983) alludes to the fact that teacher reflection should form a central and critical part of professional educator responsibility, as it provides a continuous avenue for the teacher to consider many factors which should inform the decision on how to act in particular and varied situations.

Loughran, Berry, & Mulhall (2006) assert that, for teachers, thinking about teaching is a complex task and that it is important to promote ways of sharing teachers' professional knowledge of teaching to further enhance understanding of teaching and learning in science. Many studies (e.g. Appleton & Kindt, 1999; Graven, 2002; Gunstone et al., 1993) acknowledge that collaborative support can encourage innovation, boost teacher confidence, foster professional enthusiasm and, more importantly, reduce the teacher's isolation. The study done by Graven (2002) confirmed that teacher learning in in-service contexts, is a social process that demands a socio-cultural perspective to do justice to the complexity of the social factors influencing it. One of the main focuses of that study was to investigate the role of confidence in mathematics teacher learning, and how this confidence should be constructed and understood from a social perspective.

Goodnough (2003) enhanced her understanding of what action research process entails by using the process of reflective practice to foster collaborative inquiry in the context of an action research group. While working with a group of four science teachers, she engaged in critical self-reflection about her dual roles of a researcher and a facilitator, to explore multiple

intelligences (MI), in the context of science education. She found out that, even though the action research group collaborative spirit was good and the group was highly motivated with high levels of trust , but still there were always several challenges and tensions throughout the process. Most tensions which emerged for the participants were around the constraints of time. They found that the planning and implementation of MI theory and student-centred activities was time consuming and that data collection and analysis, especially making journal entries was far too demanding and added to their already heavy workloads. What Goodnough (2003) learned in her study was that, in order to fulfil the role of establishing a context where individuals involved are able to reach their goals, a facilitator of the action research group is required to exhibit considerable flexibility. Another important finding was the realisation that it was only through critical self-reflection and group discourse throughout the process, that one is able to know when to assume different roles or meet changing needs and contexts. These experiences are critical for this study and will be taken to heart during the process of this study.

Harris & Anthony (2001) explored the nature of collegiality and its role in teacher development by analysing two sets of data. One was an analysis of an interview with a veteran teacher, reflecting on her 30 years of experience in teaching, and another set was an analysis of the conversations of six beginning teachers, as they participated in a shared inquiry group. From these analyses, the dynamics of two different types of relationships emerged, one that provides a supportive working environment and the other that results in significant professional growth.

What is of great significance to the present study are the arguments Harris and Anthony (2001) raise about the challenges of initiating sustainable collegial relations in professional development, and the nature of relationships that characterize genuine and effective collegial spirit. They argue that, for colleagues to truly collaborate and take ownership of the process of inquiry together, it is critical that they have some shared values, goals and a common vision of teaching. Another critical point raised is that the relationships must be characterized by trust, care and mutual respect. It is also important that the participants are comfortable sharing self-doubts, without being made to feel like failures, as well as be able to celebrate success without feeling arrogant. A non-judgmental atmosphere should be created, such that the participants are willing to receive both constructive feedback and reinforcement.

Another critical challenge is that because of the nature of the process of engaging in collaborative enquiry, which is both demanding in terms of time and effort, commitment from all participants is essential. An even more complex challenge raised is that, even though formation of such relationships need to be fostered and should not be left to chance, they at the same time cannot be prescribed. In my opinion, the only way the process can be sustained lies in the extent to which the programme is of immediate relevance and benefit to the learning and teaching contexts of participants, and, of even more importance, on how the experience of participation in the process will continue to arouse enthusiasm and passion from the participants.

As already argued in section 2.2.1 on situated learning, one other reason for preferring collaborative action research is that learning is a process that takes place in a participation framework, not in an individual mind. This means, among other things, that it is mediated by the differences of perspective among the co-participants (Lave & Wenger, 1991). Learning, as explained by Vygotsky (1978), awakens a variety of internal development processes that are only possible in the context where the learner is cooperating with peers and interacting with people in his environment. I concur with Geddis (1991)'s argument that as teachers begin to conceptualise the central intellectual task of teaching as that of transforming content knowledge into forms that are accessible to learners, this would motivate them to start engaging in action research, reflective practice and collegial relations, with the aim of enriching and exploring their own grasp of content, their learners' prior conceptions, as well as plausible reasons why learners hold these conceptions.

Inevitably, self-study and action research share a lot in purposes and practices, but what differentiates the two is that, while action research has its focus on action and the development of a plan of action, self-study has a focus on the self and the development of the self, on both the personal and professional level. Self-study is a self-initiated personal pedagogical strategy, which requires teachers to engage in a close monitoring and continuous justification of strategies they adopt through reflective practice within a collaborative forum. Methods employed in a self-study should therefore be interactive and responsive to what those who teach do, as well as capture the complexity of their work as practising teachers.

Samaras & Freese (2006) point out that self-study is paradoxical in nature, because even though it is about the individual, it requires collective and collaborative participation; even though it is a personal journey, the process is interpersonal and collaborative; and even

though it is a private endeavour, it is public because, as a form of validation, it requires a continuous process of making one's findings available for public scrutiny.

There have been recent and various studies using self-study as a research methodology, where teacher educators (Guðjónsson, 2007; Strong-Wilson, 2007; Loughran, 2005; Lougran, Hamilton, LaBoskey & Russel, 2004) and teachers themselves (Thomas & Manroe, 2006; Pitjeng, 2011; Ndlovu, 2012) studied their own practice, and where self-study was used as teacher learning in professional teacher development (Hoban, Butler & Lesslie, 2007). Self-study has proved to be a good strategy to support teachers to engage with deep issues in their practices. In a study, where Hoban et al., (2007) worked with two elementary teachers who undertook self-studies of their learning during a professional development programme, they found that one of the teachers appreciated and learned a lot about the dynamics involved in her own learning and how to manage that, while the other learned about the importance of analysing her own teaching approaches to get to the root of the epistemological underpinnings of her practices.

2.2.3 The Notion of PCK as a Research Construct

In the following section, I discuss how Shulman first came up with the construct of PCK, and review literature on the main challenges of working with PCK as a research tool, how the concept is perceived and the various ways different researchers took it forward. In this study, PCK is used as a lens to map the development of the participating teachers towards reform-aligned strategies. I then move on to review literature of the case studies which inspired this research.

Most of the recent research in the science knowledge for teaching field has been inspired by the works of Lee Shulman (1986; 1987). According to Wilson, Shulman, & Richert (1987), when teachers prepare to teach their content, as well as during instruction, they develop knowledge that is enriched and enhanced by other types of knowledge such as: knowledge of the learner, knowledge of the curriculum, knowledge of the context and knowledge of pedagogy. This form of knowledge is referred to as pedagogical content knowledge. Shulman (1986) conceptualised PCK as a form of content knowledge that

> *... 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 representations of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations – in a word the ways of representing and formulating the subject matter that make it comprehensible to others .... Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different*

ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. If those preconceptions are misconceptions which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganising the understanding of learners …' (pg 9)

Around the 1980s in the United States of America, Shulman was part of the debate about whether teaching should be regarded as merely skilled work or whether it qualifies as a profession, such as law and medicine (Kind, 2009). Shulman's contribution to these debates was to offer a model which established teaching as a profession. He however firstly acknowledged that, unlike established professions, such as medicine and law, the 1970s and 1980s debates on the analysis of teachers' skills and competencies, left behind critical questions about teaching. He directly raised the question '*where did the subject matter go* (1986, p. 11)*?'* to highlight what he referred to as the missing paradigm in teacher knowledge research.

He put the nature of content for instruction in the spotlight, by cautioning against focus on teacher behaviours, and moved towards centring teacher thinking as the 'process' of teaching – in essence, involving active transformation of teacher knowledge.

To unravel this challenge, he drew from philosophy, psychology and case work to try to respond to the four questions he posed about the specialized knowledge base for teaching:

1. What are the sources of knowledge base for teaching?
2. In what terms can these sources be conceptualized?
3. What are the processes of pedagogical reasoning and action?
4. What are the implications for teaching policy and educational reform?

He coined PCK as one of seven categories of teacher knowledge. His foundation for teaching reform was built on the idea of teaching that emphasized comprehension and reason, as well as transformation and reflection (Shulman, 1987).

One challenge of working with the concept of PCK is that, since Shulman's initial work, the term has been conceptualized in various forms by different authors. Alongside inputs from other researchers, Shulman and his colleagues also continued to refine and redefine this concept further. Another is that, because of its tacit nature, it is very difficult to capture, portray and share knowledge of practice in ways that are intelligible and meaningful to others.

Several researchers (e.g. Kind, 2009) agree that the field of Science Education would benefit greatly from understanding the types of factors and influences at play, in producing effective

science teachers, and knowing how these can be used in developing pre-service teachers' PCK. Abell (2007) argues that science education PCK literature is lacking, because researchers working in this field continue to introduce new constructs into the literature without building on each other's preceding work. This makes categorisation of work in this area very difficult. To this end, three different reviews (Van Driel, Verloop, & de Vos, 1998; Abell, 2007; Kind, 2009) surveyed literature on science teacher knowledge and PCK, thereby bringing some coherence and clarity into what progress has been made in this field of study.

In their article, Van Driel, Verloop, & de Vos (1998) surveyed five studies, and provided a useful analysis of conceptions of PCK portrayed by the different authors. A close look at their summary reveals that Grossman's (1990) model shares the same features as Shulman (1986), in that they both separate subject matter knowledge (SMK) from PCK. Cochran, DeRuiterr, & King (1993), on the other hand, consider SMK as a sub-category of PCK. An analysis of the PCK models portrayed by the five studies, varies in terms of their incorporation of the following features in their PCK definitions: student learning and conceptions, representations and strategies, subject matter and curriculum, context and purposes and general pedagogy.

One way of looking at the various models in the PCK literature, is to categorise them according to how they describe PCK and SMK (Kind, 2009). One line of thought (e.g. Grossman, 1990; Magnusson, Krajcik, & Borko, 1999), follows Shulman's model, where PCK and SMK are considered as two distinct categories, and PCK is seen as a special kind of knowledge the teacher uses to transform SMK to make it accessible to learners. The other line of thought is of those (Marks, 1990; Cochran, DeRuiterr, & King (1993) who do not recognise PCK as a distinct knowledge category, but see it as the knowledge the teacher has and applies in the classroom, thus merging it with SMK which is regarded as its sub-category. Gess-Newsome (1999b) offers a helpful frame: models which consider PCK and SMK as related but distinct categories are regarded as transformative, and those which consider SMK as a subcategory of PCK as integrative. Even though this study follows a transformative line of thought, it draws its strengths from an integrative approach, to try to conceive a holistic framework of empowering environments for the development of science teacher PCK.

In her theoretical paper, Kind (2009) analysed various PCK models proposed in the literature, as well as the methods put forward to shed light on experienced and novice teachers' PCK, to try and clarify how the potential offered by PCK could be exploited to enhance science

teacher education. She reiterated that the quality of inputs made in science teacher education could be greatly improved, by using PCK more actively to engage and help both novice and experienced teachers to understand what PCK is, and how it can benefit and enhance their professional growth efforts. She further recommended the adoption of a transformative model of PCK for initial training, or in situations where teachers are learning to teach a new subject, as well as explicit use of PCK and its tools (e.g. CoRe) in teacher development programmes to develop reflective practice skills. The third aspect she called attention to is the emotional side of becoming and being a teacher, which includes analysis of belief systems, as well as confidence and self-efficacy.

Another review on science teacher knowledge was done by Abell (2007), with the main thrust of her review being to establish whether the varying epistemological and methodological assumptions, guiding studies of subject matter knowledge (SMK), lead to the same or different conclusions. She concluded that research on PCK is not as well organised and coherent as that on SMK, because researchers in this field do not build on previous studies or reference the same body of literature; hence they do not agree on terminology and methodology. She argues that conceptual frameworks in this field should be made explicit and should be grounded on whether the new terminologies and variations brought in are conceptually necessary to expand understanding of science teacher knowledge. She calls for more studies which are bound in the teaching context, and can elucidate on how teacher knowledge affects students, and how SMK develops and plays out in the teaching context, in relation to other kinds of teacher knowledge.

Even though this thesis emphasises teacher learning environments for supporting teacher practice, PCK as a construct ensures that the development of teacher knowledge is implied and actually takes centre stage. Since this thesis aims to contribute towards identifying appropriate strategies to support the teachers in their efforts of orienting their practices towards curriculum aligned approaches, elucidation of how their science SMK relates to their other knowledge domains, in practice became a natural outcome. To frame exploration of how science teachers respond to the challenges of implementing a new topic within the new science curriculum through self-studies, was a deliberate move. This allowed exploration of how the different teacher knowledge domains interact and the types of factors that emerge as affordances or constraints to their efforts. This framework ensures a capture of both subject and topic specific aspects of the development of the teachers' PCK.

Another challenge facing those investigating PCK is its tacit nature. Even though PCK is potentially a valuable resource which could be a shared, the challenge presented by its tacit nature, it is not an easy task to capture, portray as well as to share this knowledge of practice in ways that are meaningful to others. The work of Loughran, Mulhall, & Berry (2004) was motivated by this challenge where previous research did not address ways in which PCK of science teachers could be captured, codified as well as portrayed, , in ways that makes it accessible to and useable by other teachers. Loughran, Berry, & Mulhall (2006) argue that, as teachers share their knowledge through stories, anecdotes and other forms that offer brief glimpses into their expertise and skill in the classroom, these forms of sharing do not highlight that teachers are in fact producers, and not just users of a sophisticated knowledge of teaching and learning. They further argue that the complexity, associated with exemplary practice, will only be effectively portrayed and shared in meaningful ways, if labels and descriptors such as PCK are better understood and used. They recognize the language that comprises aspects of professional practice as being critical and central to moving knowledge of practice away from individuals, and into the professional community (pg 15).

2.2.4 Review of Rich PCK Case Studies

As argued in several studies (Geddis & Wood, 1997; Shulman, 1986), the case method is a powerful tool that can contribute to both our theoretical and practical knowledge of teaching. It allows the capturing of a detailed and rich picture of the phenomenon under examination. In this study, PCK is used as a lens to map the shifts in the development of the participating teachers, towards reform-aligned strategies, as they attempted to teach a new science topic for the first time. Therefore, the selection of rich cases to review was partly based on PCK, as a lens to distinguish between productive and unproductive teaching, as well as cases that focused on the three critical aspects of the new science curriculum which are central to a secured SMK: positioning learners at the centre of learning, shifts to inquiry-based approaches and aspects surrounding learning to teach a topic for the first time.

Studies in the field of PCK (Tiong & Aun, 2004; Geddis, 1993; Shulman, 1986) put emphasis on the central intellectual task of teaching as that of transforming content knowledge into forms that are accessible to students. Even though this might not be obvious to novice and ill-trained teachers, this crucial task of teaching is the one that distinguishes effective from non-effective teaching strategies. Achieving good and effective teaching in a specific learning area is a very abstract process, yet those who have never taught may undermine this task and

fail to appreciate its dynamic and abstract nature until they themselves are faced with the challenge and the responsibility of doing it. The lack of appreciation of this intellectually demanding task is what leads to many ineffective methods employed by many teachers in their classrooms.

A. The role of SMK in PCK of In-service, Pre-service and Novice teachers

Several studies (De Jong, Van Driel, & Verloop, 2005; Magnusson, Krajcik, & Borko, 1999) assert that the development of PCK is a complex process, which is dependent on several aspects, including the nature of the topic, the context in which the topic is taught and the way in which the teacher reflects on teaching experiences. Some studies (Shulman, 1986, 1987; Abell, 2007; Lederman, Gess-Newsome, & Latz, 1994) allude to the centrality of SMK to teachers' effectiveness. Loughran, Berry, & Mulhall (2006) argue that much of research done on PCK so far, reflects that interest in this construct did not necessarily aim to find ways to help teachers improve their practice.

Geddis (1993) worked with a group of pre-service secondary science teachers to explore how the concept of PCK can play a critical role, first in emphasizing the need for teachers to transform content knowledge into forms that are accessible to children, and second, in training teachers to reflect on how to accomplish this transformation. The strategy used in this study was to first allow the teachers to confront their own misconceptions about the topic. The study illustrated that, as a group of teachers reflect together on learners' misconceptions about a specific science concept and try to understand the manner in which learners might reasonably hold such conceptions, this created opportunities for acquiring subject matter representations and teaching strategies which have the potential of promoting the reasoned adoption of a scientific view of this concept in their learners. Since some of the teachers held the same alternative conceptions as those commonly held by learners, it was easy to relate to where learners were coming from, and to move on to try to formulate strategies of how to best assist their learners to overcome their learning barriers.

Bucat (2004) points out that a prerequisite to generating PCK about a given topic is an analysis of the 'sorts of knowing' that will enrich one's understanding of that topic. In their study, Van Driel, Verloop & de Vos (1998) investigated the effects of participation in an in-service workshop, and conducting an experimental course in the classroom on participating teachers' PCK. They worked with a group of 12 experienced teachers in a long-term three cycle research project in the Netherlands, focusing on the topic of equilibrium. The case

study explored in the paper (Van Driel, Verloop, & de Vos, 1998) focused only on the in-service workshop which was part of the third cycle of the study. What the study revealed was that teaching experience is a major source of PCK, and that thorough and coherent knowledge of subject matter is its prerequisite. They claim that craft knowledge guiding experienced science teachers' classroom practice, is constituted by a framework that integrates knowledge and beliefs about the teaching and learning of science, the nature of science, subject matter and students. Their argument is, since science teachers' craft knowledge is often reported to hinder the innovations of science education, then understanding of teachers' craft knowledge is a vital source for in-service and pre-service teacher education that aims to improve science teaching practice.

Their study informs the present study by providing general guidelines for the design of teacher training programs which aim to develop PCK. They argue that if such programs focus on enabling teachers to study the subject matter knowledge of specific topics from a teaching perspective, then their own subject matter knowledge will improve from exploration of the structure and evolution of students' ideas about particular topics. They further propose that these programs should provide opportunities to use PCK in teaching situations, and to reflect on these practical experiences. In addition to these general guidelines, they suggest that a course on topic related PCK should include activities that give teachers opportunities to a) critically review school books; b) perform scientific experiments and c) study authentic student responses.

There are surely noted parallels between experiences of novice teachers, pre-service students during their teaching experiences and experienced teachers teaching topics outside of their field of expertise. This study takes interest in those parallels because it explored the development of the participating science teachers as they approached a new topic within the framework of the new curriculum. Several studies on beginning teachers (Geddis & Wood, 1997; Grossman, 1990; Gallagher & Tobin, 1987) attest to the fact that many novice teachers seem to perceive the task of teaching as simple transmission of content in an intact form to their students. In line with this view, they normally take the responsibility of preparation for teaching, as simply to review or study the subject matter that they plan to transmit to their students.

There is a case to re-look at strategies employed in teacher education, especially in the light of student teachers' maintaining that they learn more about teaching during teaching their

teaching practicals (experience) than in their professional preparation courses. The Geddis & Wood, 1997 study is an interesting one, because it focused on the experiences and dilemmas of an experienced teacher educator, while trying to develop PCK of his pre-service students (novice teachers). With Wood playing the role of both the researched and the researcher, the study gives a rich picture of the complexities and the dynamics surrounding the task of teacher preparation. They highlight the uncertainty in teaching, both as a result of pre-service teachers being novices in the field, as well as the inevitable uncertainties inherent in the nature of the teaching task itself.

Geddis (1993) also argue that teacher educators are faced with a unique problem they refer to as the *problem of familiarity*, which is not known in the preparation of other professionals. Since preservice teachers, unlike other novices, have spent many years as students in the teaching work context, they normally feel that there is little for them to learn until they are faced with a class full of learners. This attitude normally leads to a reality shock which has the potential of paralysing their professional growth prospects. Instead of being led into a path of innovative exploration of the teaching and learning possibilities and opportunities before them, the novice teachers normally retreat into an authoritarian disposition in their efforts to survive the shock and gain some ground.

The case study of Wood illustrates how he worked with his mathematics methodology class to try to overcome some of these challenges. The aim was to empower the learners to develop a *disposition of examining their own thinking and learning as a basis for drawing inferences about how to teach* (pp 618). He modelled this in his own instruction, as well as offering his students opprotunities to develop these metacognitive skills. He chose to work with addition of integers deliberately, to ensure that the content they used was familiar, as well as to demonstrate that teaching is a different ball game which needs thorough preparation because, even if one is dealing with the simplest and most basic of topics, a successful lesson requires the need for deep critical analysis.

He used a threefold strategy which aimed at:

- Making the complex, uncertain nature of teaching explicit to his learners
- Reducing the uncertainties by providing scaffolds in the form of routines and tools which could serve to offer some level of achievable comfort
- Situating these routines within the context of career long professional growth

Hashweh (1987) examined the effects of SMK of six experienced science teachers, three with physics and three with biology specialisation, on their planning for instruction and their simulated teaching. They worked with photosynthesis as a biology topic and levers as a physics topic. He found that within their fields of expertise, the teachers possessed rich and versatile topic knowledge, which was apparent in their knowledge of high order principles inherent in their particular discipline, as well as in their capacity to coherently make concept connections, even with other entities within the discipline.

What was of even greater significance was that he was able to link strong SMK to other aspects, such as the teachers' capacities to transform materials during planning into innovative activities, effective and versatile responses to critical incidents during lesson delivery, as well as being able to pose higher order cognitive level questions. Outside their area of specialisations, the teachers were out of depth and exhibited qualities normally associated with novice teaching, such as relying on teacher centred transmission of knowledge, heavy reliance on textbook information and asking low order recall questions.

In another related study, Sanders, Borko, & Lockard (1993) investigated similarities and differences that emerged, as three experienced science teachers taught topics within and outside their areas of specialisation. They found out that, in some aspects of their teaching, all three teachers exhibited characteristic novice authoritative practices when teaching outside their field of expertise, but were more in charge, talked less, involved students more and engaged them in riskier activities when operating within their area of specialisation. Carlsen, 1993's work also revealed that, when teaching an unfamiliar topic, his four participating Biology trainee teachers exhibited fruitless teacher-centred tendencies of engaging learners less while they themselves talked more often for extended periods, and also relied on frequently asking their students low cognitive level questions.

B. Cases on knowledge of learners' Prior Knowledge and learning

As Geddis (1993) put it, PCK is critical for effective teaching because, in order for the teacher to be able to transform subject-matter content knowledge into a form accessible to students, she or he needs to know a multitude of particular things about the content that are relevant to its teachability. Outcomes of several studies (Briggs & Holding, 1986; de Vos & Verdonk, 1996; Papadimitrou, Solomonidou & Stavridou, 1997) into learners' alternative

conceptions about science ideas have really captured and elucidated the complexity of learning and teaching of science. Research in this field draws from the social constructivist perspective, and is based on the premise that students' learning is influenced by their own personal cognitive frameworks which came about due to their prior experiences and by the ideas of the culture in which they live.

Luft (2009) takes the debate further, by associating the understanding of the importance of placing students at the centre of teaching, with responsive and reformative teacher beliefs. She argues that those who cannot understand this central aspect of good PCK are unlikely to engage in the reorganization and reconstruction of their instruction, and tend to stick to instructional choices that are static and teacher-centred. Leou, Abder, Riordan & Zoller (2006) argue that, despite the fact that many teachers regard their questioning strategies as their most powerful teaching avenue, research indicates that most teachers do not encourage inquiry and problem solving but rather employ lower-order cognitive skills such as recall, memorisation and application of algorithms to familiar situations to engage their learners.

As Loughran, Berry & Mulhall (2006) argue, effective or successful science teaching is more likely if the teacher is not only knowledgeable about common student alternative conceptions, but also draws on this knowledge to shape teaching. This will require the teacher to engage in a complex process of mediating learning, as opposed to just being a transmitter of knowledge.

This role of teachers is intellectually complex in that it requires the teachers to engage in monitoring their learners' understanding in ways that allow them to be responsive and supportive to their cognitive needs by creating opportunities that facilitate their full grasp of the concept under consideration (Loughran, Berry & Mulhall, 2006).

In my opinion, this intellectually complex process requires that the teacher has certain conceptual tools to support her/his efforts. In the paragraph below, Hewson, Beeth & Thorley (1998) capture the complex nature of this intellectual task demanded from teachers.

… they need to know the content of the science curriculum, its associated pedagogical content knowledge, the range of its ideas that their students are likely to hold about the content topic, an understanding of conceptual issues significant in the historical development of the topic, and the empirical underpinnings of the of the content. They also need to be founded in philosophical issues related to the nature of scientific knowledge (e.g. its methods of inquiry and epistemological foundations.

Several studies (Brodie 2006; Hill, Ball, & Schilling, 2008) turn this debate on its tail by showing how working with learner's responses and recognition of the status of these responses, is more than just right or wrong, and can serve as a strategy to help teachers

acquire PCK. Along this line of thought, other studies (De Jong, Van Driel & Verloop, 2005); Van Driel, Verloop, & de Vos, 1998; Geddis, 1993) which have endeavoured to develop teachers' PCK, demonstrate that considerations on addressing the learners' alternative conceptions in science, as well as construction of plausible reasons to give to learners, in attempts to address these preconceived ideas, is fertile ground for establishing reflective practice and the spirit of collegiality among science teachers.

C. PCK in Inquiry Based Teaching

According to Clermont et al., (1993), PCK can be enhanced through intensive, short-term, skills-oriented workshops. In another study, Tiong and Aun (2004) worked with a group of 33 secondary school physics teachers over a 30 hour in-service course with the aim of developing their PCK using a Group Investigation approach. Their study reveals that a group investigation approach with its four basic features of investigation, interaction, interpretation and intrinsic motivation, serves as a good tool for the development of PCK within an inquiring community of teachers. In their paper, they offer useful resources around which they organised their programme which I will modify and use for the purpose of this study.

Mamlok-Naaman et al., (2005) studied the development of PCK of a group of seven experienced chemistry teachers, through their experiences of participating in an evidence-based continuous professional development programme. The study, which took place in Israel, involved three-hour monthly workshops with the teachers over a period of one year, reflecting on and sharing their experiences of initiating and sustaining an inquiry approach to their chemistry learners, using a teacher package which was developed by the researchers. The main goal of the project was to develop a continuous professional development programme that engaged classroom teachers in collaborative research, which aimed to support them to develop a set of characteristics and protocols, assembled in the form of a portfolio that can be used to demonstrate evidence-based accomplished practice in science.

As in South Africa and most parts of the world, their study showed that teaching science, using an inquiry approach, presents both teachers and learners with challenges in Israel. So another aim of the programme was to give the teachers an opportunity to undergo an intensive process of professional development, so as to allow them to experience the same skills, knowledge and thinking habits they were supposed to promote and nurture in their learners, as well as to undergo the entire enquiry process themselves, so that they are better equipped to instruct their learners.

What will greatly inform this present study is Mamlok-Naaman, Taitelbaum, Carmeli, & Hofstein (2005)'s findings that the structure of evidence that they developed served as a suitable tool, around which meaningful discussions were held which promoted meta-cognitive skills and encouraged teachers to reflect on their instruction in a systematic way. What they found to be challenging to the teachers was gathering and presenting evidence from their classrooms. The difficulties which emerged were typically around defining the objectives for presenting certain artefacts, and then analysing the data and drawing conclusions for future instruction.

Their findings confirm Borko & Putman's (1998) findings, that chemistry teachers should develop a different and new PCK, in order to become competent in teaching using an inquiry approach. The study revealed that different teachers used different ways of support while implementing the inquiry approach for the first time. The variation that emerged, ranged from a very high level of scaffolding from a colleague, in which every step taken in the experiment, every decision and student assessment are discussed, to postponing the time of inquiry and making observations during an expert teacher's lesson before teaching that lesson oneself. Others prefer to implement one skill at a time, rather than all at once as a whole programme. What will serve to inform this present study are the findings that indicate the potential of evidence-based portfolio construction in meaningful professional development of teachers and that for teachers to be able to build these portfolios, they need constant support and scaffolding at all stages of their work.

2.3 The South African Education System and its Challenges

As already discussed extensively in the last chapter, the South African education system, and therefore its curriculum, has been undergoing innovations to match the aspirations of the post-apartheid government, which is experiencing a complex socio-political context. It is a difficult balancing act, and we have witnessed quite a number of series of changes in the system which began immediately after the country's democratic elections in 1994, where new curriculum policies were ushered in and then terminated quite sporadically as new alternatives were put in place. The formal schooling system in South Africa is organised into the following three levels:

- General Education and Training (GET) which ranges from Grade R to Grade 9;
- Further Education and Training (FET) which ranges from Grade 10 to Grade 12;

- Higher Education (HE) and Training, also known as Tertiary Education, which provides the highest level of education.

2.3.1 The Background of the South African Education System

In March 1997, the South African government launched Curriculum 2005 (C2005). which was to be introduced in GET and FET phases. This marked a great change in the education system, because C2005 (DoE, 1997) with its three distinct philosophical features of learner centredness, outcomes based (OBE) and integrated approach to knowledge (Chisolm et al., 2000) presented a profound shift of how curriculum and teaching were to be understood. OBE is an educational approach in which decisions about the curriculum are driven by a designated set of exit learning outcomes which the students should be able to demonstrate at the end of the course.

Due to confusion brought by issues related to a lack of clarity from an elaborate yet cumbersome framework, the Ministry of Education called for the streamlining of C2005 two years later, before it was implemented in the FET phase. This resulted in the Revised National Curriculum Statements (RNCS), which became policy in 2002. As C2005 had only started at the GET level, the RNCS document addressed the requirements of the GET phase only. It was only in 2003 that the National Curriculum Statement (NCS), which addresses the teaching and learning in the FET band, was ushered in.

Even though the rolling out of these new curriculum policies in schools was done incrementally from one grade to another, what was very significant is the frustration resulting from imposing an idealistic and ambitious curriculum on the realities of the socio-economic and political crisis described above. In the physical sciences curriculum, the result of this conundrum took the form of a retreat from the vision of equating and addressing scientific inquiry and the STS focused learning outcomes with the content focused one (Nakedi, Taylor, Mundalamo, Rollnick & Mokeleche, 2012), a vision which was meant to set the curriculum on a progressive global trend.

The curriculum in operation at the time of the study was the NCS. The NCS as expressed in a National Curriculum Statement (DoE, 2003), claimed to provide the foundation for the fulfilment of the country's constitutional aim of establishing a democratic nation through nine principles that underpin the curriculum (Nakedi et al., 2012). The NCS also claimed to offer learners three different pathways, which can be followed after completion of the compulsory

phase (end of grade 9). The general pathway is offered in schools through completion of grades 10 to 12, while FET colleges prepare learners for vocational work through the general vocational pathway, and industry-based providers offer the trade, occupational and professional pathway through learnerships.

Entry into Higher Education is through a Grade 12 (Matric) pass for diplomas and a Grade 12 (Matric) pass with exemption[4] for university degrees. The present set-up involved science teachers operating at FET level. Unlike subject offerings in the previous curriculum, which were not really relevant for learners' further education or for success in the workplace, the subjects in the NCS were lodged within Learning Fields, and are deliberately organised into occupational categories to broaden access to a range of career options for learners.

To ensure that the learning fields remain dynamic and responsive to new knowledge, integration across the learning fields were maintained by blurring of boundaries between them. Cognate subjects, such as physics and chemistry within the learning fields, were driven by learning outcomes, which are learner-focused statements of intended results of learning, and integrate knowledge, skills and values. Each learning outcome was elaborated in the form of assessment standards, which provide a set of criteria for the types of evidence that should demonstrate learner knowledge in a particular grade.

2.3.2 Research and Debates on Curriculum Implementation in South Africa

Within the context of outcomes based education (OBE), an outcome can be defined as a culminating exhibition of learning. What OBE stipulates is that all learning and teaching inputs be based on that set of predetermined formal outcomes. In the early stages of the South African curriculum reform, Jansen, one of the most prolific and expressive scholars of South Africa, was a lonely voice bold enough to level criticism against the OBE curriculum. His seminal work 'why OBE will fail' stirred vibrant debates amongst South African scholars. Ten years down the line, in his article, 'It is time to end the decade of confusion', William Spady, the founder of OBE, claimed that OBE was never implemented in South Africa.

Amongst four of the most insightful criticisms levelled by Jansen on why he thought OBE would fail, was that the policy was driven by political imperatives devoid of classroom life realities (Jansen, 1999, pp. 146–147). The other significant criticism was that since outcomes

[4] Minimum University entrance requirements

were not content specific, they were vague and opened room for a range of interpretation which as argued by Maodzwa–Taruvinga & Cross (2012) could lead to continuities and discontinuities with the apartheid curriculum, depending on the ideological context of the school and the nature of the teacher. Another criticism was that the fragmented and atomistic nature of OBE and the notion of competencies and learning areas trivialised curriculum knowledge by overlooking the interdisciplinary basis of teaching tasks. As Maodzwa–Taruvinga & Cross (2012) put it, knowledge in the classroom was reduced to constructs that teachers and learners individually brought to the classroom.

Allais (2010) argues that the biggest mistake of the South African curriculum is that it hid disciplinary knowledge and the integrity of subjects, resulting in a great loss for the teachers in the discipline. I will argue that the choice of OBE as a curriculum philosophy was not only a step in the right direction but also an appropriate and progressive one, consistent with the global trends. I am also not convinced that the types of criticisms levelled at an outcomes approach in its own right are appropriate and justifiable. I will further argue that the flaws are not in the essence of an outcomes based approach but in the translation of its philosophy into policy as well as simplistic misrepresentations of policy at implementation level. As in the case of NCS, Rogan & Grayson (2003) argue that in most cases curricula that are implemented across the globe are usually well designed with aims that are intended to achieve laudable outcomes. (Verspoor, 1989, p. 133) in his analysis of 21 World Bank funded education change programmes points out that nearly all instances of low outcomes resulted from poor implementation of what was essentially a good idea.

As argued in many studies (Rogan and Grayson, 2003; Verspoor, 1989; Jansen, 1999), attention and energies of policy makers and politicians focus on the '*what'* of the desired educational outcomes and neglect the *how*. To fully accommodate an innovation of such magnitude required major overhauling of the whole education system (Jansen, 1999). What really failed the system is well captured in Jansen's criticism that the implementation drive was founded on flawed assumptions. The process was not informed by the realities inherent in schools especially in terms of capacity of the teachers who exist in the system and how they organise and manage learning in their classrooms. Of significance to note also is that the nature of the political context and racial power dynamics on which C2005 rested were deeply challenged and uniquely fragile due to being born out of attempted democracy based on transplacement (negotiated transfer of power) rather than through revolution (regime overthrow) or replacement (regime substitution). Build on politics of compromise, its

aftermath was a very fluid and uncertain context ruled by subtle racial power dynamics which undermined any hopes for change. As Taruvinga and Cross (2012) puts it, the South African OBE policy can be viewed as an anachronistic albatross with built-in contradictions that eventually led to its demise.

I will also argue that there are inconsistencies and inner contradictions in the types of criticisms levelled because issues are taken out of context and in lots of areas like is not compared with like. For instance, a statement by Allais (2010) that syllabus documents are more useful than outcome statements is really not comparing similar things. What I understand by outcomes is that instead of expressing learning goals in terms of teacher inputs (objectives), one expresses them in terms of learner attainments or what a learner is capable of doing.

Some of the criticisms are enlightening and appropriate only if we can distinguish between the integrity of a theory and the contextual challenges arising in trying to translate it into practice. Morrow (2007) makes a compelling argument that unless the concept of teaching is retrieved, teachers' work will continue to be incoherent and unmanageable and we will have no hope of getting the learning which is happening in the classrooms right (bottom p.15).

Definitely, the notion of teaching is muddled in the confusion and needs to be salvaged. As Morrow puts it, good teachers are a rare commodity and expecting teachers to become curriculum developers and all the other roles specified by the Norms and Standards, is not only expecting too much from them but also diverting their focus and attention from their central role of teaching.

Morrow's notion of basic education is a very good case scenario to illustrate this. It is not facts, concepts and principles that are needed to master the art of reading and numeracy, but procedural skills which will enable learners to acquire the facts, concepts and principles underpinning any discipline.

Allais (2010) argues that *a good curriculum is designed by thinking carefully about how the body of knowledge or subject in question, is organised, with the aim of carefully selecting key knowledge areas and skills that need to be mastered* (p. 32). I will argue that the three science learning outcomes are very well conceived and capture the essence of this statement and even more. The NCS curriculum was outcomes based with all the subjects except for

mathematics underpinned by three learning outcomes where one had a focus on skills, one on relevance and one on content knowledge.

The criticism that Morrow (2007) levels as 'moving target' argument and 'no finish line' argument, are very well addressed within the physical science NCS and actually consistent with the nature of scientific knowledge. Schwab (1969) explained subject matter knowledge as constituting of two structures, referred to as *substantive* and *syntactic*. Substantive structure has to do with the organization of facts, concepts, principles, laws and theories, while the syntactic structure has to do with the rules of evidence used for the generation and justification of knowledge claims made within the discipline.

Coming from the science school curriculum background, I will argue that the NCS was a robust quality curriculum framework with far reaching and laudable aims. Shalem (2010) actually puts a finger on part of what the problem is about SA curriculum implementation efforts:

Majority of teachers in South Africa struggle to decode and outcomes based curriculum and have been unable to organise systematic learning in their classrooms (pg. 89).

Another part of the problem is that you need teachers with firm and very secure content knowledge to be able to take up such a formidable curriculum as the NCS, and the reality is that SA teachers work from a very shaky content base. This is the problem is the problem that needs to be addressed at implementation level instead of continually revisiting and rewriting the curriculum. If the teachers do not have intellectual tools to access the curriculum, what is needed is to put in place, scaffolding measures to gradually empower teachers to improve their ability to access the curriculum, instead of focusing on simplifying curriculum policy.

2.4 The Challenges of Implementing the Science NCS

The quality of science and mathematics education is constantly under scrutiny, because of the recognition of the critical role played by these two learning areas in the economic and technological growth and development of any country. To this end, any good science curriculum has two critical roles to play, in ensuring that science really makes its contribution. These depend on a clear understanding of the nature of science on the part of science teachers.

In a country like South Africa, the first challenge would be to ensure a curriculum that can promote scientific literacy through changing previously held negative perceptions about science and the role of scientists, entrenched by the previous 'ready-made-science' curricula. The second is to ensure a curriculum which can attract learners to the field of science and engineering, for the much needed output of the rare scientific skills and expertise, to promote and sustain the country's development.

In line with the global trend of introducing reformed curricula, concepts such as *public understanding of science, science technology and society* and *scientific literacy,* have become part of the common vocabulary of most South African teachers, politicians and funders. Kuhn, Schauble & Garcia-Mila (1992) describe a scientifically literate person as one who is capable of evaluating the quality of scientific information based on its source and the methods used in its generation.

In the previous curriculum, science was presented as a set of rules or facts, and there was no evidence of any attempt to bring in the historic development of different concepts as a way of portraying the human and dynamic aspects, as well as socio-cultural contexts underpinning generation of scientific knowledge. The contested nature of science, the relationships of theories and scientific laws and their roles in the generation of scientific knowledge, was non-existent.

The NCS curriculum had a constructivist approach illustrated in the first and the third learning outcomes (LO), as well as in their assessment standards, offering a framework for addressing the science content (enacted in LO2) with the principles underlying NCS. LO1 focuses on skills underpinning scientific investigations, and is in line with international trends towards inquiry-oriented sciences education (Minner, Levy, & Century, 2010; Chinn & Malhotra, 2002) and LO3 which is about relevance is in line with the Science, Technology and Society movement (Aikenhead & Ryan, 1992; Solomon, 1993) as well as Nature of Science movement (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). A table in Appendix J gives all three for natural science (from grades 7 to 9) and for physical science (grades 10 to 12) learning outcomes, together with their assessment standards, as depicted in the policy document.

For Learning Outcome one (LO1), in the South African Natural science curriculum, teachers are expected to help their learners to develop skills for carrying out open-ended investigations. The task of a science teacher, as implied in the National Curriculum

Statements (NCS), is to create learning environments that will build on children's natural inclination to seek explanations, and motivate them to find answers to questions through active investigations. The Natural Sciences LO1 for Further Education and Training and the accompanying assessment standards states:

The learner is able to use process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts.

The statement below from the (American) National Science Education Standards (1996) encapsulates the role of science teachers as seen today*:*

… effective teachers of science create an environment in which they and students work together as active learners. While students are engaged in learning about the natural world and the scientific principles needed to understand it, teachers are working with their colleagues to expand their knowledge about science teaching. To teach science as portrayed by the 'Standards', teachers must have a theoretical and practical knowledge and abilities about science, learning, and science teaching. (p. 27)

For science teachers to effectively develop, manage and nurture these skills in their learners, they need to possess such skills themselves, and, more importantly, these should be reflected in the way they approach their professional teaching task. With this background, there is definitely a case for science teachers to be at the forefront of transforming their school environment into centres of learning through promotion of reflective practice, and fostering the spirit of collegiality through engagement in action learning. The following statement (Socketed, 1996) captures the essence of the types of skills required from a natural science teacher:

... be capable of profound reflection on practice, competent to enter into dialogue of the practice they know and the theory or literature they read; able to engage in. ... interpretation and critique with colleagues and with children; and able to observe, document and analyze their own practice and experience, and take that analysis into the white-hot cauldron of public forums and public accountability". (p. 26)

As argued by Chiappetta & Adams (2004), teachers require an understanding of the roles of content and process in school science to have a better understanding and better practice regarding inquiry-based instruction. They further pinpoint how use of the relationship between content, process and inquiry-based teaching can enhance the planning and implementation of effective inquiry-based instruction. The following five reasons Chiappetta & Adams (2004) identify for using inquiry-based instructions in the science classes, are consistent with the framework of the three learning outcomes of the natural science NCS. These are to promote:

- understanding of fundamental facts, concepts, principles, laws and theories;

- development of skills that enhance the acquisition of knowledge and understanding of natural phenomena;
- cultivation of the description to find answers to questions and to question the truthfulness of statements about natural world;
- formation of positive attitudes towards science
- and acquisition of understanding about the nature of science.

2.4.1 Debates Relevant to the Implementation of Science NCS

We live in an era where the world is progressing very fast, and therefore we should anticipate that a curriculum, which is able to keep pace with current trends and development, would of necessity be idealistic and quite complex in its nature. Consequently, the ideals of the science NCS were quite ambitious, and made demands which were far removed from how most teachers were trained. The important thing to note is that they were in line with the global trends for an ever advancing civilisation. It was indeed a paradigm shift which dictated that, for science teachers to remain functional and effective, they had to strive very hard to align their thinking and practices with these new ideals on an on-going basis.

A closer look at the framework of the three physical science LOs and their assessment standards, together with the syllabus document (DoE, 2008) reveals that Physical Science NCS was able to capture the integrity, complexity and as Bernstein, (2000) in Moore, (2004, p. 144) puts it, *a coherent, explicit systematically principled structure* of that learning area. Shalem (2010) argues that the collection form of outcomes based curriculum hides content knowledge and its specialised structure. This criticism did not hold for the physical sciences NCS because as will be expanded in the next section, the three science learning outcomes ensure that the science content, the necessary procedural skills and the relevance to society are all addressed at higher order cognitive levels. The problem is that this structure needs unpacking because most science teachers in the South African classrooms are unable to comprehend and translate it into their practice. The framework of the three LOs should be used together with Physical Science content document (Department of Education, 2006) in which the relevant content for each grade is laid out.

The move from NCS to the Curriculum and Assessment Policy Statement (CAPS) published in 2011 was well intentioned but it is actually a draw-back we all ought to be seriously

concerned about. It is not only a retreat back to the apartheid curriculum but it is plunging the system into further confusion by changing the syllabus without signposting the changes. The NCS had an internally built in framework which took a lot of work and expertise to put in place, and with the move to CAPS this heritage was totally lost.

Morrow (2007) raises a critical point against the idea of teachers being free to choose what and how to teach, which I totally concur with, and that is: since practices have historical heritage and therefore teacher's professional judgement should be in sync with that history and should never be an outcome of someone's eventful invention. Indeed curriculum must be formulated from selection of those appropriate practices and the teacher's professional authority in planning systematic learning, that is, decisions on what to teach, how to teach and how to assess should be formulated from what has been proven to be a shared good. It can be appreciated in the next section that the three science learning outcomes are informed by a heritage of global trends which captures the open inquiry, the human endeavour and contested as well as the context and socially embedded nature of scientific knowledge. As discussed in section 2.6, this study did not only engage the participating teachers in well tested powerful metacognitive processes of planning and reflections, but also identified a well-tested instructional model, 5Es (a constructivist aligned instructional strategy), for teachers to explore as way of systematising their teaching efforts.

The research ground for curriculum development in South Africa is still very fertile. There are still ample research opportunities to unravel what is really happening in our schools. Seven articles (Rogan, 2000; Rogan & Grayson, 2003; Rogan, 2004a; Rogan, 2004b; Rogan & Aldous, 2005; Hattingh et al., 2005; Rogan 2007a) report on a series of progressive studies done by Rogan and his colleagues, seeking to develop a theory on the implementation of curricula in developing countries, with a special focus on C2005 and the South African context. The progressive research was based on the work done over a period of three years, on the implementation of C2005 within a programme called the Mpumalanga Secondary School Initiative (MSSI), based in a rural province in the east of South Africa.

The studies recognise that, even though science education may well be a priority in the agenda of most developing countries, most initiatives which aim to improve science education focus in a limited way on the development of science curricula, while neglecting to give full focus on the details of how the curricula will be implemented. Rogan & Grayson (2003) offer a framework for curriculum implementation at school level in developing

countries, and several of their other articles use this framework to analyse data collected during the project. Their work departs from a premise that C2005 has the potential to offer much to the SA education system, provided it is implemented in a realistic manner, by giving teachers ownership of both the content of the curriculum, as well as the implementation processes (Rogan, 2000).

The continuous, systematic and comprehensive nature of these series of studies offers deep insights into issues of curriculum implementation in South Africa. The studies draw on school development, educational change and science education literature, to build the framework of curriculum implementation referred to above. In the first article of the series, Rogan (2000) begins by drawing from research to suggest that schools, as systems, fall along a developmental continuum. With a special focus on C2005, the article proceeds to examine the implications of such a continuum on the implementation of an innovation.

Since there is not much research done on system wide curriculum implementation in the South African context, the article draws on some of the research done in other developing countries to address five critical questions: Where, in terms of the proposed continuum, should the innovation be targeted? To what extent should innovatory versus open-ended practices be structured? What is the role of theory versus practice in innovation? How long does it take for an innovation to take root? How should the nature of the innovatory practice be defined? It suggested that a long-term research and development agenda should be based on the continuum, and current efforts at innovation should be established. It also advocated the creation of test-beds, instituted through collaboration of NGOs, departments of education and research institutions where C2005 implementation can be developed and researched.

The theory that emerged from these studies proposes that the success of curriculum implementation lies in a framework that takes cognizance of the enormous diversity in the nature of schools in South Africa, and offers a variety of implementation routes. The heart of this proposed theory consists of three constructs for analysing school implementation: profile of implementation, capacity to innovate and outside support. This theory is comprehensive; it starts by recognising the current reality, and moves on to build on the strength of various existing components of the educational system, such as teachers, learners and the school environment.

The model suggests that a critical, practical indicator of a realistic implementation of the new curriculum is the recognition that there should be a next step or a level to aspire to, in line

with values or expected outcomes of the curriculum. This model is premised on the recognition that the diversity in quality of the schooling system in South Africa, cannot be catered for by a blanket policy implementation strategy.

One other feature is that, unlike many curriculum implementation models which are based on a deficit approach to curriculum change, as well as *one size fits all* implementation strategies, the Rogan and Grayson model maintains a positive outlook by focusing on the building and consolidation of strengths, rather than on the remedying of weaknesses. Rogan and Grayson (2003) adapted Vygotsky's (1978) idea of the Zone of Proximal Development (ZPD) to the field of curriculum and school systems development. They refer to their analogous concept of curriculum and school system development as *Zone of Feasible Innovation* (ZFI). The ZFI is a hypothetical construct which suggests that innovation should not exceed current practice by too large a gap between existing practice and the demands of the innovation. It therefore, offers a framework, to ensure suitable and varied strategies for different schools at different levels of development.

Two of these studies (Rogan & Aldous, 2005; Rogan, 2007b) are on the application of this theory to particular cases. As in many other studies on learning environments, the Rogan and Aldous (2005) study revealed that school ethos, and the way in which a school is managed, has a great impact on implementation. The level and style of accountability are also important. The article argues that whole school development is more important than professional development in selected learning areas, since different approaches to curriculum change in a school can be counter-productive. It further proposes that professional development needs should be institutionalized and approached in a systemic and systematic way, otherwise it becomes a futile exercise. Rogan (2007b) analyses how science teachers in one rural school responded to the demands of this new curriculum. The levels of implementation are analysed in terms of the ZFP.

What the study revealed was that the teachers in the case study were willing to change, but the enormity of the challenges was overwhelming because of lack of proper support. This study emphasises the need for education departments to appreciate the fact that schools differ in their capacity and readiness to implement innovation and to realise the futility of the one size fits all approach to planning of implementation. Another critical argument raised in this article is that the department should expend less time on top-down policy-making, and more on the development of support structures that might facilitate implementation.

The same message should go to the critics of OBE and the South African curriculum to spend less time on attacking the curriculum policy through failures and inadequacies experienced at implementation level and rather add value by studying the dynamics and challenges inherent in the process with the aim of advising the support structures that aim to turn policy to practice. As is done in this study, this is achievable through use of methodologies which blend dichotomies between intervention and evaluation, between knowledge based and skills based approaches as well as taking an experiential outlook to one's practice.

As discussed in chapters 3, 4 and 5 the Rogan and Grayson's curriculum development model was used extensively in this study to capture and analyse contextual issues enveloping the change environment as well as to study the contrasting features of intervention programmes that emerged in this study.

2.4.2 Research on the Physical Sciences NCS

Green & Naidoo (2006) developed a multi-dimensional analytic framework to interrogate the content of the grade 10 Interim Physical Science curriculum document (IS) (DoE, 1995) and the NCS for Physical Science (DoE, 2008), with the aim of investigating changes in knowledge values in these two policies. They suggest that, on the whole, NCS reconceptualises valid science knowledge, while IS portrays an absolutist view of science. Two arguments arise out of this analysis: the first, in relation to the overall change projected in the document, and the second to do with the knowledge structure of the curriculum. They argue that the NCS appears to be a hybrid product that intersects different ideological traditions, different discourses and a range of competences and complexities.

There is a possibility that a diverse range of voices (ranging from state agents, science and other educationists, scientists etc.) is reflected in the structure, the nature, content and goals of the curriculum. They argue that the particular socio-historical context, and probably global forces, have shaped the curriculum that has emerged. With this background, they argue that science for its intrinsic worth appears to be overshadowed by the need to study science for its social constructionist and utilitarian worth. Another argument raised which is also in line with Rogan and Grayson's (2003) theory, is that the openness and the ambiguity in the structure of the NCS document lends it to possible multiple interpretations in different socio-economic contexts, for social justice.

In another study, Ramsuran (2005) examined the RNCS (DoE, 2002) documents, and interviewed policy writers with the aim of exploring the concept of scientific literacy and the ideology underpinning its use. The study employed three dimensions of ideology as an analytical framework, to interrogate definitions of scientific literacy and ideological responses to transformational agenda, underpinning policy development process and the resulting documents. The three ideological dimensions are: epistemology (how we know), ontology (what is real) and axiology (how we should act). In her findings, she argued that both C2005 and the RNCS are similar to overseas documents (such as Australia, UK, USA) where the goals of scientific literacy are expressed through prescribed outcomes and standards.

In terms of the three ideological dimensions, she argues that policies were strongly underpinned by ideologies which derived from equity, transformation, multiculturalism, constructivism, and the professionalism of policy writers. She also identifies several emerging concerns and tensions, and argues that the dispositions, the broad ideological commitments and professionalisation of the writers played a critical role in shaping the two curriculum policies. One important concern that emerged was fear of dilution of science content. On the tension of *globalisation vs localisation*, she argued that the writers held to a universal notion of scientific literacy, with very little attempt to localize the definition, for instance, in response to African cultures and rural experience. Two other tensions which emerged were *individualization vs collectivism* and discourses between *economic* and *democratic*, where she argues that dominant ideologies are humanist, multicultural and socially critical.

Lubben & Bennett (2008) studied the use of contextualisation in chemistry in the NCS document and textbooks, examinations and compared this with NATED 550. Their study focused on exploring the changing role of contextualisation over 15 years as reflected in South African and English curriculum policy documents. Their study revealed that everyday context in recent curricula is used more to illustrate chemical concepts rather than as justifications for studying these concepts or for application or synthesis of chemical knowledge.

Edwards (2010) used a two dimensional table to analyse the South African Grade 12 Physical Sciences core curriculum content, as exemplified in the 2008 exemplar papers and the 2008 and 2009 final examination papers. Using a revised Blooms taxonomy, the results revealed

cognitive level discrepencies in both Physics and Chemistry as well as a marked shift to higher cognitive levels which confirmed the claim of increase in cognitive complexity of the Physical Sciences curriculum. In their article 'Death of an outcome…', Clerk & Naidoo (2010) analysed the 2008 Grade 12 Physics examination paper and revealed a demise of problem solving which they claim might explain the high failure rate of first year students doing physics in that year.

Nakedi et al., (2012) examined the NCS curriculum documents and examination papers to see if there were any congruency between successive documents regarding the weighting and conceptualisation of the LOs. The study revealed a retreat from the original vision of weighting skills (LO1) and relevance (LO3) equally with content (LO2) resulting in privileging of content oriented science at the expense of inquiry oriented and contextualised science. The retreat from these two best practices in the of learning and teaching of science has now been cemented by the introduction of CAPS, a move which has served to subvert the heritage and retard the progress which was already registered within the science education/schooling community as already discussed in section 2.3 above.

2.4.3 Teacher Management of Science LOs - Scientific Inquiry, Content and STS

Gott and Duggan (1996) argue that achieving scientific literacy is dependent on a clear understanding of the nature of scientific evidence, and its central role in procedural competencies of experimental design, measurement and data handling. Inquiry-based tasks or open investigations are activities in which learners are given an opportunity to take the initiative in finding solutions to problems (Watson & Fairbrother (1993). In the NCS, this was about the first science learning outcome (LO1). Research in science education has revealed the understanding of the nature of science as one of the major constraints on teachers in the implementation of effective inquiry-based instruction (Roehrig, 2004). Nature of science refers to values and beliefs which are inherent in science, as a way of knowing and in the generation of its knowledge (Abd-El Khalick, Lederman, Bell & Schwartz, 2002).

We need to acknowledge that most science teachers have been schooled in traditions that portray science as an absolute truth that has been discovered through observation and experimentation, which follows a fixed scientific method and is objective (theory-neutral). Training that present science as being independent of social and cultural context, and that *through its auspices, more and more truths about the world are discovered over time.* This type of training would entrench a belief system that scientific knowledge can be proven, that

it gives a true account of the natural world, and that, when making observations, scientists eliminate their beliefs and values, that scientific investigation follows the scientific method and that scientific inquiry almost always starts with observations of nature and never comes from scientific and non-scientific sources (Abd-El Khalick, Lederman, Bell & Schwartz, 2002).

The shift from viewing learning as a transmission of established facts, to viewing it as an active and participatory process where learners construct their own knowledge, is in line with the contemporary (post-modern) view of the nature of science and scientific knowledge as tentative and dynamic (Luft, 2009). From a constructivist perspective, teaching should start from the recognition that learners use their own beliefs and understandings of the world around them to interpret experiences and construct meaning for those experiences. This is in line with the most current understanding of the nature of science and how scientific knowledge is generated. According to this view, scientific knowledge is a human construct which is tentative, empirically-based, subjective (theory-laden), partly a product of human inference, imagination and creativity, and socially and culturally embedded (Abd-El Khalick, Lederman, Bell, & Schwartz 2002). What is also important to note is that the development of scientific knowledge progresses through scientific encounters of a series of conceptions, which are dependent on social negotiations within the scientific community. The implications for our science lessons is that learners should be given opportunity to work collaboratively, discuss ideas with each other, think creatively and view science as a problem solving exercise.

The core skills of scientific reasoning encompass the capacity to logically link existing theories, with evidence bearing on them (Kuhn, Schauble & Garcia-Mila, 1992; Kuhn, 1993). In line with Natural Science (NS) Learning Outcome (LO1), a good science curriculum should promote in learners a questioning, reflective and critical approach to issues. This can be achieved by instilling in learners particular ways of looking at the world, which put emphasis on the importance of evidence in forming conclusions, as well as that evaluation of scientific knowledge which varies with varying situations.

The task of a science teacher, as implied in the National Curriculum Statements (NCS), is to create learning environments that will build on children's natural inclination to seek explanations, and motivate them to find answers to questions through active investigation. In

order for learners to develop relevant conceptual and procedural competencies in science, they should be presented with opportunities to carry out scientific investigation, which is based on concrete experiences of natural phenomena. Learners should be engaged in resolving scientific problems, which require them to plan the course of action, carry out that plan by collecting the necessary data, organising and interpreting the data, and reaching a conclusion which is then communicated in some form (Garnett, Garnett and Hackling, 1995, p. 27). Learners should also be engaged in issues of validity: in order to ensure confidence in the collected data, there is a need to ascertain that tests were fair and that sources of error were minimised by controlling variables and using repeat trials or replication.

To ensure that meaningful links can be established between the practical and theoretical aspects of science in the classroom, all forms of practical work should be carefully planned and integrated within an instructional sequence (Hackling M. , 2005). To be able to relate to and understand the multitude of inferential and theoretical entities and terms (e.g. atoms, electrons, magnetic field etc.) that inhabit the world of science, we must assist our learners to be able to make distinctions between observations and inferences (Abd-El Khalick, Lederman, Bell & Schwartz, 2002). It is very important to note that observations are descriptive statements about which two observers can easily reach consensus, because they are about a natural phenomenon that is directly accessible to our senses (or extensions of senses), while inferences, on the other hand, are mental constructs and are statements about phenomena that are not directly accessible to our senses.

Given how scientific knowledge is generated, several studies (Geddis, 1991; Kuhn, 1993; Driver, Newton, & Osborne, 2000) express dismay at the culture of science teaching that continues to present science as a ready-made, unproblematic body of unambiguous right answers that should be transmitted into learners' heads. They argue for strategies that 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.

During science lessons, the notion of establishing learners as communities of practice, consistent with the culture of how scientific knowledge is generated, should be promoted. Argument is a central feature of the resolution of scientific controversies; therefore, learners should be given opportunity to take a critical stance against accepted theories, as well as being engaged in a critical examination of how society influences what counts as scientific

knowledge, and social issues related to accepted scientific knowledge (Driver, Newton & Osborne, 2000).

Even though the spirit of how scientific knowledge is generated has to be captured, and critical thinking promoted, through debating of issues and formulation of consensus during science lessons, it is critical that the right status due to established theories be given during instructions. *Scientific theories are well-established, highly substantiated, internally consistent systems of explanation which serve to explain relatively huge sets of seemingly unrelated observations in more than one field of investigation* (Abd-El Khalick, Lederman, Bell, & Schwartz, 2002). Learners need to understand that scientific observations are guided by theory, and almost always depend on what scientists set out to find.

To address the other two LOs requires that learners be engaged in tasks which enable them to develop the process skills that underpin the *doing of science,* as well as the nature of science, and its relevance to contemporary issues. Good tasks of such nature are those which allow learners to assume the role of a scientist, to interact and engage with issues in their everyday contexts or to study the life story (case study) of renowned scientists which reveals the circumstances around the birth of their theories. Other good tasks would be those which allow learners to assume different roles in a scientifically underpinned socio-economic debate which is relevant to their lives. Since these materials are meant for an individual student's engagement, conceptual tasks embedded in such hypothetical contexts can serve to promote appropriate scientific and problem solving skills.

It is also important to note that, as the GET curriculum shifted from C2005 to RNCS, the meaning of scientific literacy changed. There emerged two different parallel approaches in the way the GET and the FET policy writers responded, to ensure that the *science literacy* angle to the curriculum was not lost as C2005 was streamlined (reducing 9 LO s to 3 and trying to make content much more pronounced).

The strategy employed in the GET was to say that only 70% of the school curriculum should be drawn from the prescribed core knowledge, while 30% could be drawn from the local context.

> *The other 30% of the time should be used to extend these minimum knowledge statements; alternatively, science content from contexts which are significant to the learners and local community may be used. The contexts may be economic, environmental, social, or health matters…* (RNCS-61)

Another important quote that captures the definition of science literacy from the NCS document is:

> *The natural science learning area deals with the promotion of scientific literacy. It does this by: the development and use of science process skills in a variety of settings; the development and application of scientific knowledge and understanding; and appreciation of the relationships and responsibilities between science, society and the environment (RNCS-4)*

In the case of FET, the move to RNCS involved a very strong and deliberate move to make content even more pronounced (development of core syllabus etc.) Another prominent feature, resulting from the shift, is the loss of emphasis on certain aspects of STS, such as the indigenous knowledge system (IKS). A strong feature of the FET NCS, which establishes the aspect of STS, is the presence of a new theme (also the focus of this study) referred to as *Chemical Systems*. This is a unifying theme which deals with the impact of science on the society and the environment. This theme lends itself well to addressing LO3, as it creates opportunities to assess whether a learner can critically evaluate science knowledge claims, as well as evaluate the impact of scientific knowledge on socio-economic development.

2.5 Learning and Teaching Issues Related to Chemistry Content

In science and mathematics, one of the most challenging South African issues which continues to widen the gap between the intended and the implemented curriculum, is the weak content knowledge of many teachers. In science, this situation was further exacerbated by the introduction of new topics, some of which used to form part of first year university curriculum, as well as the complexity of the three science learning outcomes, which are very far removed from how most of the teachers were trained and hence from their current classroom practices. To try to get to the heart of this gap, this thesis explores how two teams of science teachers respond to the challenges posed by the NCS curriculum to their practices and their content knowledge for teaching.

Chemical systems, the topic of focus in this research, is a very broad theme, just like chemical change, matter, materials and other physics related themes. But unlike these themes, it is a unifying theme which deals with the impact of science on society and the environment, and therefore draws on knowledge of all the other themes. At the FET level, the different topics under chemical systems are actually extensions of the chemical change, and matter and materials knowledge areas that emphasise the role of chemistry in daily life, and the effects of technological applications and processes on society and the environment.

This review is limited to the content sections where the four case study teachers concentrated their inputs and assessment tasks. Literature is reviewed on the concepts underpinning the teaching of these topics, as well as established learning barriers associated with the teaching of these topics. The sections of chemical systems are: water cycle in grade 10, atmospheric chemistry in grade 11 and electrochemistry (batteries, electrolytic cells and chloralkali industry) in grade 12.

2.5.1 Particulate Theory of Matter

In this thesis, literature on the teaching of particulate theory, as well as bonding and intermolecular forces, is reviewed because these are foundational concepts underpinning, not only water cycle and atmospheric chemistry, but also electrochemistry. The particulate theory of matter is the most widely used model for explanations in chemistry, and is regarded as a very powerful tool to aid both the understanding and explaining of many properties of matter and related phenomena. It is, therefore, seen as an important part of science knowledge taught in schools (including primary schools). This model is premised on the reasoning that, because matter is built up of particles, then it should logically follow that all properties of matter must depend and be explicable in terms of those constituent particles.

Literature on science students' prior conceptions (Briggs & Holding, 1986; de Vos & Verdonk, 1996) revealed that many students experience difficulties in using microscopically recognisable attributes of substances to account for their behaviour. Other studies (e.g. Driver, 1985; Papadimitrou, Solomonidou & Stavridou, 1997) have revealed that most pupils of all ages have a continuous view of matter, rather than a particulate view. In their report, (Briggs & Holding, 1986) revealed that students' prior knowledge (knowledge acquired in their everyday lives) heavily interfered with their learning**.** de Vos & Verdonk (1996) suggested that the development of ideas of pupils, attributing bulk properties to molecules, could be a natural and unavoidable stage in the cognitive development of learners.

Some studies (Kruger & Summers, 1989; Cosgrove & Osborne, 1981) have established parallels between scientific concepts held by children, and those held by primary science teachers. According to these studies, the difference between the views of children and teachers was that the latter presented more varied and complex arguments, which might be a sign of wider experiences of the world, or a more evolved and mature command of language. The studies revealed that teachers showed considerable uncertainty when their beliefs were subjected to considerable probing.

Research done on the concepts of pre-service and in-service elementary science teachers (Papadimitrou, Solomonidou & Stavridou, 1997; Bar & Travis, 1991) and secondary school science teachers (Taber & Tan, 2011; Taştan, Yalçınkaya, & Boz, 2010; Treagust, Duit, & Nieswandt, 2000) revealed the possibility that a great proportion of primary and secondary school science teachers may not possess sufficient understanding of science to enable them to fulfil the demands of the National Curriculum in schools, in most parts of the world. Apart from the inherent difficulties in understanding and handling of abstract models, such as the particulate model, there is a major problem created by how these models are presented and taught in schools. The models are usually taught completely independently from the phenomena, and are not properly related to them. These methods result in pupils not being able to make proper connections between models and phenomena, and therefore having great difficulty using models in their descriptions and explanations of phenomena.

The challenge faced in school science teaching, is use of models that oversimplify concepts, and thereby introduce misconceptions. Studies in this field show that misconceptions are resistant to change and that students face several cognitive conflicts when dealing with chemical concepts. Beerenwinkel, Parchmann and Gräsel (2011) argue that physics and chemistry use highly abstract concepts to explain phenomena, and therefore students are not only confronted with issues of dealing with abstract ideas, such as atoms, molecules or bonding, but they also have to become skilled in using different kinds of models to connect these ideas with observable phenomena. The trick to successful teaching is that ideas need to be presented in ways that are simple enough to be meaningfully understood by learners, yet be authentic representations of the scientific concepts.

Two good sources for misconceptions in chemistry are the publications by Taber (2002) and Garnett and Hackling (1995) and from the literature, the following is a list of what most agree to be common learner misconceptions regarding these two topics:

For particulate nature of matter:

- Matter expands because its particles get bigger.
- Water in the solid state has the heaviest molecules.
- Atoms become larger as they change from liquids to gases.
- The nucleus of an atom attracts all electrons around it equally.
- There is considerable space between the molecules in a liquid.

For chemical bonding and intermolecular forces:

- Intermolecular forces are the forces within a molecule
- Breaking chemical bonds releases energy.
- Chemical reactions are caused by mixing substances.
- Equal sharing of electrons occurs in all bonds.
- Bond polarity determines molecular shape.

2.5.2 Grade 10 - water cycle and Grade 11 – Atmospheric chemistry

Water changes its form as it moves in a cycle between the hydrosphere, atmosphere and lithosphere in what we refer to as the 'water cycle'. Figure 1 below helps with the visualising of the changes as it illustrates the structure of the atmosphere and the types of temperature and pressure variations happening across the varying altitudes. Because of temperature variations across the different layers of the atmosphere, water is retained in the troposphere, and therefore the water cycle happens only in this layer of the atmosphere. Due to the constant mixing of circulating air masses in the troposphere, the composition of this lowest layer of the atmosphere is constant. What is variable is the water content due to continuous evaporation of water from the oceans and rivers, formation of clouds and precipitation.

The one critical role played by the tropopause is that it preserves the water molecules from decomposing by preventing them from escaping beyond the troposphere. This is a critical phenomenon, because, if water is lost, there will be no life on Earth. The water cycle plays a critical role in absorbing and transferring energy from the sun and the earth. Because of that sharp change in temperature trend at the tropopause, water molecules are retained in the troposphere. If water molecules could escape to the higher regions of the atmosphere, they would absorb ultraviolet rays from the sun and thereby decompose into hydrogen and oxygen. That region high in the troposphere is where clouds form as the water vapour freezes.

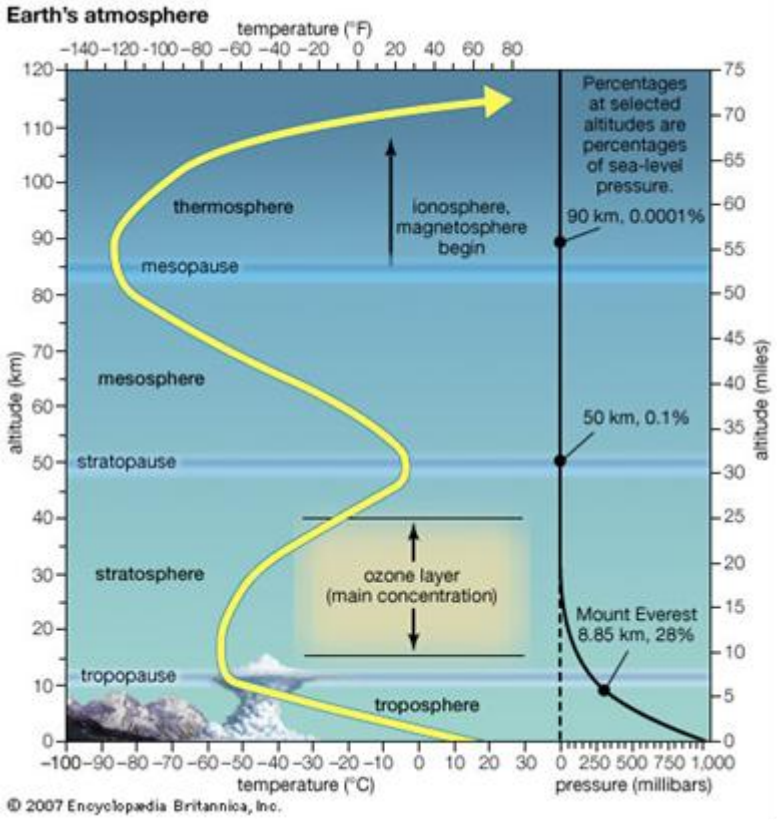


Figure 1: Earth's Atmosphere

The Earth is continuously receiving large quantities of energy from the Sun. To keep the balance, there must be an identical quantity exchange of energy emitted by the Earth back into space. The radiation which does not reach the ground is actually high energy ultraviolet radiation which could be very harmful to life on the Earth. The 45% which reaches the ground is infrared, visible and low energy ultraviolet radiation and is responsible for warming the Earth. Besides the sustaining role played by the atmosphere in life on Earth, it is has a shielding, as well as an incubating role. The atmosphere protects the earth from harmful radiation and from most objects from outer space that would otherwise strike the earth's surface. Of the 55% which does not reach the ground, 25% is actually absorbed by the atmosphere, thereby playing a shielding role. When we consider the shielding and the incubating roles, three popular global issues, two being related but distinct (greenhouse effect and global warming), and one distinct, as well as totally unrelated (ozone depletion), come to the fore. There is always confusion amongst students and teachers concerning these three phenomena. The reason is a lack of appreciation that global warming is about physical

changes in the troposphere, while ozone depletion is about chemical changes in the strato-/mesosphere.

The following is a list of some of the common misconceptions pertaining to this topic identified in the literature. These were used as points of discussions with participating teachers during contact sessions which focused on this topic.

Learners' common misconceptions:

- Holes in the stratospheric ozone layer increase the greenhouse effect;
- Global warming is caused by the hole in the ozone layer (Jeffries, Boyes, & Stanisstreet, 2001);
- Global warming, due to the greenhouse effect, results in ozone distraction;
- Both the ozone hole and the greenhouse effect are caused by automobiles;
- That the greenhouse effect and ozone formation are essential is a natural phenomenon which has been occurring for millions of years;
- The holes in the ozone layer trigger the greenhouse effect;
- May think of CFCs as contributing to smog formation;
- Ozone is an environmental toxic that is hazardous to humans;
- Difficult to appreciate that global warming and ozone depletion are two independent, distinctive phenomena with separate causes

2.5.3 Grade 12 - Reduction and Oxidation Reactions

Electrochemistry is one of the topics of chemistry which has been identified as difficult for both teachers and students (Garnett & Treagust, 1992). It deals with chemical reactions that produce an electrical current or use an electrical current to drive a chemical reaction. Broadly speaking, at grade 12, the whole knowledge area of chemical systems requires firm understanding of fundamental concepts in the structure and properties of matter, energy changes and rates of reactions, organic chemistry, chemical equilibrium, as well as electrochemistry.

The Chloroalkali industry topic requires a very firm understanding of electrochemistry, and, with its focus on the role of technological processes and applications in the society and the environment, could therefore serve as a very good extension which addresses LO3 for the

electrochemical reactions topic, under the knowledge area of chemical change. This includes the following concepts: Electrolytes in solution, redox reactions, ionization and conductivity, substitution, elimination and addition reactions, energy and chemical change, electrochemistry, standard electrode potentials

The foundational knowledge for the topic of batteries (torch etc.) or electrochemical cells would be the electric circuits topic under Electricity and Magnetism in grade 12, as well as the electrochemical reaction section of the chemical change theme in grade 12. Therefore, as in the case of Chloroalkali industry, this topic could also be sequenced as an extension of the topic electrochemical reactions, thereby offering learners an opportunity to engage in LO3 tasks.

This review confines itself to the in-depth consideration of the concepts of reduction-oxidation (redox), as they hold most of these concepts together (big idea) and are at the core of understanding of this knowledge area. Many studies (Ogude & Bradley, 1996; Ringnes, 1995; Sanger & Greenbowe, 1997a; 1997b) have shown that electrochemistry is considered as one of the most difficult topics in chemistry. Ringnes (1995) argues that oxidation and reduction (redox) concepts are perceived as a difficult topic by most students in schools, mainly because of the way the topic is introduced to the students.

Part of the problem is that typical of any form of scientific knowledge, different models of these concepts have evolved over the years and four of these, and their related definitions of these concepts, are used alongside each other in schools. These four redox models are: the oxygen, the hydrogen, the electron and the oxidation number models. What makes the problem even more complex is that these historical definitions are often in conflict with everyday linguistic reasoning, and the concepts are normally taught in isolation, without reference to their historical origins. Ringnes traces the foundations of students' common misconceptions from this omission, and argues that these concepts should be given a thorough, clear and coherent linguistic, historical, as well as chemical presentation.

Consistent with the notion of *indexicality* of scientific concepts as discussed earlier in the section on socio-cultural perspective of knowledge, Österlund (2010) makes the point that sources of students' misconceptions or complexity of certain topics arise, due to their being related to different theories and models. As these models continue to develop over time, the meaning of the concept changes but the label remains. A case in point is the three different meanings which are attributable to the term oxidation as follows: gain of oxygen or loss of hydrogen or loss of electrons or increase in oxidation number. She argues that what leads to

these misconceptions or the complexity of these concepts, is that the way models are normally presented during teaching ignores how these models came to be, their functions and how they are connected to the phenomenon under examination. The problem is further exacerbated when competing models coexist; their relationships and chronological sequencing are totally ignored. Carr (1984) argues that effective teaching would be explicit and would cover the historical development of the model, for what purposes was it introduced and how it relates and differs from the previous one and why it functions better.

The following is a list of some of the common misconceptions related to the topics electricity/electrochemistry identified in the literature:

- Energy is used up in electric circuits.
- Electricity in chemistry and physics is different because current flows in opposite directions.
- The flow of electrons is responsible for electric current in electrolytes.
- Current flows because there is a difference in charge at the anode and the cathode of a cell.
- No reactions will occur at the surface of an inert electrode.

Studies (Ogude & Bradley, 1996; Ringnes, 1995; Sanger & Greenbowe, 1997) which involved identifying learners' misconceptions related to the topic of electrochemistry, found the most common ideas students held were:

- that electrons (and not ions) flowed through a salt bridge and an electrolyte solution to complete the electrical circuit
- that half-cell potential is an intrinsic property that can be used to predict the spontaneity of an individual cell
- "electrons flow in the electrolyte" (Garnett & Treagust, 1992)
- "only negatively charged ions constitute a flow of current through the solutions and the salt bridge" (Sanger & Greenbowe, 1997)
- "the anode is negatively charged and releases electrons; the cathode is positively charged and attracts electrons" (Sanger & Greenbowe, 1997)
- electrons move through solution by being attracted from one ion to the other. (Sanger & Greenbowe, 1997)
- electrons move through solution by attaching themselves to ions at the cathode and are carried by that ion to the anode.

- electrons enter the solution from the cathode, travel through the solutions and the salt bridge, and emerge at the anode to complete the circuit.
- anions in the salt bridge and the electrolyte transfer electrons from the cathode to the anode.
- Cations in the salt bridge and the electrolyte accept electrons and transfer them from the cathode to the anode.

2.6 Teacher Development and Support during Curriculum Innovation

As Fullan & Hargreaves (1992) put it, *the greatest problem in teaching is not how to get rid of 'dead wood,' but how to create, sustain and motivate good teachers throughout their careers*. The question that remains is: what should the nature of that support be? For many years, the only forms of teacher professional development were short term staff development or in-service training, aimed at offering teachers new information regarding some particular aspects of their work. The type of teacher's professional development viewed as ideal in this study is one which involves sustained and continuous professional learning in natural settings where teachers are active agents in shaping their own professional growth.

Conceptualising teacher professional development in this fashion is in line with Day (1999)'s notion that it is about learning that comes about naturally as teachers, individually and collectively, continue to review, renew and extend their commitment as agents of change. In doing this, they continue to gain experience from all those consciously planned activities, which are intended to be of direct or indirect benefit to the individual, group or school, in terms of improving quality of education in the classroom. The Norms and Standards for Educators in the February 2000 government gazette of the National Department of Education, express what it means to be a professional educator in South Africa. Webster-Wright (2009) argues that this vision, which is mostly accepted in research on professional development, is actually rarely implemented in practice, because most institutions still offer traditional training programs which focus on content or techniques.

This statement, from the American Norms and Standards for Science Educators, captures the spirit of the seven roles of Educators, as depicted in the various South African policy documents on the envisaged standard of science teaching in South Africa.

In the vision of science education portrayed by the 'Standards', effective teachers of science create an environment in which they and students work together as active learners. While students are engaged in

learning about the natural world and the scientific principles needed to understand it, teachers are working with their colleagues to expand their knowledge about science teaching. To teach science as portrayed by the 'Standards', teachers must have a theoretical and practical knowledge and abilities about science learning, and science teaching.

2.6.1 What are the Challenges?

The diversity in both content and focus of studies related to curriculum reform, bear witness to the complexity of issues surrounding curriculum reform, both in developed and developing countries. The teachers' roles, knowledge, procedural skills, attitudes and belief systems are central, as we consider the prospects of ensuring that intended curriculum reach the classrooms. In this literature review, we will briefly discuss these issues which, in a way, highlight the type of complexity the emerging framework is attempting to capture, and represent usable forms that can serve as teacher development and support programmes aimed at supporting teachers during climates of curriculum change.

Some work on teacher knowledge (e.g. Shulman, 1986; Wilson et al., 1987; Cochran et al., 1993) have recognised that when teachers prepare to teach their content as well as during instruction, they develop knowledge that is enriched by other types of knowledge such as knowledge of the learner, knowledge of the curriculum, knowledge of the context and knowledge of pedagogy. Besides the poor content knowledge of science teachers reported widely in South Africa (e.g. Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008), the challenge is exacerbated by the introduction of new topics in the curriculum without the necessary resources to support the teachers. Another challenge is the management of three learning outcomes simultaneously while teaching that content.

Among other factors, the problems in the South African reform process seem to emanate from the emphasis by teacher development programs on innovative teaching and learning strategies, at the expense of content knowledge. Teachers are expected to take forward a complex curriculum, with very high ideals, with a very shaky science content knowledge background. As echoed by some expert teacher educationists (Adler, Slonimsky and Reed, 2002), teacher education faces critical challenges in rethinking what constitutes teachers' conceptual knowledge in-practice, and how this can be developed and acquired through pre-service and in-service education programmes.

The government needs to appreciate the magnitude of the challenges and realities of teacher development and training. As put by Taylor and Vinjevold (1999),

> *... reform initiatives aimed at revitalising teacher education and classroom practices must not only create a new ideological orientation consonant with the goals of the new South Africa. They also need to get to grips with what is likely to be a far more intractable problem: the massive upgrading and scaffolding of teachers' conceptual knowledge and skills.* (p. 160)

Adler, Slonimsky and Reed (in Adler & Reed, 2002) suggest that any simplistic response to upgrading teachers' subject knowledge will not yield its promise of better learner attainment. As Adler (in Adler & Reed, 2002) puts it, there is often a sense of urgency in implementing reform, and consequently a tendency to organise short periods of INSET in support of reform. Some studies (Graven, 2002; Muwanga-Zake, 2000) have established, however, that short term programmes do not easily translate into changed or better classroom practices.

Implementing educational change is difficult and complex, and therefore requires that both teachers and learners be supported in a range of ways (Gray, 1999). As he pointed out, one of the most crucial support systems which can play an important part in shaping both the teaching and the learning is good curriculum materials. Fullan M (2001) agrees with these sentiments and puts forward a persuasive argument that achievement of large scale reform cannot depend on people's capacity to bring about substantial change in the short run. He points to the need to propel the process with high quality teaching and training materials.

Powell and Anderson (2002) highlight the complexity of the teacher support task in curriculum reform contexts, by pointing out that, for effective intervention, professional development programmes would need to incorporate multiple elements of instruction, which are directed to the teachers, the learners, the content and the environment. They further assert that curriculum materials have a role in helping to initiate and sustain reform in science education, in that they are tangible vehicles for embodying essential ideals for reform. At the same time, they argue for recognition of the inert character of curriculum materials, and hence have reasonable expectations about their role in supporting reform. They warn that curriculum materials do not generate change by themselves, but are rather just tools that teachers can use to enact change. Studies such as Loucks-Horsley at al., (1998) and Powell and Anderson, (2002), argue for use of reform-based curriculum materials, coupled with comprehensive professional development as an effective mechanism to support reform in science education.

Further, other studies (Powell & Anderson, 2002; Haney, Czerniak & Lumpe, 1996; Pajares, 1992) take the complexity of the issues surrounding teacher development deeper, by highlighting the centrality of the behaviour and belief of teachers on how the curriculum is

put into action. The ideas teachers hold about learning and teaching are at the core of their practice. These studies highlight how previous reform efforts, which largely ignored the influential nature of teacher beliefs on changes in teaching practice, fell short of success. Powell and Anderson (2002) argue that because of the centrality of teachers thinking in translating the curriculum into practice, it is essential to consider research on teacher knowledge and beliefs in relationship to reform efforts.

Several review documents (NCCRD, 2000; Curriculum 2005 Review Committee Report (C2005-RCR), 2000) at the time of the implementation of the NCS curriculum in South Africa, pointed to the fact that this was happening within an environment that is undergoing many revolutions, and therefore leading to issues of unsustainability. One of the biggest limitations of the South African education transformation process still is lack of integration and coordination of the different pieces of educational policy (C2005-RCR, 2000). This leads to uncoordinated inputs made to schools, thereby destabilising the normal running of the schools, as well as putting lots of undue pressure on the teachers. In describing education reform context, which is similar to what we face today in South Africa, Fullan and Hargreaves (1998), argue that all these changes come with demands, which can be very exhausting and demoralising for teachers. They point out that:

> *too much educational reform and restructuring is destroying teachers' confidence, draining their energy, eating up their time and taking away their hope* (p.3).

A study done on *Educator Morale in South Africa* (Hayward, 2002), revealed that 41.2% of respondents indicated low or very low levels of morale towards their profession. Hargreaves (1994) argues that the structures and cultures of education need to change even more, if teachers are not to be trapped by guilt, pressed by time and overburdened by decisions imposed upon them. This resonates with the South African context. It is quite evident that the teacher's world is ruthlessly invaded, their lives harassed and their dignity degraded, and my belief is that to have a claim on their time, without immediate response of systematic support for issues they face on a daily basis, is becoming unethical.

The critical question becomes, how do we then continue to support teachers' much needed development in these times of reform, in such ways as to instil hope and ensure success in high quality education in our schools? As Gray (1999) puts it, the responsibility for the professional development of teachers needs to rest on the shoulders of the teachers

themselves, and the authorities' role should be one of support with such efforts, in ways that are feasible and do not seek to control. Fuller and Snyder (1992) capture the concern clearly in their statement that, *the more we learn about what teachers should be doing, the more we realise just how constrained their social roles actually are within schools*.

More progressive professional development programmes, which view professional development as a continuous, long-term process, aimed at engaging teachers continuously and systematically in arrays of a well-planned variety of growth-promoting activities, have been explored. The idea of a school-based support programme is consistent with the notion raised by most social constructivists (Rogoff, 1990; Cochran et al., 1993; Kass & McDonald, 1998) that learning is a social and context-bound exercise. Kass & McDonald (1998) argue that, if learning is both a constructive and an enactive process in which a person and a setting co-emerge, then the context in which learning is situated is an important part of the picture. Another strong confirming argument is put forth by Cochran et al., (1993), that understanding is situated or context-bound, because social interactions are fundamental and inseparably bound to the development of the tools for thinking and understanding how to use them.

An ideal professional development programme should seek to cultivate a habit of mind in teachers which can support their professional growth in a holistic manner. According to Fullan and Hargreaves (1998),

> *the single distinguishing characteristic of the best professionals in any field is that they consistently strive to better results, and are always learning to become more effective, from whatever source they can find*.

Collegiality, collaboration and supportive communities are increasingly acknowledged in many studies (Gunstone et al., 1993; Appleton & Kindt, 1999), as critical elements in teacher development and training. Collaborative support can encourage innovation, boost teacher confidence, foster professional enthusiasm and, more importantly, reduce the teacher's isolation.

In South Africa, there are district-based government officials, designated to offer teachers in schools much needed professional support on a continuous basis. Some studies (NCCRD, 2000; C2005 Review Committee Report (RCR), 2000, Nakedi, 2003) which aimed at creating a support base for teachers in schools by forging collaborations with these district officials, revealed that these officials are often already too overloaded to give full and

meaningful attention to any particular programme. The other challenge was that, in many cases, most teachers have lost respect and confidence in the officials and do not view their participation in a constructive light. In most cases, they see the officials as incompetent inspectors, who cannot offer clear guidance and support on issues of translation of policy into practice, instead of viewing them as mentors, with the sole aim of intervening constructively in their professional development.

Gray (1999) argues for a sustainable support to teachers. He proposed a professional learning communities (PLC) approach, which involves establishment of what he refers as local teacher collectives, that own, drive and run the process, but are also strategically supported by the authorities and outside agencies in a variety of ways. According to his vision, the success of the model will crucially relate to securing an intrinsic motivation amongst teachers to engage professionally, and to take responsibility for their own on-going professional development. What he argues is that such a shift in power, although real, is not of a nature that is likely to undermine an education department's ability to administer its schooling system effectively. According to this model, a reasonably resourced working base is required, that has on its staff a key person that is able to play a facilitative support role and to link with an outside resource person. He argues that such a resource person should ideally be based in a tertiary institution, involved in teacher education or an NGO.

2.6.2 Teachers' Beliefs in the face of Curriculum Change

Many studies (Aldridge et al., 1997; Pajares, 1992; Nespor, 1987; Munby, 1982) have revealed the critical role played by teachers' beliefs in the process of reform, because of their resistance to change. Some studies indicate that mismatches between belief and practice, in the face of reform, arise as a result of either the stability of the initial epistemological system or lack of support for the enacted constructivist epistemology. Tobin et al, (1990); Bryan and Abell, (1999); Luft, (2007) argue that for science teacher development programmes to have any lasting impact, they have to be underpinned by clear understanding of teacher beliefs and their role in practice. She further reiterates the importance of understanding how science teachers' beliefs are formed, in the designing of pre-service and professional development programs which are conducive to optimal development of science teachers.

Powell and Anderson (2002) argue that, because of the centrality of teachers' thinking in translating the curriculum into practice, it is essential to consider research on teacher

knowledge and beliefs, in relationship to reform efforts. They further assert that in the context of curriculum reform, if teacher beliefs and knowledge are not aligned to the philosophy promoted by reform-based materials, the use of these materials is likely to be inconsequential. In such cases, even though curriculum developers have gone to great lengths to provide links between theory and practice, such links will remain unhelpful until the teachers make the connections themselves (Powell & Anderson, 2002).

In two case studies investigating the influence of teacher beliefs on curriculum implementation, Cronin-Jones (1991) found that, because the existing belief structures of the two teachers involved in the study were incongruent with the underlying philosophy of the intended curriculum, this served to hamper successful classroom implementation. She therefore argued that teacher education should focus on identifying teacher-learners' existing beliefs, and engage them in activities which stimulate them to examine and perhaps change their beliefs about issues (such as how students learn and the teacher's role in the classroom).

In another study, which focused on curriculum implementation processes of one fifth grade science teacher, Smith and Anderson (1984) established that the marked difference between the intended and the implemented curriculum was due to the fact that the teacher and the curriculum developers held different views about the concept of learning and the nature of science. They argue that the philosophy underpinning instructional strategies in curriculum materials need to be made much more explicit and evident in the teachers' guides, so as to support teacher belief shifts and hence maximise effective classroom use of the materials.

In a case and cross-case comparison study, Roehrig (2004) engaged beginning secondary science teachers in inquiry-based instruction within a science-focused induction program, with the aim of understanding the types of constraints they encountered in their implementation efforts. The study indentified five main constraints associated with enactment of inquiry-based instruction as teachers: understanding of the nature of science and scientific inquiry, content knowledge, pedagogical content knowledge, teaching beliefs and concerns about management and students. The study revealed that none of these factors operated in isolation, to influence instruction, but rather operated collectively in different degrees to serve as predictors for the implementation of inquiry-based instruction.

In a study where she worked with three science teachers, Brickhouse (1990) established that the teachers' beliefs about the nature of science not only influenced their science classroom instructions explicitly, but also shaped an implicit curriculum concerning the nature of

scientific knowledge. Brickhouse (1990) argued that, in order to enable prospective teachers to realise and appreciate the connections between their views about the nature of science, the nature of science learning and classroom practice, their study of subject matter, learning theory and clinical practice should occur concurrently.

From the behavioural paradigm, Ajzen (1986) came up with a *theory of planned behaviour,* which explains beliefs and their impact on action. This theory proposes that all human actions are guided by three types of considerations (Ajzen, 1991; Ajzen & Madden, 1986). The first is termed *behavioural beliefs* and is concerned with beliefs about the outcome of the behaviour and the evaluation thereof. The second is referred to as normative beliefs and is concerned with beliefs about other people's critical expectations and the motivation to comply with those expectations. The third is termed *control beliefs,* and has to do with beliefs about the presence of factors, which can either facilitate or impede performance of the behaviour, as well as the perceived power associated with these factors. Each of these three constructs leads to a distinct pattern of response, with behavioural beliefs producing favourable or unfavourable *attitudes towards the behaviour*, normative belief resulting in *perceived social pressures* (subjective norm) and the control beliefs giving rise to *perceived behavioural control,* which may be internal and pertaining to inner powers, or external and pertaining to contextual powers.

According to this theory, a combination of these three aspects leads to a formation of behavioural *intention,* and, generally, the more positive the attitude and subjective norm and the stronger the perceived behavioural control, the stronger will be the person's intention to perform the behaviour. What this theory hypothesises is that ultimately, if an individual has a sufficient degree of *actual* control over the behaviour, they are bound to carry out their intentions when the opportunity arises.

This theory is behavioural in perspective while the present study draws from social constructivism and situated cognition orientations. Even though one can argue that perspectives used in this study clash and are irreconcilable in orientation to behavioural perspectives, nonetheless, these diametrically opposed theories show that beliefs are at the heart of change, and that for teachers to be able to sustain suggested changes in their practice, they require to make fundamental and conscious shifts in both knowledge and beliefs (Haney, Czerniak, & Lumpe, 1996).

This theme is very important, as it highlights the complexity of the issues surrounding teacher development and support, by emphasising the centrality of the behaviour and belief of teachers about how the curriculum is put into action. The argument that these studies raise, is that ideas teachers hold about learning and teaching, are at the core of their practice. This can be said to account for how reform efforts, which largely ignore the influential nature of teacher beliefs on changes in teaching practice, fall short of success because ideas teachers hold about learning and teaching are at the core of their practice.

Given the picture displayed by the studies above, there is a case for assisting science teachers to engage in action learning and reflective practice. Another even more compelling reason is captured in the quote below, that beliefs are critical resources, especially during times of change, because they are the centre of avenues for changing and creating new cultures.

> *Teachers' thoughts, perceptions, beliefs and experience are all aspects of teachers' culture which we need to know about and be aware of as a key factor in education, especially in times of change. Yet this crucial aspect of education is probably undervalued and certainly under researched. ... When people tell stories, anecdotes and other kinds of narratives they are engaged in a perceptual activity that organises data into a special pattern which represents and explains experience. (Branigan, 1992, p. 3)*

2.7 An Integrated Approach towards Science Teacher Support

Coupling PCK with self-study ensured that the teachers dealt with the depth and breadth of complexities, inherent in the teaching of science concepts, while, at the same time, not losing focus on the cognitive and meta-cognitive aspects of the present reform-based science curriculum. Related to this, Brown et al. (1989) launch their argument through the key concept of *indexicality*. They argue that, much like indexical words (and some believe that most words are indexical), concepts are situated. The meaning of a word/concept cannot be captured by a definition – its meaning depends on the context, and so part of its meaning is inherited from the context. A concept continually evolves with each occasion of its use, and it is always under construction.

Abstract science concepts, like energy, atoms, orbital, electronegativity, oxidation etc. are only understood by their manifestations during use – they are inventions of the science community to serve particular purposes in the science domain, and therefore are fundamentally situated. It follows then, that learning and knowledge are situated, since the constituent parts of knowledge index the word. They suggest the use of knowledge as a tool which is determined by the community or culture using it, and hence *activity*, *concept/tool* and *culture* are interdependent. None of the three can be understood without the other two.

They further argue that tools and the way they are used reflect particular accumulated insights of communities.

That conceptual tools reflect cumulative wisdom of the culture in which they are used, the insights and experience of individuals involved, and that their meanings are product of negotiations within those communities, brings to the fore the contested and socio-cultural perspective to the generation of scientific knowledge. The argument presented is that learning must involve activity, concept and culture in their interdependent relation to one another, in order to achieve understanding. This is consistent with the philosophy underpinning the new science curriculum, and its three science learning outcomes. Given this background, Brown et al.'s (1989) notion of *cognitive apprenticeship* as discussed in the next section, becomes relevant in framing the teacher's learning environments.

2.7.1 Cognitive Apprenticeship and Metacognition

Cognitive apprenticeship involves approaches that attempt to enculturate students into *authentic* practices, through *authentic* activities and social interaction. Although this study has a focus on teacher learning, rather than student learning, learning is learning and this notion is of relevance to experiences of these teachers as they grapple with the implementation of a new science topic within the framework of a new science curriculum. Considering that social interaction and conversation only happens within groups, cognitive apprenticeship implicitly entails *collaborative learning*.

This thesis focused on teacher learning in two distinct contexts, where the tensions of merging learning processes with the context in which they occur, were negotiated differently. In the first phase of this study, which is referred to as the minor case study and discussed in the fourth and the fifth chapters, the programme was conceptualised as a school-based action learning project, aimed at drawing together science teachers in a high school and two of its neighbouring middle schools. In the second phase, which is referred to as the major case study and is discussed in the fifth, sixth and the seventh chapters, the four participating teachers undertook self-studies on the development of their PCK, as they approached new topics within the new science curriculum framework which they were attempting to teach for the first time.

The term *apprenticeship* emphasises the central role of activity in learning and knowledge. It highlights the context-dependent, situated and enculturating nature of learning, and suggests a role for the teacher as a coach. Besides the role of the researcher, in the present study, the

researcher assumed multiple roles of supervisor, mediator, facilitator, mentor and coach, by drawing on powerful research-based strategies and available resources to create an environment conducive to learning. This was one in which the participating teachers engaged collaboratively to support and learn from each other, in facing authentic challenges posed by their own practices. The four teachers and the researcher formed a team of collaborators, as discussed further on in the section on self-study, and also validated each participant's research process. During authentic activities, action was largely developed by the whole team, by first studying and discussing the resources provided, as well as encouraging and welcoming spontaneous thinking, improvisation and intuitive responses. Explorations led to the discovery of general principles, while the researcher supported the participants' attempts at doing the tasks, and encouraged them to continue independently.

The term *cognitive* denotes that apprenticeship techniques go well beyond physical and technical skills, to the kind of cognitive and meta-cognitive skills normally expected from and associated with conventional schooling. In most South African schools, the quality of teaching and learning has declined. This, combined with the low morale of teachers, requires focused research-based turn-around strategies. One particular difficulty arises from the emphasis put by teacher development programs on innovative teaching strategies at the expense of content knowledge. Teachers are expected to follow a complex curriculum from an inadequate science content knowledge base without appropriate support. Central to this problem is the lack of appreciation from most teacher support and development strategies, that the philosophy underpinning this new curriculum is different, and necessitates a total shift in paradigm from how most teachers were trained, as well as their present outlook on practice.

This study engaged teachers in both cognitive and meta-cognitive activities. Meta-cognition can be defined as the knowledge of one's own thinking processes and strategies, and the ability to consciously reflect and act on the knowledge of cognition to modify those processes and strategies. Both self-study and PCK are therefore, meta-cognitive in nature. Meta-cognitive capabilities are crucial life skills, and the new South African curriculum demands that teachers model and promote these process skills for their students. In South Africa, teachers come from a history where the general curricula by the old black Department of Education and Training (DET) called for adherence to the curricula which was monitored through common examinations and hence external control. This type of system led to dependency on the authorities and lack of innovation among the practising teachers, thus

crippling and disempowering them from developing their students into creative and active participants in their societies. This culture persists in types of inputs offered in schools till today. Acquisition of meta-cognitive capabilities should be encouraged and they should form a critical component of any teacher training and development programme, aimed at transforming the quality of learning and teaching in our schools.

Kitchener (1983) promotes a three-level model of cognitive processing to account for complex monitoring, in the case where individuals are engaged with what she refers to as ill-structured problems (problems where contradictory evidence and opinions co-exist). What she proposes is that, at the first level which is referred to as cognition, individuals are only engaged with reading, memorising, computing, perceiving and problem solving. At the second level, which she refers to as meta-cognition, individuals monitor their own progress when they are engaged in the first order tasks referred to above. The third level, which she calls epistemic cognition, involves individuals reflecting on the limits, the certainty and the criteria of knowing. What the model expounds is that individuals' epistemic assumptions influence how they understand the nature of problems, and the decisions they make about the kinds of strategies they feel appropriate for solving them.

This model informed several features of this study, in terms of structuring, sequencing and the nature of activities the teachers engaged in within the self-study framework. First, the teachers were provided with the materials to study on their own, and come to sessions ready to share and discuss their understanding and ideas; then they had to draw from these materials to plan and develop tasks for teaching their topics; then they brought their products in and presented them to the team, getting feedback before using them in their classrooms. At a strategic point during this process, they used tools which promoted meta-cognition (CoRes, concept maps and reflective journals) to keep track of the development and growth patterns of their PCK.

Paris and Winograd (2001) propose that self-regulated learning (SRL) is characterised by three central features which are: awareness of thinking, use of strategies and situated motivation. They argue that, for teachers to be able to understand how to nurture development of independent learning, they themselves have to experience, construct and discuss these central features among themselves. This, they claim, will lead to a shift of instructional focus from merely delivering curricula or managing classroom behaviour to fostering strategic and motivated students. They reviewed 12 principles of SRL that can be

used by the teacher in the classroom within four general categories. Three of the categories, self-appraisal, self-management and self-regulation are of interest to this study. In the category of self-appraisal, they explored how teachers can analyse their own learning styles, evaluate their own understanding and model cognitive monitoring. In the category of self-management, they discussed how teachers can promote mastery of goal orientations, time and resource management and how to use 'failure' constructively, as a point of learning. In the self-regulation category, which is of great interest in this study, they explore how SRL can be taught, using various tactics such as direct instruction, meta-cognitive discussions, modelling and self-assessment of progress.

Part of the nature of self-study is that the work should be made available for public scrutiny, as a process of validation. Therefore, carrying out self-studies meant that the participating teachers made their work public to the broader science community at both local and national conferences, which served as part of their enculturation, to ways of knowledge generation prevailing in that community of practice. PCK ensures that there is no loss of focus from the central content and its teaching. At the same time, self-study ensures integration of use of this content, for teaching with relevant procedural and process skills consistent with how scientific knowledge is generated.

2.7.2 The BSCS 5E Instructional Model

While science teachers all over the world are on a continuous journey to improve their instructional strategies to ensure effective student learning, curriculum developers on the other hand strive to identify research findings they can use to develop materials which systematically facilitate connections between teachers, curriculum and students. Bransford, Brown, & Cocking (2000), argue that sustained use of an effective, research based instructional model can assist learners to comprehend fundamental concepts in science and other domains.

On the other hand, Morrow (2007) suggests that the practice of teaching is the organisation of systematic learning and the work of teachers should be best understood as that of organising systematic learning to ensure that learners obtain their basic education. As already discussed in section 2.2.2 above, the argument he raises that teaching cannot be an outcome of someone's eventful invention because practices have historical heritage which should inform the teacher's professional judgements. Therefore, teachers' decisions on what to teach, how

to teach and how to assess, should be formulated from what has been proven to be a shared good, hence the constructivist approach to lesson sequencing adopted in this study.

The 5E strategy (Bybee, 2006) is among several recent research based models for sequencing of science instruction to facilitate student learning. Historically, the model was inspired by the works of educators such as Dewey (1930s) as well as Heiss, Osbourn and Hoffman in the 1950s and Atkin and Karplus in the 1960s. It has its roots in the constructivist work of Piaget (1964) as well as recent research on cognitive science that focuses on misconceptions (Hatano, 1996; Carr, et al., 1994) and research on the difference between novice and expert practice (Chi, et al., 1981; Bransford et al., 2000).

The BSCS 5E instructional model (table 1) views learning as dynamic and interactive where an individual is given an opportunity to redefine, reorganise, elaborate and change their initial concepts through interaction with the environment, the phenomenon or other individuals. A great deal of evidence points to the fact that effective learning happens when teachers pay attention to the knowledge and beliefs that learners bring to a learning task as well as use that knowledge as a starting point to structure instruction and monitor students' changing conceptions as instruction proceeds (Confrey, 1990; Mestre, 1994; Minstrell, 1989).

This model employs a constructivist approach to lesson sequencing which promotes the use of learners' prior knowledge. As reflected in table 1 below, the five-phased lesson sequencing strategy illustrated in figure 2 below begins with what is referred to as the *engage lesson,* which is meant to arouse learners' interest, as well as elicit their prior knowledge. The latter would be used to guide the follow-up instructional inputs. The next lesson in the sequence, referred to as the *explore lesson,* is aimed at giving the learners an opportunity to experience the phenomenon of focus, and allow them to explore questions and test their ideas through inquiry-based investigation and problem-solving activities.

The third is the *explain* lesson which is aimed at comparing ideas, introducing definitions and concept names, as well as helping learners to construct explanations and justify them in terms of observations and data. The fourth and fifth which are not a focus for this study are respectively referred to as elaboration and evaluation lessons. All the participating teachers in the major case study were encouraged to explore the use of the 5-E curriculum design learning cycle because of its close alignment with the aspirations of the new curriculum.

Table 1: Summary of BSCS 5E Instructional Model (Bybee, 2006)

Engagement	The teacher or a curriculum task accesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.
Exploration	Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.
Explanation	The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.
Elaboration	Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.
Evaluation	The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

2.8 Conclusions

This research partly focused on trying to identify strategies which can be employed to support the development of the participating science teachers' PCK towards curriculum-aligned approaches, against the myriad challenges posed by the phasing in of the new curriculum. In this chapter, I have reviewed literature to show how the different pieces related to my study will be pulled together to come up with a framework that can inform this study. I started the chapter with a presentation of the two broad perspectives which underpin this study which are: the cognitive and the situated perspectives as well as PCK.

Next, I drew on literature pertaining to the context under which this study is happening:

- the South African socio-political context and its schooling system
- issues and processes surrounding its new schooling curriculum
- the nature of the NCS curriculum with a special focus on the science curriculum
- subject and topic specific challenges surrounding the teaching of chemical systems at grades 10, 11 and 12, with special focus on water cycle, atmospheric chemistry and electrochemistry

- the resulting challenges faced by science teachers

I then moved on to consider literature on the critical role of teachers' beliefs in the face of curriculum reform and their significance to this study. Lastly and in the light of the different issues raised and their implications, I considered and justified the models of teacher development strategies consistent with the nature of the science curriculum, and the types of issues surrounding its implementation. The research process in this study is guided by a multi-paradigm perspective, which draws heavily on qualitative, interpretive, social constructivist and situated cognition orientation. In the interest of capturing a holistic picture from the diverse aspects raised in the different sections of this chapter, the theories discussed served to inform conceptualization of an eclectic theoretical approach with a multidimensional analytic framework, which is articulated in the next chapter.

CHAPTER 3
RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This study investigates how two groups of science teachers, in two different settings, responded to the challenges posed by a new curriculum on their classroom practices within a supportive framed environment. In order to research this, ways needed to be developed to access the teachers' views about their strategies to address the new curriculum, as well as their actual classroom practices. The study involved mapping the participating teachers' changing perceptions of science teaching and their PCK, as they actively engaged with strategies to systematise their planning, designing, classroom implementation and peer engagement processes of curriculum-aligned lessons. In this chapter, I start with a brief introduction of the research design used in this study and the data collection processes followed in the two case studies. I then move on to consider the methodological underpinnings of this study, first by drawing from the literature reviewed in the previous chapter to conceptualise the theoretical framework of this study. Next I discuss the data collection methods used in this study and their rationale as well as how the analytic framework was used to guide the study in terms of the analysis and interpretation of data in response to the research questions. I then move on to focus on methodological limitations by discussing how issues of rigour, credibility and ethical considerations were addressed in this study.

3.2 Research Design

Henning (2004) identifies three paradigms with distinct philosophical and ontological underpinnings which overarch many theoretical perspectives in social science research as positivist, interpretive and critical orientations. As already alluded to in the first and the second chapters, the NCS South African curriculum was complex, as are the socio-cultural settings of most schools in South Africa. The research process in this study adopted a multi-paradigm perspective, which drew on qualitative, interpretive, social constructivist and situated cognition as perspectives.

Since change and action learning lie at the heart of this study, in some aspects it can be classified as action research, but not in others. This study employs case study as the design,

and action learning techniques as the method. Action learning was an attractive technique for this study because of the fluidity of the context and the pressing issues facing our society, as raised in the introduction. My conviction is that even though there will continue to be a need to study situations closely so as to come up with effective solutions to problems facing our society, it is only ethical and economic that the research agenda be integrated with a redress agenda. As Winter (1987) argues, action research centres on using the changes made in practice as a way of inducing the necessary improvement in the practice itself while simultaneously learning and gaining insights into the rationale of the work at hand as well as the context in which it features. Action research uses strategic action as a probe for improvement and understanding and these two criteria are paramount in guiding its particular selection of variety of practice.

This study employed a multiple-case study approach, with PCK as a conceptual framework and interpretive analysis grounded in phenomenological hermeneutics as a methodological framework. Adelman et al (1980) describe a case study as *the study of an instance in action*. A multiple-case design was used with each of the two programmes constituting cases. The first one is referred to as the minor and the second as the major. Within each of the above cases, the key teacher in the minor case study constituted a case, through which the story of all other teachers involved is told, and, in the major case study, each of the four teachers constituted further cases in their own right. Cohen, Manion and Morrison (2007) argue that case studies can penetrate situations and make possible observation of effects which are powerful determinants of both cause and effect in real contexts. This is a strength which, they argue, is not possible through numerical analysis.

Yin (1994) argues for multiple cases, as opposed to a single case, in that they are more compelling and make the overall study more vigorous. Another rationale for using multiple case-study designs is to avoid a situation where the case represents an extreme or unique condition, which is very rare to find in new persons. Cases have been reported to serve as important tools in portraying PCK to other teachers (Hiebert, Gallimore, & Stigler, 2002). As pointed by Levin (1995), they also serve as tools to highlight various problems and copying strategies, such as mismatches between teachers' goals and lesson plans, lack of modelling in lessons, differential expectations for students and developmentally inappropriate tasks.

Hermeneutic phenomenology is a method involving the study of social phenomena, concerned with human experience as it is lived (Polkinghorne, 1983; Van Manen, 1997;

Ajjawi & Higgs, 2007). According to Steinar (1996), hermeneutics involves the study of human cultural activity as texts, with the aim of uncovering the intended or expressed meanings. It is mainly used as a research methodology, to uncover interpretation of meanings of selected phenomena that is not immediately apparent, through production of rich, textual descriptions.

Annells (1996) explains hermeneutics as an interpretive process that seeks to facilitate understanding by disclosing and making the nature of phenomena explicit, through language. This thesis employs a two-pronged thematic data analysis, informed by the works of Ajjawi & Higgs, (2007) and Titchen (2000). In this thesis, CoRes were used to capture written accounts of the teachers' content knowledge for teaching specific topics within the chemical systems theme. Engaging teachers in self-study as a strategy to support the development of their topic-specific SMK and PCK, allowed for systematic identification of their conceptions, interpretation and constructs, which were then superimposed on the researcher's own conceptions, interpretations and constructs.

The minor case study was conceptualised as a school-based action research programme, which was aimed at encouraging and supporting teachers to assume a learning disposition by taking an experiential and reflective outlook on their practice. This case drew on a variety of data from 10 teachers of a neighbouring primary and high school south of Johannesburg. Due to unforeseen contextual issues, the activities of the first case study were interrupted and therefore most of the data in this case study consists of baseline data which was meant to establish where the teachers were at the beginning. This informed the development of a more relevant intervention programme.

In the major case study, the four teachers (registered on a part-time honours course) and their supervisor (myself) formed a collaborative team, and met weekly for a three-hour session over a period of 12 weeks. Through this process, the teachers used research-based strategies to generate high quality lesson plans, and associated resources, which could be shared with other teachers. The process started with the construction of a content representation, referred to as a CoRe (Loughran, Berry, & Mulhall, 2006), and the design of a series of lessons for each topic, covering two weeks of teaching. The lessons were presented to the collaborative team for input. Relevant resources were shared with the teachers for incorporation in their lesson designs. All lessons were videotaped for subsequent analysis. The teachers also presented their work at teacher workshops, and local and national conferences.

Literature on qualitative studies McMillan & Schumacher (1993) and LeCompte & Preissle (1993) challenges the idea of the completely detached and objective observer. In both case studies, I played a role of a participant observer and to curb the problem of subjectivity, I used multiple data collection techniques as well as being careful not to claim generalisability beyond the context of the study.

3.3 Research Participants and Sampling Technique

Even though the sampling technique employed in this study involved selection of the most accessible, it is more a convenience (or opportunistic) sampling rather than self-selecting. Self-selecting techniques rely on volunteering rather than recruitment. A convenience sampling technique would mostly employ an open period of recruitment that continues until a required number of participants, events or institutions are enrolled (Patton, 1987). This approach was used in differing ways in both the minor and major case studies. Considering the delicacy and the revealing nature of this study, especially in seeking to reveal the conceptual understanding of teachers, videotaping their lessons and demanding total commitment to the dynamic processes, there was a need for me to establish a rapport with the teachers.

Therefore, in the minor case study, I relied on willing and enthusiastic teachers and schools, implying that the teachers were carefully selected. The programme involved participation of ten science teachers (see table 2), with varying levels of participation from Bojanala high school and the neighbouring Pelonomi primary school (both pseudonyms). Therefore, varying data were collected for each teacher. Data collected for three of the teachers (Lerato, Mpho and Molefe) were richer than the rest, because of their continued enthusiasm and commitment to the programme. Participation of the other seven teachers was minimal. The programme was aborted during the second cycle due to circumstances which became the focus of the next chapter.

For the major case study, I worked with four teachers who chose the topic of their project for their BSc honours projects. This suffices as a convenience sample because of its recruitment element where students were invited and given time to choose from a list of project descriptions (topics) with names of supervisors put forward to them. The sample is therefore not representative. The four teachers are identified as Noma, Colleen, Bongani and Sipho. Noma and Bongani were teaching at high schools in the East Rand, while Sipho was teaching at a township school South of Johannesburg and Colleen was at an all-girls old model C

school east of Johannesburg. Table 2 below presents profiles of the teachers who participated in this study.

Table 2: Details of the Teacher Participants

Teacher	Pseudonym	M/F	Qualification	Position	Teaching Experience	Science teaching Experience	Current teaching
Minor Case study							
T1S1	Lerato	F	FDE (school management); B Ed hons (maths & science)Public certificate in EE, ACE (science FET)	Science HOD	21 years	21 years	Grades 9, 10 and 11
T2S1	Mpho	F	Diploma in nursing, one year upgrade course for teaching technology	Senior phase natural science teacher	5 years	3 years	Grades 8 and 9 natural science
T3S1	Molefe	M	Social science degree	FET science teacher	18 years teaching experience and 15 years as language teacher	3 years	Grades 11 and 12 physical science
T4S1	Salang	F	Teaching Diploma	Science GET teacher	3 years	2 years	Grade 9
T5S1	Elga	F	Teaching Diploma with University of Zimbabwe	Science GET teacher	11 year teaching maths	0	Grade 9
T6S1	Malebo	F	Teaching Diploma with Tshia College in Xwaxwa	Science GET teacher	1 ½ years		Grade 8
Major Case study							
T1S2	Bongani	M	FDE in science (RAU);	FET maths & science teacher	14 years trained and working as a technical teacher	Retrained and practised as science teacher for 7 years	Grade 11 maths and science
T2S2	Noma	F	BA degree, FDE in Science (Wits);	10 years HOD & 23 years Senior-FET science teacher	23 years	23 years	Grade 9 natural science, grades 10, 11 physical science
T3S2	Sipho	M	STD major in PS & Bio; Education Management (UP); FDE science (Wits)	HOD & Senior-FET science teacher	21 years in 5 different schools & 16 in present school	8–9 years Bio, PS grades 9 to 12	Grade 8, 9 natural science & grade 10 physical science
T4S2	Colleen	F	B Sc (Wits); registered BSc Hons (Wits)	Senior-FET science	15 years	15 years	Grade 9 natural science, grades 11 & 12 physical science

3.4 The Conceptual and Analytic Framework

In developing a theoretical framework for the study, I took cognisance of the argument raised by Schwab (1969) that there should be a shift of curriculum energies from theoretical, to the practical, to the quasi practical and to what he refers to as the eclectic. This last he considers to be:

... the arts by which systematic, uneasy, but usable focus on a body of problems is affected among diverse theories, each relevant to the problem in a different way. (p. 101)

This study intends to capture and explore the types of environment and insights that emerge from use of reflective practice, and meta-cognitive tools to enhance the teachers' practice at multiple levels. A challenge which emerges is how to capture a holistic picture from a changing environment with such diverse aspects. To tackle this challenge, the study employed an eclectic theoretical approach with a multidimensional analytic framework, so as to ensure that the picture captured is holistic.

The conceptual and data analysis framework of this study is situated in what O'Brien (1998) refers to as the paradigm of praxis drawn from three models. For purposes of explicating theoretical underpinnings of this study, a description of the three models and how they were used in this study is given. This framework evolved and emerged, as the study proceeded. Hence it has been important to provide the contextual information surrounding the participants. The following three theoretical models underpinning this study were integrated to provide a conceptual and data analysis framework, to interpret the findings obtained from the two case studies.

- *The Interconnected Model of Professional growth* (Clarke & Hollingsworth, 2002)
- *The 'spinning top' – a metaphor for professional knowledge* (Bishop & Denley, 2007)
- *School Curriculum Implementation model* (Rogan & Aldous, 2005)

The emerging framework is a dynamic one which altered in the light of on-going data analysis. I will start by presenting the three models and explore how they are integrated, according to their particular strengths, to serve different purposes. The models variously offered a framework for research planning purposes, an analytical lens for mapping and categorising teacher change data, as well as discerning changing patterns in the teacher's PCK.

3.4.1 The Interconnected Model of Professional growth

The *Interconnected Model of Professional growth* by (Clarke & Hollingsworth, 2002) in Fig. 2 below, is based on the premise that to be realistic and effective, there is need for a shift of perception from seeing professional development programs as changing teachers, to the perception of seeing teachers as active learners, shaping their professional growth through reflective participation in professional development programs and in practice. Drawing from situated perspective, this model appreciates that any process involving teacher professional growth will be subjected factors in the enveloping change environment. What this model further proposes is that teacher change occurs through the mediating processes of 'reflection' and 'enactment', in four distinct domains which encompass the teacher's world:

> *the personal domain (knowledge, beliefs/values and attitudes), the domain of practice (professional experimentation), the domain of consequences (salient outcomes) and the external domain (sources of information, stimulus or support* (p. 950)

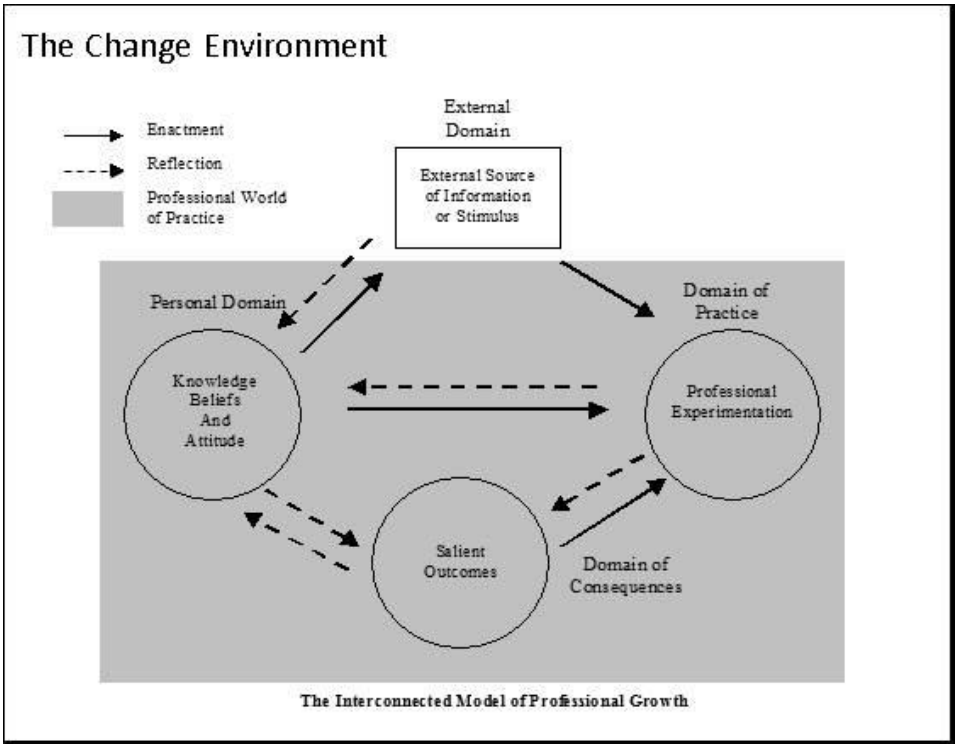


Figure 2: The interconnected Model of Professional Growth (Clarke & Hollingsworth, 2002)

The external domain is seen as falling outside the teacher's world. As illustrated in Figure 2 above, this model highlights the complexities of professional growth by identifying multiple growth pathways between the domains. The challenge of this present study was in tracing and mapping these growth pathways, using a variety of data collection techniques as the teachers continue on their journey. The model considers professional growth as an inevitable

and continuous process of learning since change from one of the four domains to the next, is being mediated through alternating processes of action and reflection.

As should be expected, any processes of professional growth represented in the model would naturally occur within the constraints and affordances of the enveloping change environment. This model locates 'change' in any of the four domains, with the type of change, reflecting its specific domain. If a teacher experiments with a new teaching strategy in their classroom, the type of change that follows will reside in the domain of practice. Any new knowledge, learning or belief would reside in the personal domain, while the change in perception of salient outcomes associated with the classroom practice belongs to the domain of consequences.

What this model expounds is that change in one domain is translated into change in another domain through the mediating processes of reflection and enactment. In the framework being developed here, this model is used as a tool to map, categorise and analyse teacher change data. Data was analysed, by empirically tracing and locating change processes from one domain to another with their associated domains as well as through studying the structural patterns in each key teacher's professional growth. The teachers' reflective journals, progressive concept maps and CoRes, as well as planning and teaching artefacts generated during the process, are the main sources of data.

This present study brings together cognitive and situated perspectives on learning, focusing on PCK, a theoretical construct that connects practice and teacher knowledge. The study also focuses on exploring strategies, which promote a reflective and experiential approach to practice, and hence the element of practice is further elaborated into the notion of learning, as increased participation in communities of practice (Wenger, 2000). Therefore, within the emerging framework, what is referred to as external stimuli, does not lie outside the teacher's world but forms an integral part of that world, through mediating processes of inquiry, feedback and responsive inputs.

In this study the framework is modified so that the four domains are collapsed into three by integrating the domain of consequences and the external domain into what we refer to as *the challenge, synthesis and enculturation domain*. In this model, the two sub-categories within the challenge, synthesis and enculturation domain are, in turn, referred to as *peer and resources engagements*, and *learner feedback and classroom outcomes.* The *peer and resource engagements* constitute all internal and external collegial engagements and forums,

where science teachers draw from their own classroom experiences, as well as from the expertise and resources within the broader science education community, to collaborate and engage in systematic learning. At the intersection of the two sub-categories, learning and insights from peer engagements, learner feedback and classroom outcomes are processed into new knowledge and practice, through the mediating process of framing and reframing.

In this framework, all the domains are personal spaces for the teacher within a participatory framework, and therefore the personal domain in the Clarke and Hollingsworth model is what is intrinsic within each teacher, and is referred to as the knowledge, beliefs and attitude domain to distinguish it from other domains. This domain pertains to all the capacities, thought processes and dispositions inherent in each teacher, which prompts certain professional actions and responses to different situations in their work, thereby gaining expression within the domain of action and practice. Those actions, in turn, lead to certain consequences identified within the sub-domain of *learner feedback and classroom outcomes*.

Learning which results in increased capacities feeding the domain of knowledge, beliefs and attitudes, as well as improved internal contemplations that inform the domain of action and practice, is referred to as framing and re-framing, and is located at the intersection of the two sub-domains of challenge, synthesis and enculturation domain. It generates challenge and invokes new ways of enactment and reflection, and is the product of the interfacing of the two sub-domains.

3.4.2 The Curriculum Implementation Model

The second model used in this study is Rogan & Grayson's (2003) model of curriculum implementation illustrated below. Consistent with the focus of this study, this model focuses on the learning environment as a unit of analysis. This model is based on the following three constructs: *profile of implementation*, *capacity to innovate* and *nature of outside support*. Each of these constructs has dimensions that explicate its area of focus and levels (see Appendices D, E and F) which map out a route for progress in the implementation process.

The two emphases of this model are that there must be some reasonable set steps to be followed if progress is to be made and that implementation should be informed by each school's constraints and capabilities. As reflected in Figure 3 below, *the profile of implementation* expresses the extent to which the curriculum is being executed in the classroom. This construct is elaborated through the four dimensions of science classroom

dynamics which are: classroom interactions, science practical work, science in society and assessment.

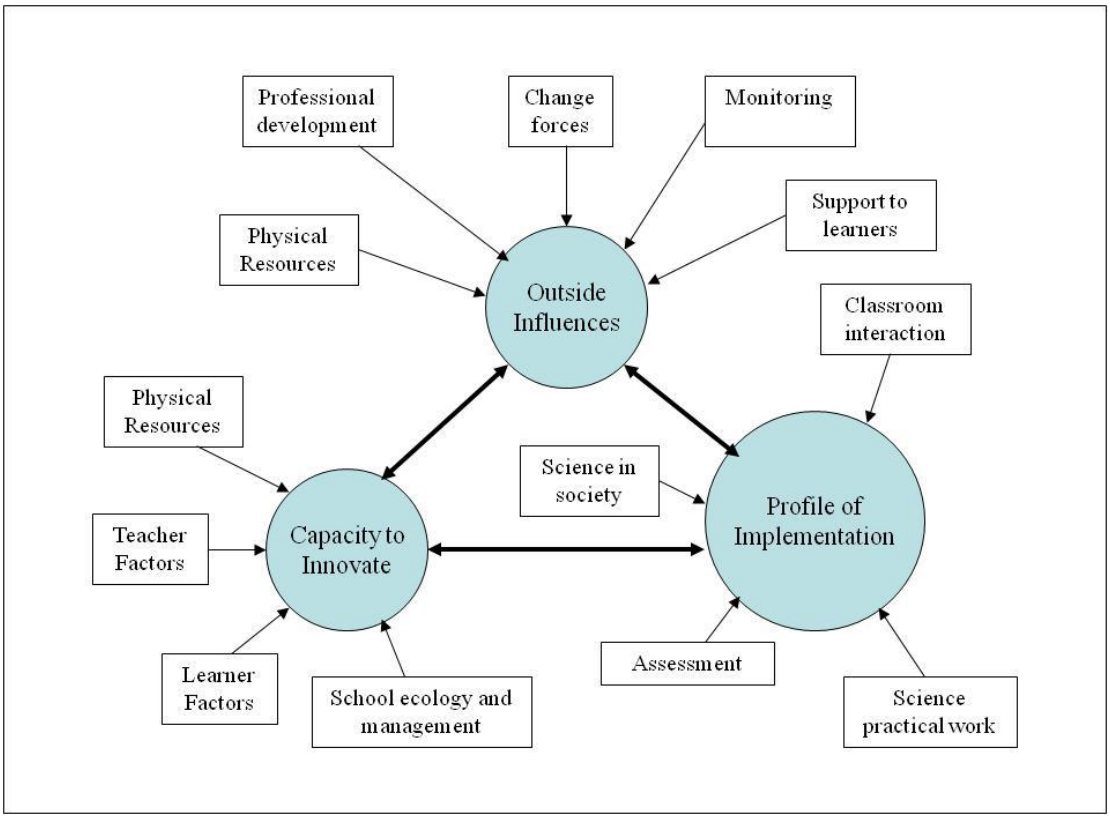


Figure 3: Curriculum Implementation Model (Rogan & Grayson, 2003)

For the purpose of this study the levels of the dimensions for this construct (Appendix D) were modified and used together with Luft's (2007) teacher beliefs interview (TBI) maps to develop a Beliefs-Practice cross case analysis matrix which is presented in Chapter 7 and serves as a tool to discern consistencies, inconsistencies and shifts in what the participating teachers profess to do and what they actually do in the classroom. This modification is done to emphasize techniques which are consistent with the NCS which is the curriculum the participating teachers are expected to implement.

The other two constructs, *capacity to support innovation* and the *profile of support from outside agencies* are seen as dimensions external to the immediate learning environment but directly relevant to the implementation processes. Further below in this chapter, the dimensions of the *capacity to support innovation* are used as indicators within Hollingsworth and Clarkson's notion of the enveloping change environment to profile each teacher's contextual working environment. These profiles of the teachers' contextual working environments are discussed fully in the next chapter. This model is also used to study the

nature and dynamics of the school-based in-service research programmes in both the minor and the major case studies using the *profile of outside support* as presented in Chapter 5.

3.4.3 The Enveloping Change Environment

Pertaining to the enveloping change environment drawn from the Clarke & Hollingsworth IMPG, four indicators which were slightly modified from Rogan & Grayson's (2003) model were used. These are *physical resources, school ecology and management, learner factors* and *teacher factors*. Consistent with Cohen and Ball (1999), Rogan & Aldous (2005) view capacity of a school to innovate comprising not only teacher factors. With the recognition that not all schools will have the capacity to support innovation to the same extent, Rogan & Grayson's *capacity to support innovation* construct is extended to four indicators as illustrated in Table 3 below.

Table 3: Capacity to Support Innovation Construct (Rogan & Grayson, 2003)

Level	Physical resources	Teacher factors	Learner factors	School ecology and management
1	Basic buildings – classrooms and one office, but in poor condition. Toilets available. Some textbooks – not enough for all.	Teacher is under-qualified for position, but does have a professional qualification.	Learners have some proficiency in language of instruction, but several grades below grade level.	*Management* A timetable, class lists and other routines are in evidence. The presence of the principal is felt in the school at least half the time, and staff meetings are held at times. *Ecology* School functions i.e. teaching and learning occur most of the time, albeit erratically. School is secure and access is denied to unauthorized personnel.
2	Adequate basic buildings in good condition. Suitable furniture – adequate and in good condition. Electricity in at least one room. Textbooks for all. Some apparatus for science.	Teacher has the minimum qualification for position. Teacher is motivated and diligent. Enjoys his/her work. Teacher participates in professional development activities. Teacher has a good relationship with and treatment of learners.	Learners are reasonably proficient in language of instruction. Learners attend school on a regular basis. Learners are well nourished. Learners are given adequate time away from home responsibilities to do school work.	*Management* Teacher attends school/classes regularly. Principal is present at school most of the time and is in regular contact with his/her staff. Timetable properly implemented. Extramural activities are organized in such a way that they rarely interfere with scheduled classes. Teachers/learners who shirk their duties or display deviant behaviour are held accountable. *Ecology* Responsibility for making the school function is shared by management, teachers and learners to a limited extent. A School Governing Body is in existence. Schoolsfunctions all the time i.e. learning and teaching always take place as scheduled.
3	Good buildings, with enough classrooms and a science room. Electricity in all rooms. Running water. Textbooks for all pupils and teachers. Sufficient science apparatus.	Teacher is qualified for position and has a sound understanding of subject matter. Teacher is an active participant in professional development activities. Conscientious attendance of class by teacher.	Learners are proficient in language of instruction. Learners have access to quiet, safe place to study. Learners come from a supportive home environment. Learners can afford textbooks and extra	*Management* Principal takes strong leadership role, is very visible during school hours. Teachers and learners play an active role in school management. *Ecology* Everyone in the school is committed to making it work. Parents play active role in

Level	Physical resources	Teacher factors	Learner factors	School ecology and management
	Secure premises. Well-kept grounds.	Teacher makes an extra effort to improve teaching.	lessons. Parents show interest in their children's progress.	School Governing Bodies and in supporting the school in general.
4	Excellent buildings. One or more well equipped science laboratory. Library or resource centre. Adequate curriculum materials other than textbooks. Good teaching and learning resources (e.g. computers, models). Attractive grounds. Good copying facilities.	Teacher is over-qualified for position and has an excellent knowledge of content matter. Teacher has an extraordinary commitment to teaching. Teacher shows willingness to change, improvise and collaborate, and has a vision of innovation. Teacher shows local and national leadership in professional development activities.	Learners are fluent in the language of instruction. Learners take responsibility for their own learning. Learners are willing to try new kinds of learning.	*Ecology* There is a shared vision. The school plans for, supports and monitors change. Collaboration of all stakeholders is encouraged and practised. *Management* There is a visionary, but participatory, leadership at the school.

In this study, this construct together with its indicators was aimed at understanding and elaborating on the school based factors that are able to support or frustrate the implementation of innovative ideas and practices. The four are: physical resourses, teacher factors, learner factors, school ecology and management. Within a school, physical resources is one of the major factors that can set limit to what teachers and learners can achieve in the classroom. In the present study, this factor was modified as Resources and Time Constraints because time also emerged as a factor from the data. Teacher factors have to do with the teacher's own background, training, level of confidence and commitment to their task of teaching. Learner Factors on the other hand pertains to the learners' backgrounds and the types of strengths and shortcomings they bring to the learning situation. School ecology and leadership are two separate aspects which are put together in this study because they are mostly intertwinned since strong leadership would create healthy functional learning environments while a weak one normally leads to confusion and dysfunctionality.

3.4.4 The Spinning Top PCK Model

The third model which was modified and used to provide the categories for identifying and mapping teachers' PCK across the three interconnected model domains, is a *model of the relationships among the domains of teacher knowledge*, based on Bishop and Denley's (2007) PCK model (figure 4). Their model is a metaphor for explaining the relationship between PCK and the other six knowledge bases proposed by Shulman: *knowledge of content, knowledge of learners and learning, knowledge of context, knowledge of curriculum, general pedagogical knowledge, knowledge of values, ends and purposes*.

Their metaphor is called the *spinning top* because they emphasise the tacit nature of PCK. As Shulman said, it is an amalgam and a blending of knowledge bases, *a dynamic construct that*

is not amenable to static representation. Their proposed model is that of considering professional knowledge as a spinning top with knowledge categories represented as coloured segments which are readily distinguishable from one another when the top is still, but merge and form a different colour when the top is spun.

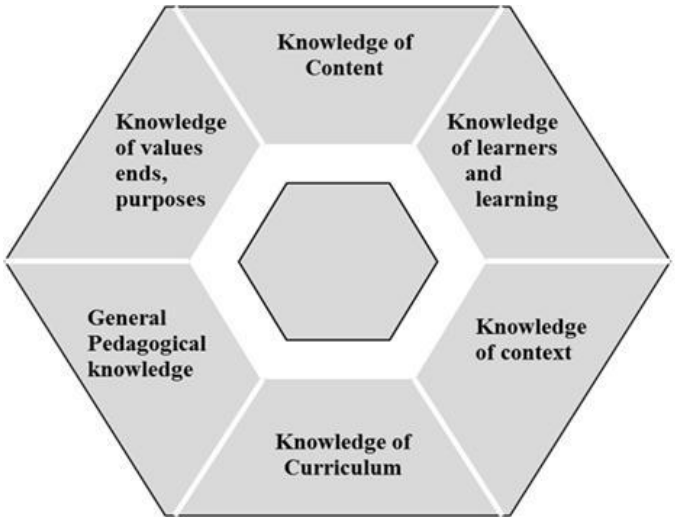


Figure 4: Spinning Top Metaphor (Bishop and Denley, 2007)

This metaphor emphasises that PCK comes alive in practice through the ability of the teacher to blend the individual knowledge bases together appropriately in response to the demands of the lesson. As described in the next section and illustrated in the framework of this study presented in figure 5, there were initial attempts to use this model to modify the three domains and offer lenses through which the pattern of change in PCK from one domain to the other can be discerned. However, the categories proofed to be too generic. Unlike Shulman's notion where PCK is seen as a distinct knowledge domain which teachers use to transform SMK, Bishop & Denley's notion is integrative and does not take PCK as a distinct knowledge domain. This is a critical distinction which explains why the Bishop and Denley categories remain generic and do not capture the topic specific aspects of PCK which constitute Shulman's notions of PCK. In this present study, there were initial attempts to integrate some aspects of this model with some aspects of the *interconnected model* to come up with the *Learning for Teaching through Participation (LTtP)* model which is used to guide this study. The evolution of the LTtP model is discussed fully in the next section.

The data that informed this thesis was wide and varied within each case study, and hence the model that informs this study and is also its theoretical contribution, evolved throughout the study and its evolution, and is apparent in the varied versions within each chapter. The

versions of models which were used to guide each of Chapters 4, 6 and 7 are included at the beginning of these chapters. Below is the discussion of how the model evolved across the chapters, and what is presented in this chapter is the initial model (figure 5). The discussion pertains to how figure 5 evolved into figure17, which drew from all the learning throughout the thesis and is discussed fully in the last chapter of the thesis.

3.4.5 The Learning for Teaching through Participation (LTtP) model

Lave & Wenger (1991) argue that it is crucial to base the field or education on explicit accounts of its different theoretical perspectives. To this end, this study employed an eclectic theoretical approach which draws from cognitive constructivism, socio-cultural and situated orientations to learning in order to ensure that a holistic picture from diverse and dynamic environment is captured. Based on these research perspectives a multidimensional analytic framework drawing from the three models discussed in the previous section was conceptualised to guide this study.

Following a situated perspective to learning this model (figure 5) expounds that any process involving teacher professional growth will naturally be subjected to the constraints and affordances of the enveloping change environment (1) derived from factors such as school management and ecology (3), resources and time constraints (2), learners (4) and teacher factors (5). Even though this study was aimed at the teachers' PCK and how it can be supported, the school contextual issues emerged so strongly as a factor that they formed the main finding of the minor case study. These are discussed in full details in the next chapter.

LTtP is premised on the need for a shift of perception from seeing professional development programs as changing teachers to seeing teachers as active learners, shaping their professional growth through reflective participation in professional development and in practice. The LTtP model is a framework for understanding the process of supporting teacher learning which emerged from this study as well as serving as its analytical framework.

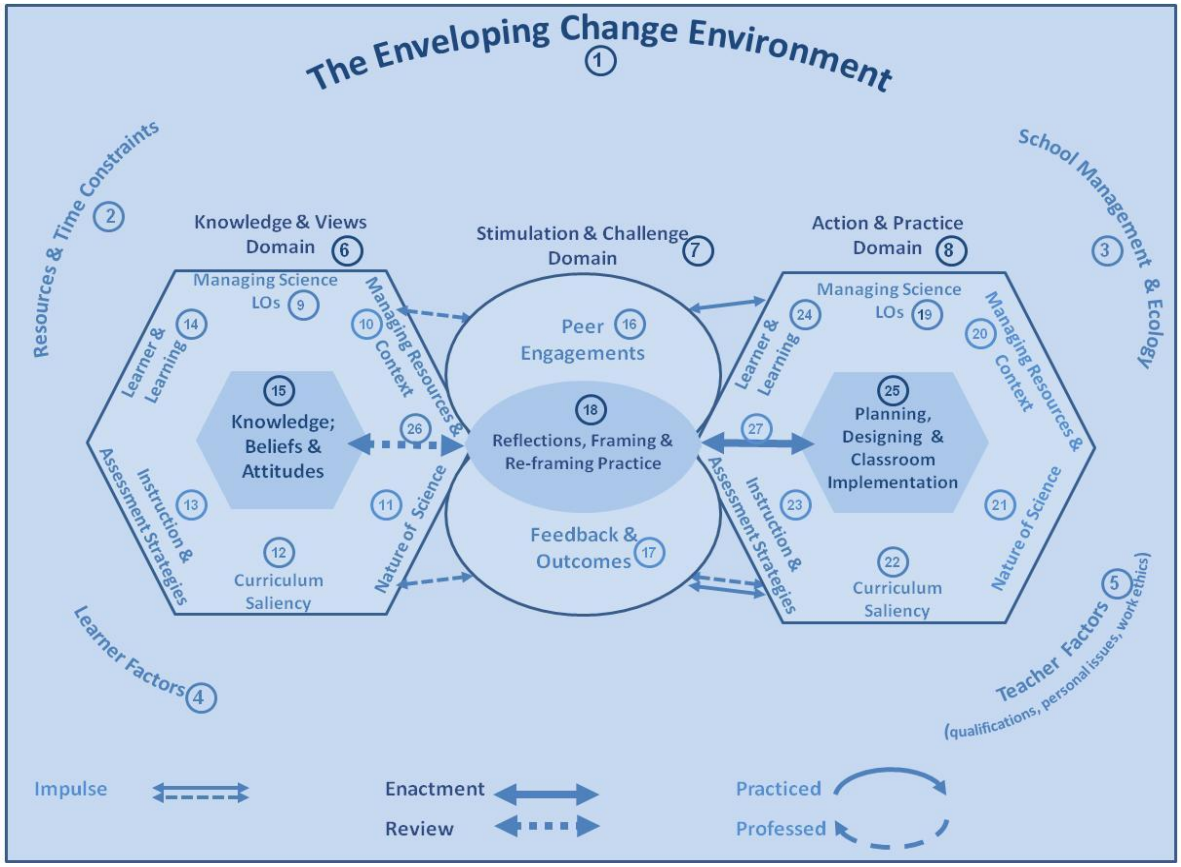


Figure 5: Initial Learning for Teaching through Participation (LTtP) Model

This framework identifies three interrelated domains (6, 7, 8) which encompass the teachers' professional world and presents multiple professional growth pathways (26, 27 etc). The domain of *knowledge and views* (6) pertains to all the capacities, thought processes and dispositions inherent in each teacher which prompts certain professional actions and responses to different situations in their work and thereby gaining expression within the domain of *action and practice* (8).

Those actions in turn lead to certain consequences latent within the realm of *feedback & outcomes* (17) and presenting certain professional growth opportunities. These opportunities which can be harnessed and used within the *stimulation and challenge* domain (7) to support teachers to engage and collaborate with each other in efforts of systematise and reflect on their own practice. The domain of *stimulation and challenge* (7) draws not only from classroom outcomes and feedback (17) but also from external expertise from peer engagements (16) in the wider community of practice, which should serve to reinvigorate and stimulate deeper learning.

There was an initial attempt to work with the Bishop & Denley (2007) categories which proved to be too generic in the face of engagement with data as well as continuing and further review of literature. Unlike in the spinning top model (figure 4), where the six categories are just about teachers' knowledge domains, the modified framework categories (in figure 5) are about knowledge, beliefs and attitudes. As reflected in figure 5, modified sub-categories which were formulated through iterative engagement with the original model, data from the minor case study and review of relevant literature are: content knowledge, managing resources and context, managing science learning outcomes, curriculum saliency, nature of science and learners and learning. These are the categories which were used in Chapters 6 and continued to be modified with each set of data analysis, as well as continued literature review, to gain a sharper focus in capturing the intricate features of the South African science curriculum.

The category of *values, ends and purposes* found a new expression which was more science specific in *nature of science* (11) which was a category that emerged from data. Another category which emerged from the data was the *management of science learning outcomes* (9) which captured both content knowledge and relevance. In this new model, the Bishop and Denley categories related to *general pedagogical knowledge* and *knowledge of context* emerged from the minor case study data as *instructional and assessment strategies* (13) and *managing resources and context* (10). With further review of literature, the *managing resources and context* sub-category was modified and used in chapter 7 and 8 as *alternative curriculum resources* to capture and give focus an aspect of Shulman's notion of curriculum knowledge which entails the teacher's broad strategic curriculum resources knowledge and management.

Instruction and assessment were put together in one category to emphasise the notion of assessing for learning, rather than of evaluating, and therefore the formative and diagnostic inclination role, as opposed to the summative role. The knowledge of curriculum category in this study borrowed from Geddis and Wood (1997)'s notion of curriculum saliency to capture the strategic knowledge aspects of knowledge of depth and breadth of a topic as well as sequencing of concepts across different levels or grades.

The Bishop and Denley (2007), integrative approach to PCK as opposed to Shulman's transformative approach, led to omission of the topic specific aspects such as *learners' conceptions and misconceptions* as well as *alternative forms of representations*, which are what comprise Shulman's PCK. When analysing classroom implementation data, as well as

continued literature review, this omission became apparent and hence the modification of the LTtP model used in chapter 7. In the initial model, effective management of the three science learning outcomes with one having focus on content, the other on skills and the other on relevance, content knowledge was subsumed within this category. While defining and working with content knowledge within the implementation data, the need to set content knowledge as a distinct sub-category of PCK became very apparent.

Schwab (1964) in (Shulman 1986) explained subject matter knowledge as consisting of two structures, referred to as *substantive* and *syntactic* (SnS). Substantive structure has to do with the organization of facts, concepts, principles, laws and theories, while the syntactic structure has to do with the rules of evidence used for the generation and justification of knowledge claims made within the discipline. Catering for the three science learning outcomes requires appreciation and knowledge of the structure, and therefore in this study (Chapter 6, 7 & 8), the aspect of content knowledge needed to be made conspicuous. It became a separate sub-category which in chapter 6 was expressed as mere science content knowledge and in chapters 7 and 8 as *Syntactic & Substantive Subject Matter Knowledge (SnS_SMK)* to ensure that the emphasis is explicit.

What also became apparent was that because the *nature of science* is at the core and underpins practice, identifying it as one of the six aspects of the two domains of teacher PCK was out of place. Even though knowledge and views about NOS is critical to the teacher's understanding of the new curriculum, it is not just one of the aspects but it is at the core of all aspects and manifests itself in the teacher's syntactic subject matter knowledge, as well as their knowledge of developing learners' meta-cognitive and socio procedural skills related to the generation and justification of scientific knowledge claims. In chapter 7 and 8 *VNOS* became part of the core of the *knowledge and belief domain*.

While analysing classroom implementation data it also became apparent that the sub-category, *learners and learning* was too broad, as it did not distinguish between generic and topic-specific aspects, related to learners and learning. Informed by arguments raised by Shulman regarding the critical aspect of the teacher's PCK as their capacity to engage with what makes any given topic difficult to understand, this sub-category was modified to give focus to *learners' conceptions and misconceptions.* Related to this argument was also the skills aspect of the three science learning outcomes. Drawing from Shulman's PCK notion of the critical role of learners' conceptions and misconceptions, the *management of science learning outcomes* (9) was subsequently conflated with the *learners and learning* (14)

category into two new categories as a way of sharpening focus on possible barriers to the critical features of the curriculum, referred to as *learner's prior conceptions* and *learners' procedural knowledge.*

In Chapter 8, further insights pointed to the centrality of SMK, just like NOS, as underpinning all other aspects rather than occupying the same status. SMK was then distinguished as one of the core knowledge components, contributing to PCK development and underpinning teacher practice. This explains the move to put content knowledge at the core of the *knowledge, beliefs and attitudes* domain in Figure 17 instead of taking it as one of the 6 aspects.

The LTtP model was used to synthesise a profile of each teacher on each of the three domains using data collected. The methods of data collection for each domain are now considered separately below.

3.5 Data Collection Methods

The instruments used in this study are a concept challenge questionnaire, modified from chemical inventory (Mulford & Robinson, 2002), planning and reflection questionnaire (Appendix L) and belief and attitude about teaching interviews (Luft & Roerig, 2007) and questionnaires, CoRe prompts, analysis of assessment documents and lesson plans. All instruments used during the study were either established or well tested instruments. Those which were generated especially for this study were reviewed by two colleagues giving valuable feedback which was used to refine the instruments before use in the study. The description of the instruments and how they were used in the minor and major case studies is given the sections that follow below.

3.5.1 Classroom Observations, Case Methods and Videotapes

In the minor case study, each teacher was observed in the classroom at least once and the lessons were video recorded. The videos were used as data capturing tools, as well as during reflection sessions, for collection of further data. Engaging teachers in such activities was used as a strategy to develop their meta-cognitive and reflective capacities. In the minor case study, I played both the mentor and researcher roles, while, in the major case study, the role was extended to a third role, that of supervisor. In the mentor capacity, I ensured that the environment was rich in support for the teachers' classroom efforts, by drawing from and exposing them to various tangible curriculum-aligned learning and teaching resources. At the

process skills level, I drew from current research-based meta-cognitive, learning and teaching strategies to engage the teachers in a reflective and planning process, in preparation for their classroom implementation. In the supervisory capacity, I augmented the weekly research method seminars, by guiding the whole research process, pointing them to current readings in the field of their research, facilitating the process of obtaining ethics clearance and guiding the data collection, analysis and write-up processes. In the researcher capacity, the focus was on collecting evidence and keeping keen track of each teacher's participation and progress in the process. The weekly research sessions were divided to cater for all these processes, with priority given to the research agenda.

The processes in the major case study were a bit different, as the researcher did not observe the lessons personally. Instead, each teacher video recorded their own lessons, and brought these to the research project sessions for group reflections and data analysis. Each teacher also individually studied materials provided, and contributed to the discussions during project sessions. They also engaged in collaborative planning and development of lessons, addressing their particular topic of focus within the *chemical systems* theme. During some of these sessions, each teacher got an opportunity to present their CoRes, lesson plans and teaching tasks, and received feedback from the collaborative team. All the research project sessions were audio recorded for subsequent analysis. The teachers then implemented and kept record of all the sessions in a reflective journal, as well as submitted all the artefacts and curriculum materials used during these lessons. Most lessons were video-taped for subsequent analysis.

The main focus of the video analysis was to see how the teachers transfer the skills, ideas and learning, gained from their participation in the research group interactions, to their classrooms. In the minor case study, pre- and post-lesson interviews were held with the teachers to allow them to share their plans and their reflections, as a strategy to get them into the mode of systematising and reflecting on their teaching efforts. In the main case study, prior to each lesson, each teacher was expected to have research, as well as learning and teaching objectives. As they continued to engage with the learning of the topic of their focus, in preparation for teaching, as well as developing assessment tasks and lesson plans, the teachers in the main case study constructed CoRes at strategic points in the process, and kept reflective journals, to capture and map the development of their PCK.

Hall (2000) interrogated issues around collecting and reporting videotaped research sessions. What he emphasizes is the importance of avoiding confusing videotapes with *raw data,* because he argues that every time a camera or microphone focuses on one aspect of a situation rather than the other, prejudices are introduced about what is important and what is not. Kelly & Lesh (2000) warn against interpreting videotaped records as a one-time event. They say that the interpretation should rather involve many interactions and recursions, for research to go beyond the surface level phenomena and recognize deeper patterns of behaviour. In this study, in order to avoid a situation where other details of perspective about the classroom interactions are systematically ignored due to use of video data, other data collection methods, such as field notes and interviews with the teachers about the lesson sessions, were used.

3.5.2 Reflective Journals

Goodnough (2003) argues that journal writing is a great tool to assist participants in making their thoughts explicit, in practising reflection-on-action, as well as for data capturing purposes. During the minor case study, I used a reflective journal to engage in critical self-reflection as a facilitator, researcher and teacher-educator, in an attempt to clarify thoughts and critically analyse what was happening, and decide how best to move the process forward. Through this experience, as well as drawing from literature a format for use by all participants in reflective journaling was modified (see appendix Y). The four journal entries were drawn from Hatton & Smith (1995) four operational aspects of reflection, which categorises levels of reflections into descriptive (non-reflective), descriptive reflections, dialogical reflection and critical reflections. The *taking stock of my learning section*, which aims to pull the whole topic/week reflections together, was drawn from the (SASP Physics, 2009) keeping reflective journal article.

All research participants were offered a reflective journal template (appendix Y) and encouraged to keep it as a data capturing as well as reflection training tool. Most of the teachers found the consistent keeping of a journal a great challenge. Only Lerato in the minor case study, and Colleen and Noma in the major case study, managed to keep journals consistently. As a data capturing tool, it served to maintain a log of events and, as a reflective training tool, it served to inculcate a habit of reflection-on-action, by encouraging participants to make their thought processes explicit in a conscious and deliberate way.

3.5.3 The CoRes and PaPerRs

Content Representation (CoRe) and the Pedagogical and Professional experience Repertoires (PaPeRs) are tools proposed by Loughran, Mulhall, & Berry (2004), for capturing and portraying the subtleties of science teachers' PCK. The CoRe (table 4) and PaPeRs offer a framework for capturing science teachers' PCK and portraying it in a documentable form (Loughran, Mulhall, & Berry, 2004). The CoRe and PaPeRs have proved to be useful and valuable in their ability to serve as tools, for collecting data of great depth and breadth in an area which had previously proved to be difficult to pin down. In this study, the CoRe is used to capture the details of participating teachers' understanding of particular science content and PaPeRs extensively capture the associated pedagogical manifestations. As reflected in Table 4 below, the prompts used encapsulate crucial science teachers' understanding of particular aspects of PCK, such as: their overview of the main ideas; their knowledge of alternative conceptions; their insightful ways of testing for understanding; their knowledge of known points of confusion; their strategy on effective sequencing; and their important approaches to the framing of ideas.

Table 4: The Concept Representative (CoRe) Framework (Loughran et al, 2004)

Important Science Concepts			
Prompts	**Big Idea 1**	**Big Idea 2**	**Big Idea 3**
1. What you intend students to learn about this idea?			
2. Why is it important for students to know this?			
3. What else do you know about this idea (which you do not intend your learners to know yet)?			
4. Difficulties/limitations connected with teaching this idea			
5. Knowledge about learners' thinking which influence your teaching of this idea			
6. Other factors that influence teaching of this concept			
7.Teaching procedures (and particular reasons for using these to engage the idea)			

8. Specific ways of ascertaining learners' understanding or confusion around the idea			

The CoRe with its prompts, which encapsulate science teacher's crucial understanding of a particular aspect of PCK, was aimed at gaining insights into the teachers' PCK. In this study, these tools were used to capture, portray and monitor changes in PCK of the participating teachers, and act as a training tool for reflective practice. As explained in Loughran et al's (2004) paper, the CoRe is linked to particular science content and its purpose is to help codify teachers' knowledge in a common way across that content area, which is being examined, and, thereby, to identify important features of the content that the teachers recognise and respond to in their teaching of such content. The CoRe was also used as a training tool for lesson preparations and tracking changes in thought processes, relating to how content will be used to inform teaching. PaPerRs, on the other hand, are attached to the CoRe and offer a window into a teaching and learning situation, by helping to connect the practice seen with the understanding of particular content. Both the CoRe and its PaPerRs were used as a classroom data analysis tool, by mapping teacher knowledge and thinking patterns during preparation, delivery and reflections on the lesson.

3.5.4 Concept Maps

Generally, a concept is regarded as an idea that we use to describe an observation or an object or an event we encounter regularly. In science a fact refers to a correct statement of an observation or experimental result while concepts are terms that cluster related facts into a group or set. Therefore a concept map involves several concepts and how they relate within a topic. A concept map has its origin from Ausubel's cognitive psychology of meaningful learning which involves assimilation of new concepts into existing conceptual framework. It is a graphic meta-cognitive tool that represents the structure of information (knowledge) visually. Hence, drawing of a concept map is a challenging task because and involves both analysis and synthesis which are ranked as highest order process skills in Bloom's taxonomy. Most studies (Adamczyk and Willson 1996; Kinchin and Hay 2000; Novak and Cañas 2008; Rollnick, M., Mundalamo, F. & Booth, S., 2012) using concept mapping as a tool to evaluate conceptual understanding, continue to demonstrate the superiority of concept maps in capturing conceptual structures and reinforcing learning of participants in the learning process.

According to Kinchin, Hay and Adams (2009), most schemes for analysing concept maps are quantitative and derived from Novak and Gowin (1984) scoring protocol which tends to aggregate scores of factors such as number of valid links, the degree of cross linkages, the amount of branching as well as hierarchical structure. In line with the strong arguments raised by Kinchin, Hay and Adams (2009) this study employed a qualitative analysis framework. They argue against the use of quantitative methods of analysing concept maps because these methods miss the pedagogic value of concept mapping. They emphasise analysis strategies which put great emphasis on scoring valid links contradicts the constructivist philosophy underlying use of concept maps.

Their concern is that as soon as scores are allocated and aggregated, this serves to blur what the actual score actually reveals. They argue that analysis frameworks which only allocate scores to valid links misses the point that what is labelled invalid link might be having value to the student by supporting more valid links and more importantly, that these invalid links may reveal much about the thought processes that lead a student to a certain path of understanding. Given this background the analysis scheme (table 5 below) used in this study was conceived in this light through modification of Kinchin, Hay, & Adams (2000) scheme of analysis.

Table 5: The 3C-3S Concept Map Scheme of Analysis

	Simplistic & vague	Sound & adequate	Sophisticated & advanced
Correctness	Shallow with most concepts incorrectly represented and links reflecting superficial or no understanding	Most concepts correctly and logically represented and linked with few invalid links reflecting sound conceptual understanding	Logically encompass all related concepts correctly with discernible eminent propositions/features reflecting broad and integrated understanding of the topic.
Conceptual Depth	Simplistic association of concepts included reflecting very narrow, segregated and superficial knowledge of the topic which does not reveal much details about nature of the gaps	Logical inclusion of most of the concepts with few identifiable invalid propositions reflecting some level of narrow and less integrated understanding of the topic. The invalid and missing links reveal	Detailed, scientifically rich representation with complex interactions of different conceptual levels, reflecting sophisticated and in-depth understanding.

		misconceptions, areas of difficulty and conceptual gaps	
Connectedness	Very poor simplistic structure which lacks integration such that further additions cannot be accommodated without major structural deformation	Structure has basic features but lacks integrity in terms of coping with additions because of incorrect links in some parts.	High structural integrity with links of several justifiable levels which can cope with expansion and diversification without major deformations as new concepts are added

In this study the teachers' CoRes are analysed at two levels. Firstly as a tool to discern the teacher's knowledge base for teaching that particular topic. The second level of analysis looks at CoRe as a concept representation tool which reveals the teachers' conceptual structure. To discern this, the CoRe was subjected to the same analysis framework used for the analysis of the concept maps using the 3C-3S Scheme of Analysis (table 5 above). One can argue that the complex nature of concept maps and CoRes in how their construction involve interrelationships among several concepts equate them as good pedagogical tools in ensuring meaningful learning, as well as in assessing understanding and diagnosing misconceptions. They are both graphic meta-cognitive tools which provide external representation of structural knowledge. The critical difference between concept maps and CoRes is that whereas concept maps are normally confined to showing the interconnectedness of ideas and concepts in a specific domain of knowledge, the CoRe has content knowledge for teaching as its target and content.

In the major case study the four teachers engaged with the process in various ways. Bongani and Sipho constructed CoRes and concept maps to track their shifting knowledge base while Noma and Colleen used the CoRe and PaP-eRs. Bongani managed to construct both the pre- and post-concept map, but Sipho dropped out of the process with only a pre-concept map. Therefore, the scheme was used in section 6.3 of chapter 6 to reveal and present mainly the growing content knowledge of Bongani (see section 6.3.3) through analysis of his concept maps and CoRes as well as Sipho, Noma and Colleen's CoRes.

3.5.5 Diagnostic Test - Chemical Concepts Inventory (CCI)

The *Chemical Concepts Inventory* (Mulford & Robinson, 2002) is a field-tested instrument developed by Doug Mulford and published in the *Journal of Chemical Education*. This instrument was developed to measure the extent of alternative conceptions students hold in fundamental concepts of chemistry. The test covers basic concepts which are dealt with in general chemistry first semester courses which are: phase changes; the particulate nature of matter; properties of atoms; bonding; macroscopic versus atomic and molecular properties; gases, liquids and solutions; conservation of mass and atoms; elements, compounds and molecules , equations and stoichiometry; chemical reactions; energy, heat and temperature.

The test consists of 22 one- and two-tiered non-mathematical, conceptual, multiple-choice questions, aimed to elicit deeper understanding of the concept of chemical change, and 6 fill-in questions on word equations. These questions are based on common misconceptions revealed by research about fundamental concepts underpinning clear thinking in chemistry (See Appendix B). The items reveal difficulties normally held by both students and teachers, concerning the properties and behaviour of atoms and molecules.

Each item is designed in such a way that each selected option reveals a lot about the person's conception of that particular aspect. Therefore, responses given for each item were considered carefully and a profile of understanding of each teacher was drawn from all responses given. In this study, this tool was used with the participating teachers, first to identify their conceptual gaps for development plans, and secondly, as a starting point in considering the critical role of alternative conceptions learners bring into their classrooms.
The concept challenge data was analysed using the *conceptual category scheme* in Table 6 below. An initial *conceptual category scheme* was generated by clustering the items into categories which highlights the type of misconception the items target. The scheme was then shared with three chemistry professors for ratification to put together the final scheme presented in Table 6 below.

Table 6: Conceptual Challenge Scheme of Analysis

Molecular distinction between gases, liquids and solids	Q1 a, d, g, j, m, p
Molecular distinction between mixtures and pure substances	Q1 b, e, h, k, n, q
Molecular distinction between elements and compounds	Q1 c, f, i, l, o, r

Conservation of mass & atoms during chemical reaction	Q2, 6, 8, 9, 13, 14, 19, 20
Conservation of mass, atoms & molecules during physical change	Q3, 4, 5, 7
Macroscopic v/s sub-microscopic descriptions nature	Q11, 12, 15, 23, 24
Energy during physical & chemical change	Q10, 17, 18
Solutions & concentration	Q16, 21, 22
Word equations for acids-base reactions	Q25, 26, 27, 28, 29

Denzin & Lincoln (1994) argue that authenticity in research can be achieved by showing a range of different realities in a fair and balanced manner. The use of this tool in this study added to the variety of sources of data collection, as a way of enhancing credibility and strengthening the claims made by illuminating the phenomena from different perspectives. The findings are presented in section 4.5 in the next chapter. They provide an initial general comparative analysis of conceptual challenges experienced by all the teachers in both the minor and major case studies. At a session on the nature and critical roles of learners' misconceptions during major case study (discussed in chapter 5), we went through the test, together with the participating teachers, discussed emerging misunderstandings and considered ways of how to assist learners to overcome such conceptual difficulties.

3.5.6 Interviews

Interviews are valuable, in that they allow participants to discuss their interpretations and feelings about the world they live in, as well as express their views on the situation in question (Cohen et al., 2007). They are characterised by a specific purpose, and therefore have to be constructed with that purpose in mind; they also serve to collect very rich and detailed data around that purpose. One focus of this study was to trace the development of the participating teachers' PCK on a particular science topic, while the other focus was to trace how their practices were transforming from teacher-centred approaches to learner-centred approaches, which are more aligned to the new curriculum.

In this study I used both the structured and unstructured interviews. The structured interview was used to study the teachers' views about learning and teaching, and I discuss the methodology I applied in detail in the next part of this section. For the planning and reflective practices of the teachers, I used an unstructured interview (see the schedule in

appendix K2) and a questionnaire (appendix K1) as a form of triangulation. Both the interview schedule and the questionnaire we given to two colleagues both experienced science teachers, college lecturers and were doing their PhD's at the time. Valuable feedback was used to modify the two instruments before use.

This study also employed a well-established teacher beliefs semi-structured interview which was developed by Luft and Roerig (2007) and her colleagues, referred to as TBI. Given the resistance of beliefs to change, Yerrick, Parke, & Nugent (1997) argue that, in order to support science teachers in assimilating accurate representation of reform into their conceptual framework, they need to be given opportunities to explore and examine their underlying beliefs about teaching and learning inquiry. Since teachers' beliefs are tacit and complex, this poses challenges to research strategies employed to get at these beliefs, because such efforts may result in eliciting what *should* be done, rather than what *is* actually done in practice. To overcome this challenge, more recent research in this field has focused on epistemological beliefs which are related to teachers' views about nature and the acquisition of knowledge. Luft & Roehrig (2007) thus argue that the way teachers conceptualise knowledge will necessarily impact on their teaching beliefs because these are intertwined with their beliefs about learning, understanding or student knowledge. This indirect strategy seems to be more reliable and is hence employed in this present study.

The TBI is a semi-structured interview which was designed to explore teacher's epistemologies and beliefs they hold about learning and teaching. The TBI schedule is shown in table 7 below.

Table 7: Teacher Belief Interview Schedule

1. How do you decide what to teach and what not to teach in your science classes?
2. How do you decide when to move on in your classroom?
3. How do you describe your role as a teacher?
4. How do your students learn best?
5. How do you know when your students understand?
6. How do you know when learning is occurring in your classroom?
7. How do you maximise student learning?
8. How do you adapt your teaching to best represent the discipline of science?

They worked extensively with pre-service, induction and in-service science teachers to produce Teacher Belief Interview Category Descriptions and Maps (Luft & Roehrig, 2007). Through further reviews and refinements of the interview process, the authors developed maps which allowed them to describe and define shifts in various beliefs, underpinning the

teachers' practices towards more reform-based views and practices. The five categories used in this study that depict teachers' epistemologies and approaches in practice are: didactic (Did), instructive (Inst) which represents teacher-centred beliefs, transitional (Trans) which has a focus on behaviourist or affective, rather than cognitive attributes of students; responsive (Rsp) and reform-based (Rfm) are more learner-centred. Their interviews on beliefs with beginning secondary science teachers revealed a pattern, that teachers depicted as traditional or instructive tended to use traditional practices, those depicted as transitional used guided approaches and those depicted as responsive or reform-based conformed to inquiry-based practices.

In this study, an observation-analysis scheme (table 8), discussed fully in section 3.7, was developed to depict each teacher's changing profile towards reform-aligned approaches by subjecting and integrating *the knowledge & views* as well as *action & practice* domains of the LTtP model with the work done by Luft (2007) and her colleagues on teacher beliefs interviews (TBI). Three colleagues, who are research active with two holding doctorate degrees and one very close to acquiring one at the time, were requested to give expert inputs on an observation analysis scheme I used to analyse my data. They were requested to interrogate the *practice-belief cross case analysis* matrix (table 8) at two levels. First to check the scheme against the original maps (Luft & Roehrig, 2007) from which it was drawn and secondly to see if we can reach consensus on pieces of small data I made available. They were provided the practice –matrix; with pieces of Noma and Colleen data as well as the Luft & Roerhig article which contained the maps.

The following questions were used to guide the process:

1. Is the scheme consistent with the original maps and is it capturing the essence of the maps?
2. Considering the maps and the scheme which category would you place the teacher's responses and their classroom strategies
    a) using the maps?
    b) using the matrix?

Feedback was received from two of the three colleagues who declared that the matrix did capture critical aspects of the map and consensus was reached on the profiling of the two teacher's practice based on the pieces of data made available. There were also suggestions on how the matrix could be used to extend aspects which were not covered by the maps.

In this study, in-depth interviews were used, in conjunction with classroom observations, to elicit more information and also probe the teachers' practices and beliefs underpinning those practices, as they struggle to respond to the needs of the new curriculum. This also served the purpose of triangulation.

Data from interviews and classroom videos are analysed typologically using the category description modified from Luft (2007) TBI categories and views about science, as reflected in Table 8 in section 3.7. The whole four paged table is included in that section. Data which consisted of a section of the TBI transcripts of the four teachers in the major study were given to two colleagues to code independently and their feedback was used to compare with and ratify my analysis of the cases.

The LTtP model was used to monitor relevant aspects of the programme through different data capturing tools. The main sources of data were video recording of lessons covering a specific topic, with associated pre- and post-observation interviews per teacher and reflective journals kept by some of the participants. All text-based data were subjected to inductive, as well as typological analysis, using an *observation-analysis scheme.*

3.6 LTtP model as analytic Framework

This research focuses on the development of PCK within the framework of the new South African curriculum. The study sought to identify consistencies and inconsistencies in knowledge, views and instructional practices traced across a variety of data to depict each teacher's changing profile towards reform-aligned approaches.

3.6.1 Knowledge, Beliefs and Attitudes Domain

This is the domain of the established knowledge base, as well as the epistemological and ontological positioning of each teacher as the professional science teacher. This domain is the base for all the cognitive, procedural and affective attributes, infused in all the processes and activities in which the teacher engages within the action and practice as well as challenge, synthesis and enculturation domains. At the beginning of the study**,** teachers expressed their current ideas (perspectives and practices) about teaching and learning, both generally and in the context of a particular subject area by completing a concept challenge test, concept maps and the CoRe prompts.

Typical data for teachers' initial knowledge, beliefs and attitudes were collected through the construction of concept maps and CoRes at different stages of the process to capture the

teacher's growing content knowledge. The teachers' ideas about teaching and learning and the nature of science were captured using a structured interview about beliefs (IAB) and their planning and reflective practices were also captured planning-reflections questionnaire (appendix K1) and unstructured interview (see schedule in appendix K2). Interviews were held with each teacher at the beginning of the process to get at their initial strategies.

3.6.2 Action and Practice Domain

This is the domain where the teachers' inherent capacities gain expression during the planning phase where the teacher researches, learns new content and plans for implementation. It also includes actual classroom implementation, as well as engagement and sharing with colleagues. In the minor case study, all lessons observed were video-taped for subsequent analysis. The main focus of the observations was to see how the teachers transfer the skills, ideas and learning gained from their participation in the research group interactions in their classrooms.

In the minor case study, post-lesson interviews were held with the teachers to allow them to share their plans and their reflections as a way of getting them into a mode of systematising and reflecting on their teaching efforts. Each teacher was encouraged to have a research, as well as the learning and teaching agenda prior to each lesson. Reflection sessions were used to view videos of lessons of individual teachers as a whole team and offer critical feedback as a way of fostering reflective practice, and developing more effective and meaningful approaches to judging ideas about teaching and learning, based on shared experiences. In the major case study, teachers planned, developed and implemented lesson tasks which aimed at addressing two or all three learning outcomes, while teaching chemical systems for the first time in FET classrooms. Within the self-study methodology, the teachers and the researcher worked collaboratively to produce and validate the process and the products through a framing and re-framing process.

Data collected from classroom observations, post-classroom observation interviews, text analysis of learner assessment tasks and portfolios, teacher's work schedule and lesson plans, informed this domain.

3.6.3 Stimulation and Challenge Domain

This domain which is about systematic reviewing and re-synthesising further plans for action and reflection, draws from the engagements within the *Peer and Resources Engagement* and

the *learner feedback and classroom outcomes* from planning and designing for lessons, as well as the classroom implementation processes. Feedback comes from learners in the form of performance, and the behaviour and classroom culture engendered as a result. The teacher could also actively elicit feedback from the learners about the process and how they experience it. Feedback also came from mentor and colleagues during peer engagements, as well as from personal impressions the teacher has about the experiences during the reflection process. Outcomes are of two types, the product-based as well as the process-based outcomes. The product-based outcomes are the constructed CoRes, the lesson plans and the investigation tasks that comes out of the process, and the process-based outcomes would be the procedural skills, classroom changes (culture), meta-cognitive skills gained etc.

The second sub-domain involves the challenges posed and support provided by the intervention programme. The outcomes of the first cycle of the first case study served to clarify the context, and inform the planning process by offering insights into where the teachers are, and the challenges and gaps in their teaching and learning efforts. They also informed the starting point, in mapping teacher development and growth, and, of even more importance, they informed the development of a more responsive teacher support based on the identified needs. At the intersection of these two sub-domains are the processes and activities, which consisted of a series of workshops and reflection sessions. These systematically drew from accomplished research-based strategies and learner feedback, and classroom outcomes from classroom implementation and peer engagement to support and engage each teacher in a cycle of framing and re-framing their classroom practices, as well as in gaining deeper insights about themselves. The insights and sets of competences gained during these processes would in turn feed back into the dispositional attributes domain and consequently into the action and practice domain, as soon as an opportunity arose.

All text based data, that is, consecutive lessons covering a specific topic, with the associated pre- and post-observation interviews per teacher, a pedagogical content knowledge interview for each teacher, and other items collected during data collection were subjected to an interpretative analysis. Themes offered by the framework were used for coding of each teacher's interview transcripts, observation text and journal entries.

3.7 Beliefs–Practice cross case analysis matrix

Some studies (Cronin-Jones, 1991) have established that when the existing belief structures of teachers are incongruent with the underlying values and beliefs inherent within the

intended curriculum, this served to hamper successful classroom implementation. Luft & Roehrig (2007) argue that beliefs reveal how teachers view knowledge and learning, and consequently suggest how they may enact their classroom practices. Furthermore, a study by Roehrig (2004) revealed the understanding of the nature of science as one of the major teacher constraints in the implementation of effective inquiry based instruction. Gott and Duggan (1996) argued about how critical the understanding of the nature of scientific evidence is to scientific literacy, as it is based on procedural competencies of experimental design, measurement and data handling. In the new science curriculum, this is all about learning outcome 1.

This study had a focus on the development of PCK within the framework of the new curriculum. Therefore the other aspect of the study was to see how teachers cope with the demands of the new curriculum, by tracing movement of their practice from teacher-centred approaches to learner-centred approaches more aligned to the new curriculum. To do this, the two categories of the Knowledge and Views domain and the Action and Practice domain were subjected to further analysis to depict each teacher's changing profile towards reform-aligned approaches. These categories are derived from the work done by Luft & Roehrig (2007) on the Teacher Beliefs Interview (TBI). The TBI is a semi-structured interview which was designed by Luft (2009) and her colleagues to explore teachers' epistemologies and the beliefs they hold about learning and teaching. They worked extensively with pre-service, induction and in-service science teachers. Through further reviews and refinements of the interview process, the authors developed maps, which allowed them to describe and define shifts in various beliefs, underpinning the teachers' practices towards more reform-based views and practices.

In this study, this work was used to synthesise a Beliefs–Practice *cross-case analysis matrix,* which is used to depict each teacher's changing profile towards reform-aligned approaches by subjecting and interrogating four of the six aspects of PCK further to what I refer to in this study as profiles. The five profiles are used to depict the teachers' epistemologies and approaches in practice. These are: didactic (Did), instructive (Inst) which represents teacher-centred beliefs, transitional (Trans) which has a focus on behaviourist or affective attributes of students rather than cognitive, responsive (Rsp) and reform-based (Rfm), the last two of which are more learner-centred. Luft & Roehrig's (2007) interviews on beliefs with beginning secondary science teachers, revealed a pattern that teachers depicted as traditional

or instructive tended to use traditional practices, while those depicted as transitional used guided approaches and those depicted as responsive or reform-based conformed with inquiry-based practices.

Themes offered by the framework were used for coding of each teacher's interview transcripts, assessment tasks, journal entries, PaPeRs and for analysis of recorded video lessons. To discern how each teacher aligned their practice with the philosophy underpinning the new curriculum, this data was further subjected to an analysis, using the *Beliefs–Practice cross case analysis matrix* I developed from Luft and Roerhig's (2007) TBI categories and views about science, as reflected in Table 8 on the next three pages.

This analysis allowed for depicting of consistencies and inconsistencies in what the teachers say they do in practice and what they actually do in practice as well as their changing profile towards curriculum aligned approaches as they engaged in the project. The findings are discussed fully in section 7.3 of chapter 7.

Table 8: The Belief-Practice Cross Case Analysis Matrix

PROFILES	DESCRIPTIONS Knowledge & Views about:				Views about NOS
	Instructional and Assessment Strategies(13)	**Learners' Prior Conceptions (14)**	**Learners' procedural Knowledge (10)**	**Learner Positioning in Learning (11)**	
Didactic (Did) Teacher-centred	**Teacher focus**: on information transmission, structure, or sources. Teachers transmit the facts of science by presenting information generally through lectures and questions are used to ascertain that students can regurgitate the facts of science. **Teaching/Learning Pace**: guided by adopted curriculum of other school factors & directed by teacher.	Teacher's focus is on information and structure rather than on the learners and the learning process itself.	Learners participate in closed practical task (or teacher demonstrations) where everything about the task is prescribed and the task is used for verification. Either the chosen activities are not conceptually coherent OR if the activities are conceptually coherent but the teacher fails to understand their purpose and hence omits or inappropriately modifies inbuilt aspects which are critical in promoting learners' conceptual understanding or procedural knowledge. (Magnusson et al., 1999)	**Nature of Interactions** Learners are expected to pay attention and receive information from the teacher **Culture of Learning** The teacher provides information in a structured environment and learners are expected to stay attentive and take good notes etc.	**Objectivist view** Science as a rule or fact Science is a reflection of reality Scientific knowledge is certain and not tentative
Instructive (Inst) Teacher-centred	**Teacher focus:** on providing experiences by using variations of lecture modes, discussions, question and answer, as well as engaging learners in meaningful group work. **Teaching/Learning Pace:** based on teacher's focus/direction & basic learner understanding of facts and concepts	The teacher's focus is on providing experiences rather than addressing the learners' prior knowledge.	Learners carry out guided inquiry task that promote some limited form of inquiry where variables are specified and operationalised, method and equipment prescribed but there are many acceptable solutions. Teacher embeds a lesson on a particular contextual issue prevailing either in the lives (local) of the learners or globally and engages learners in role play that promotes limited form of argumentation.	**Nature of interaction:** Teacher-directed and confined to teacher-learner dialogue, where learners are expected to be able to reiterate or demonstrate what has been presented; **Culture of learning:** The teacher monitors learner actions or behaviours during instruction, where learners are expected to learn by mimicking the teacher (e.g. by working problems we have practiced in class)	Science as a rule or fact Objectivist view: Scientific explorations theory-neutral; Progression of science is a process of conceptual addition; Scientific knowledge is discovered; Development of science is a process of individual discovery; Science is culture independent

PROFILES	DESCRIPTIONS Knowledge & Views about:				Views about NOS
	Instructional and Assessment Strategies(13)	**Learners' Prior Conceptions (14)**	**Learners' procedural Knowledge (10)**	**Learner Positioning in Learning (11)**	
Transitional (Trns) Subject matter/Learner-centred	**Teacher focus:** on teacher/student relationships, subjective decisions, or affective response. **Teaching/Learning Pace**: In which some modification is based on learner feedback & ability of the teacher	Focus is facilitating student understanding by creating an environment where learners interact with the teacher and the phenomena.	Learners are presented with challenges that test their critical thinking and problem solving skills. Learners are engaged in demonstrations and verification practical tasks which are aimed at verifying science concepts and showing links between specific concepts and phenomena.	**Nature of interactions:** At times, teacher initiates learners interact with their peers or the teacher about the topic **Culture of learning:** Active participation of students encouraged	Science as consistent, connected and objective Post-modern view
Responsive (Rsp) Learner-centred	**Teacher focus**: on collaboration, feedback, or knowledge development. Teacher designs the classroom environment to enable learners to interact with each other and their knowledge **Teaching/Learning Pace**: based on learner feedback and other possible factors that potentially involve revisiting concepts.	Teacher focus and instructional strategies concerned with motivating and enabling learners to connect their own understandings to those of their peers, with some focus on their non-problematic prior knowledge	Learners carry out open guided inquiry task that promotes some more open form of inquiry. They are engaged in activities which allow them study patterns and trends in how phenomena unfold in the natural world by following their own interests. Even though variables are specified and operationalised, learners are encouraged to formulate hypothesis, identify variables, generate alternative solution strategies as well as explore various ways of interpreting evidence by not prescribing the method and equipment required. They are made to appreciate that there are many acceptable ways of arriving at the solutions.	**Nature of interactions:** Teacher initiates significant interactions of learners with their peers or with the teacher about the topic **Culture of learning:** Teacher creates an environment that promotes dialogue and the challenging of ideas as a mode of learning	Science as a dynamic structure in social and cultural context Science tentative, socio culturally embedded, operating within community of practice where peer reviewing is a natural process of reaching consensus on what qualifies as scientific knowledge and what does not qualify.

PROFILES	DESCRIPTIONS Knowledge & Views about:				Views about NOS
	Instructional and Assessment Strategies(13)	**Learners' Prior Conceptions (14)**	**Learners' procedural Knowledge (10)**	**Learner Positioning in Learning (11)**	
Reform-based (Rfm) Learner-centred	**Teacher focus**: on mediating student knowledge or interactions. Teacher depends upon student responses to design an environment that allows for individualised learning. Teacher uses various teaching techniques and suitable intervention to make meaningful bridges with the learners' original views and new scientifically correct ones **Teaching/Learning Pace:** based on on-going evaluation which considers student abilities to demonstrate understanding in different ways. May involve modification of lessons.	Focus is on mediating learners' prior conceptions and the knowledge of the discipline. Use instructional strategies that value learners' prior knowledge and promote strong and coherent understanding of concepts. Learners' questions or comments often determine the focus and direction of discourse	Learners are engaged in open inquiry tasks and design of their own investigation where variables are not specified but the problem for investigation could be specified. They are provided with opportunity collected and process data, support competing theories or explanations as well as reflect on the quality of their design and make improvements. Learners actively undertake a project in their local community in which they apply science to tackle a specific problem or to meet a specific need (Rogan & Grayson, 2003) - and in the process they engage in argumentative discourse, in which they must evaluate the connection between the claims they make and evidence.	**Nature of interactions:** Learners initiate significant interactions with one another and/or the teacher about the topic **Culture of learning:** Foster intellectual rigor by engaging learners in activities that promote social discourse of critically attending to, defending and evaluating understandings.	Science as a dynamic structure in social and cultural context Science tentative, socio culturally embedded, operating within community of practice where peer reviewing is a natural process of reaching consensus on what qualifies as scientific knowledge and what does not qualify.

3.8 Ethical Issues

For this study, the ethics clearance was secured (2006ECE37) through Wits University processes, as well as the Gauteng Department of Education (GDE) and the schools involved. Since this study employed interviews as well as video recording of classroom sessions all the research tools used, the information and consent forms given to the participants, as well as justifications for the procedures employed had to be part of the documents submitted for ethics clearance with the university. The University ethics clearance process took place over two months and the GDE took about four months. Consent and information forms explaining the nature and the aims of the research project were completed by the principals, the teachers, their learners and their parents. As part of the recommendation from the ethics committee, the teachers involved were reminded throughout the process of their rights and freedom to withdraw from the process at any time should they wish to. As elaborated in the fifth chapter, there were practical issues and clashes which emerged between the recommendations raised by the ethics committee and the realities on the ground in the first case study. The same process of securing ethics clearance was done for the second case study in collaboration with the teachers who participated in the honours project. Securing ethics clearance was the most tedious, frustrating and cumbersome process of all the stages of the study, and some of the contradictions in the process will be revealed in the fourth chapter.

3.9 Issues of Reliability, Rigour and Limitations of the Study

In qualitative research, credibility and rigour concur because, in order for the findings of the study to be credible, the research process should be rigorous.

This study employed systematic classroom observations Erickson (1986) as the classroom analysis method. This method involved noting the occurrence of various types of pre-determined teacher and learner behaviours offered the theoretical framework. The types of behaviour of interest were selected according to their theoretical significance. As explained by Erickson (1986), the use of predetermined categories is to assure uniformity of observation (reliability) across times of observation in the same classroom and across different classrooms. For ethical reasons and for conformability of data, I communicated with the teachers about the records of the observations and interviews, so as to confirm or modify them as appropriate. Rodwell (1998) explains conformability as the reasonableness of the inferences and the logic of the theory generated from the data.

The issue of reliability in qualitative study is almost unresolvable because naturalistic behaviour is context-bound. The exact replication of such a study can only be inferred and can never be achieved. Cohen, Manion & Morrison (2007) argue that, unlike in quantitative research where reliability involves striving for uniformity, reliability in qualitative research should be regarded as a fit between what has been recorded by the researcher as data and what actually transpired in that natural setting which is being researched. They argue for what they explain as the notion of reliability through an eclectic use of instruments, research perspectives and interpretations. As already depicted in its description, the framework developed for this study is eclectic in its nature and was used to describe, interpret and explain the findings in the different case studies. Reliability of this study is also enhanced by explicit description of the researcher role, sample selection, social context, data collection and analysis strategies and by also making the theoretical framework for the study clear.

In qualitative research validity is defined as the degree to which data is plausible, credible and trustworthy and which renders it defensible if challenged (Maxwell, 1992). Winter (2000) does not regard the term validity as a single, fixed or universal concept but rather takes it as a conditioned abstract which is inevitably bound to the processes and intentions of specific research methodologies. The reliability of data collection is enhanced by using verbatim accounts (interviewee's exact statements and direct quotations from documents). This was made possible by using tape recordings during interviews and video recording during classroom observations. *Dependability* can be achieved through respondent validations, debriefing by peers, triangulation and prolonged engagement in the field (Cohen et al., 2007). For a qualitative study, the plausibility, credibility and trustworthiness will depend on the researcher's ability to demonstrate that the conclusions arrived at are the reflections of the real world situation. Cohen et al. (2007) proposes that validity in qualitative data is marked by the honesty, the depth, the richness and the scope of the data collected, the participants involved, the degree of triangulation and the detachment or objectivity of the researcher.

Coming from a background of teacher and materials development with few research skills, I struggled to balance my training and development agenda with my research agenda during the minor case study. I found myself engulfed and more inclined to respond to the teachers' development needs, rather than to integrate research. I had to be mindful not to lose critical moments for data collection, as well as to continue reading for my literature review. It was a great challenge. There was need to establish a working understanding of action research

methodology – issues of attaining rigour (dialectic, convergent interviewing) – as the study progressed. To overcome this tension, we established a reference team together with other four colleagues, one doing her masters and the other three also doing their PhDs, where we continued to present the challenges we were faced with in our work, and give each other critical feedback on an ongoing basis.

Le Compte & Priessle (1993, pp. 323–4) identify attributes of internal validity as confidence in the data, authenticity (ability of the research to report the situation through the eyes of the participants), cogency (clearly expressed and persuasive descriptions), credibility, auditability, dependability and confirmability of data, as well as soundness of the research design. Cohen, et al. (2007) construe threats to rigour in qualitative studies arising due to the following possible internal validity issues:

- In instances where the researcher is exploring and focusing on the current and thereby missing other critical antecedent events.
- In situations where the informant selected for the study might be unrepresentative of the sample
- When the observer's presence is having effects on the normal dynamics (reactivity and ecological validity).
- In other instances the researcher might 'go native' by becoming too attached to the group to see it objectively.

The internal validity of this study was enhanced through:

- Extended fieldwork and prolonged engagement on-site
- By use of low inference descriptors is meant, the use of description which are phrased very closely to the participants' direct accounts (Johnson, 1997). This study employed verbatim which are regarded as the lowest inference descriptors because of its use of the exact words provided in direct quotes.

Audio recording and verbatim accounts were used;

- Information and conclusions were cross-checked by using data, method and theory triangulation to deepen understanding of the situation under study.
- By keeping a reflective journal of potential researcher subjectivity in efforts to strive for what Burke Johnson (1997) refers to as Reflexivity or Neutrality. This involves

critical examination of oneself so as to detect potential biases and inclinations that may affect your conclusions.

- By ensuring that no claims to generalisability beyond the context of the study are made.

To improve the external validity of the study, accurate descriptions of the samples used (teachers' profiles), as well as the site for the field observation are given. The purpose of observing individuals deeply in case studies was to try to establish generalisations about the wider population to which these individuals belong. This study was carried with this view in mind. Action learning as an approach is more complicated and risky because unlike most conventional research where one knows ahead of time what literature is relevant, in most action research the relevant data is determined by the data one collects and how one interprets it.

Most positivist research approaches gain their rigour through objectivity, control and standardization. As Dick (1993) puts it, the virtue of action learning is in its responsiveness and therefore standardization defeats its purpose. Validity of this study was enhanced by collecting and interpreting data in defensible ways at all times. Firstly this was achieved by always seeking out disconfirming evidence (Dick, 1993) through use of methods for data collection and interpretation which test or challenge the emerging interpretations. This was made possible by working with independent or partly independent multiple information sources at all times, then by employing what O'Brien (1998) refers to as *dialectical critique* which involves use of similarities and differences between data sources to increase the accuracy of the information. Secondly the validity is increased in this eventual thesis through thorough and careful justification of the methodology I employed in this study.

3.10 Conclusions

This study sought to understand how teams of science teachers respond to the challenges posed by the new curriculum to their practices. In this chapter, I have presented the methodological, as well as the theoretical underpinning framework of this study, in seeking this understanding. The framework which is used to categorise data from the variety of qualitative methods this study drew upon to capture the complexities of a complex and dynamic change environment, was conceptualised in this chapter. The framework drew from cognition, situated and socio-cultural perspective to conceptualise and bring together

categories which are used for analysis in the subsequent chapters. The next chapter focuses on the findings of the minor case study.

CHAPTER 4
CONTEXT UNDERLYING JOURNEYS OF THE HEROINES AND THE HEROES

4.1 Introduction

This is a multiple case study with two separate cases referred to as the minor and the major case studies. Even though this study was aimed at the teachers' PCK and how it can be supported, the school contextual issues emerged so strongly as a factor that they formed the main finding of the minor case study. It emerged that the central school in the minor case study was mired in contextual issues, which totally undermined any efforts of professional development. In this chapter, I report mainly on these findings of the minor case study, as well as the contexts encompassing the teachers in the major case study. Chapter 5 contrasts the teacher professional designs used in minor and major case studies and most findings of the major case study are reported in Chapters 6and 7.

The main focus of this chapter is to pull out from both the minor and the major case studies a picture of the contextual challenges, impinging on teachers' practice in a range of South African classrooms. This chapter responds to research sub-question 2.2 of this study: *what dynamics served to afford or constrain teachers' efforts in effecting curriculum aligned changes in their practices*? The *Learning for Teaching through Participation* (LTtP) Chapter Analytic Framework (Figure 6) on the next page, is a framework for supporting teacher learning which is emerging from this study, as well as serving as its analytical framework. This framework is used in all the findings chapters to relate the different aspects of teacher change that form a focus for each particular chapter. For easy reference, each of the different aspects of the model is allocated a number, and those aspects of focus in this chapter are highlighted.

4.2 The Enveloping Change Environment (1)

Using a situated perspective on learning, this model suggests that any process, involving teacher professional growth, will be subjected to the constraints and affordances of the enveloping change environment (1). As indicated in figure 6, these are the factors, such as school management and ecology (3), resources and time constraints (2), learners (4) and

teacher factors (5). Even though this chapter is not organised with these factors as headings, these form the gist of the discussions and are the threads that run across the whole chapter.

All the aspects of focus and discussions are highlighted in the model below, which provided the framework for this study.

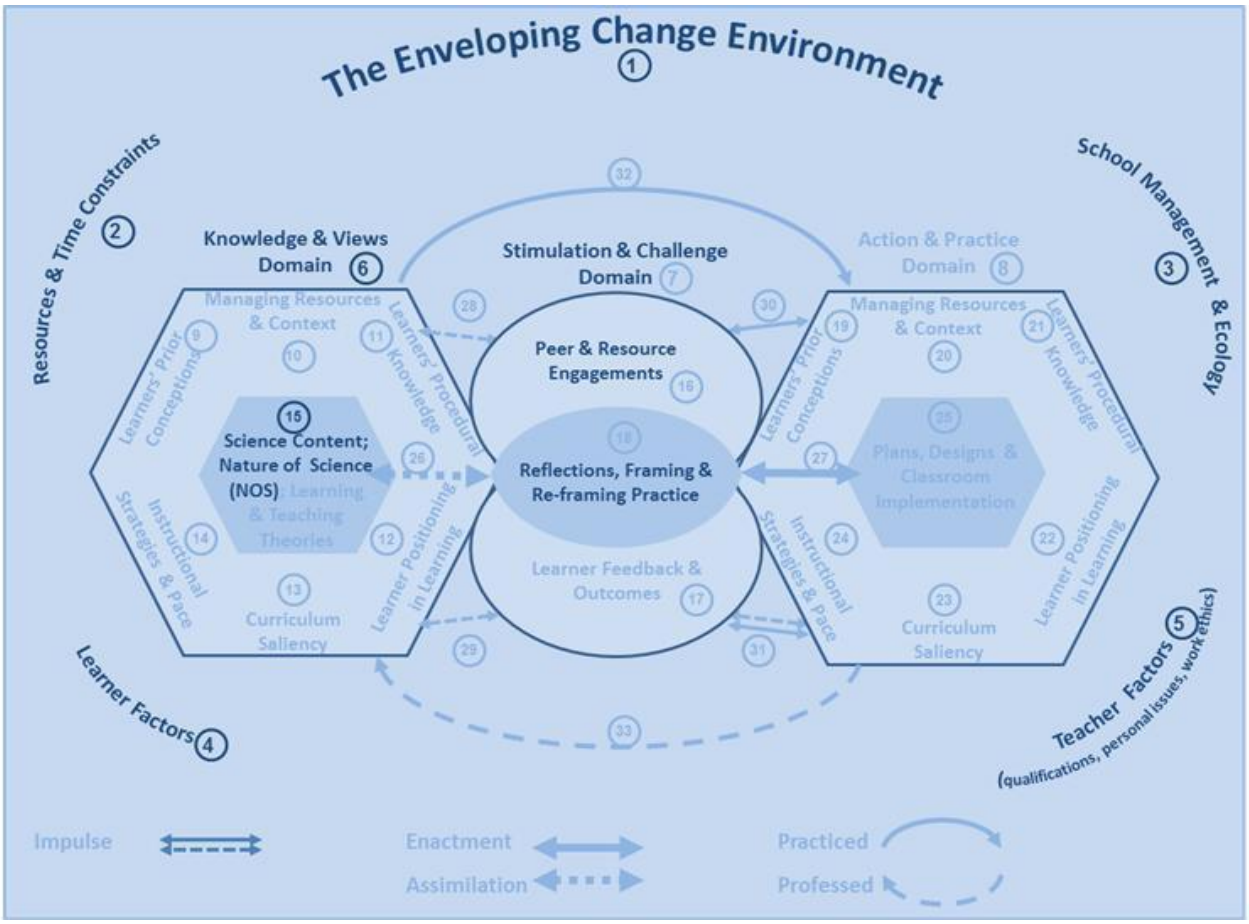


Figure 6: LTtP Chapter 4 Analytic Framework

As highlighted by several studies (e.g. Clarke & Hollingsworth, 2002; Rogan & Grayson, 2003), any processes of professional growth occur within the constraints and affordances of the enveloping change environment. In this section, I discuss how the four factors derived from Rogan & Grayson (2003) (see Appendix G): *time and resources (2), school management and ecology (3), learner factors (4)* and *teacher factors* (5) of the enveloping change environment, served to shape the teachers' learning opportunities and classroom practices within the *knowledge, beliefs and attitudes* (6), *the stimulation and challenge* (7) and *the action and practice* (8) domains, which encompass the teachers' personal worlds.

These four factors together give a picture of the capacity of a school to support and carry out an innovation. Data used in this chapter is analysed and organised using these four factors to allow us to discern the types of dynamics which were prevalent during the implementation phase of the minor case study. The findings are discussed by giving a description of the changing context of the first school, the general findings from the data gathered and the tensions and the challenges that emerged as the process unfolds, as well as the strategies that were employed to try to move the process forward.

In both major and minor case studies, data which informs this chapter is mainly drawn from the analysis of the semi-structured interviews, the planning questionnaires, the concept challenge and the reflection sessions held with teachers. For the major case study, additional sources are reflective journals and audio-taped research group sessions. Although reporting on the two case studies is kept separate and intact, the reporting on the findings of the concept challenge is done collectively to give a broader picture, and allow comparison of teacher concept knowledge across GET and FET phases.

The chapter is organised into three sections. In the first section, I consider the minor case study by discussing the background as captured through the research process, and then I move on to discuss the changing school ecology traced through the challenges that plagued the research process. Next, I discuss the planning practices at the high school and how it contrasts with the planning at the neighbouring primary school involved in this study. Through the experiences of the central teacher who took the process a bit further than the rest in this case study, I explore the elements of framing and reframing of practice which were emerging in this case study. In the second section of this chapter, I consider the enveloping change environments encompassing the practice of the four teachers in the main study. In the third section, because of the central role played by content knowledge in the teachers' practice, I explore patterns in the basic science content knowledge of all the teachers in both case studies. I conclude the chapter with discussions that draw on all the emerging issues underpinning the teachers' practice across the two case studies.

4.3 Striving in Morally Challenging Contexts – Minor Case Study

As discussed fully in the next chapter, the minor case study was conceptualised as an informal school-based collaborative action research. Due to unforeseen contextual issues, the activities of the minor case study were interrupted, and what emerged and took over as the focus of the case study became the contextual issues, enveloping the participating high school

environment. In the next section I focus on these issues to try to elucidate the nature and operations of these issues and how they undermine efforts which are meant to bring change and progress in schools.

4.3.1 Physical Resources

Clearly, physical resources is one of the major factors that can set limits on what teachers and learners can achieve in the classroom. By physical resources, is meant basic infrastructure like classrooms, toilets, electricity, running water to well equipped science laboratories, curriculum materials, teaching and learning resources such as computers, models, photocopying facilities, attractive grounds and sporting facilities. Most of issues to do with this aspect have therefore been captured in various sections in this chapter and the previous one, especially under the section of physical resource provisioning in the previous chapter and teacher factors in this present chapter.

Bojanala was a very young school, the only high school in a newly-developed, formal, settlement area (RDP houses), about 62 km south-west of Johannesburg. RDP is short for reconstruction and development programme, which is a framework that was conceived and adopted by the ruling party and its alliance in 1994, as a strategy to address the socio-economic inequities the country faced.

In 2007, the school was only in its fourth year. At the time, the school ranged from Grade 8 to Grade 12, with a student population of about 1370 learners (4). As explained further down, this was the school's first year to phase in grade 8 level. From what I was seeing initially, space was a problem as there were not enough rooms. All science teachers, including the HOD, shared the one science laboratory. It was a very awkward situation because there was literally no privacy but as it turned out later in the interview with the acting principal, there was space and some of the politically connected heads of departments (HODs) had private offices which they shared with student union leaders.

The area where the school was located was a newly developed residential area, and the school itself had been operating in temporary structures for some years, based in the neighbouring township. When the school moved to their new premises, they discovered that the new structure was too small and could not house the whole learner population. Therefore, grades 8 and 9 had to remain at the old location and only grades 10, 11 and 12 moved. This meant that the principal had to manage two schools, regarded as one, but physically located in two

different premises and in two different areas. Sometime later under new management, the department decided to separate these schools into two.

4.3.2 Learner Factors

Learner factors (see appendix K) refer to the learners' backgrounds and the types of strengths and constraints they bring to the learning situation. These may range from home socio-economic background to proficiency in the language of instruction. Do learners come from a background where parents take an interest in their children's education? In South Africa, language of instruction is likely not to be the first or the third langauage for most learners so language could be a barrier to learning. Also, South Africa is a society ripped by violence therefore issues such as gangsterism and substance abuse or eroded culture of learning could be a problem.

The excerpt below from an interview with the acting deputy principal gives a profile of the learners (4) and the types of challenges this young school faced:

> *Our school caters for pupils who generally come from socio economic background **'e e nang le' (which has)** disadvantage so that in itself creates a lot of challenges for the school because learners ... we are having a lot of orphans around here, child headed families, parents who are unemployed, and all those are creating gap in the school financially because they are unable to pay for funding '**ya skolo' (of the school)** that leads to us lacking resources though we are having funding from the Department of Education and Training but we are unable to make up for everything in terms of resources.* (Acting DP int)

To a great extent, the feeder school area overshadows the school ecology (3), because the socio-economic status of the learners in the school impinges on its administration, and can either bring enabling or constraining dynamics to the learning and teaching processes. These learner factors (4) are actually external to the learners' internal resources, and therefore have an indirect bearing on the learning and teaching processes. Below is what Elga had to say about the challenges she faced as a new teacher and the types of learners she had to deal with.

> *Learners here are difficult – very difficult to deal with. You have to be tough. Now that I am new I'm in trouble because at times learners will just walk out of the classroom as I am teaching and trying to be tough. I don't know, I just deal with those who are interested. But what I do is I take the names of those who are in class down and when I give them a task I take in the books myself and mark them. I hope this will help me to take control by the end of the term.* (Elga backgrd-int)

The excerpt below, from field notes, captures the lawlessness that prevailed and the levels of disruption the learners were capable of orchestrating in the school.

> *One Friday morning in April 2007 as I arrived at the school gate at 8h10 I noticed that learners are roaming outside and around the school premises. As I drew closer, I could hear a very loud music system playing within the school premises. I was at this school the previous day and nobody warned me that there would be no schooling on that day. I got out of my car and as I walked into the administration block I met Mpho with some of her colleagues in the foyer and she explained that the students had decided to have a bash (a party) and they had not anticipated this situation. According to the teachers, the students had approached the*

principal to request that they have a bash at school that day and the principal had declined the request so the students just went ahead and did as they pleased. Apparently there was no real cause for celebration but the students just felt like having a party that day. The music was deafening. After travelling all that distance, I was not pleased at all that our programme for the day was put off. (field notes)

This gave a window into the eroded culture of learning and the contextual issues affecting performance in schools.

4.3.3 The Changing School Management and Ecology (3)

School ecology and leadership (see appendix K) are two separate aspects which are put together because they are mostly intertwinned because strong leadership would create healthy functional learning environments while a weak one normally leads to confusion and dysfunctionality. Whether an innovation will get the necessary backing and support, depends a lot on the leadership of the principal. Therefore, in situations where the school is dysfunctional, the first priority would be to get the leadership right before trying any type of curriculum innovations.

Even though it was not apparent at the beginning, the high school emerged as a troubled, dysfunctional school. At the beginning of the study, the school was under the management of an acting principal who welcomed me warmly and opened the doors of her school. The former principal had been dismissed on a charge of embezzling school funds. It was a school on new premises. Digging deeper, one realised that the school context was a highly politicised and contested terrain and the principal's dismissal had nothing to do with his skills, capacities or competence. He was simply not a member of the (teachers') union.

As discussed earlier, the dismissed principal had had to move to new premises which could not accommodate the whole school. Moving is normally a stressful exercise but having to manage two schools in two different areas was very challenging. The question arises: was the original principal offered enough support to deal with his extra-ordinary circumstances? This excerpt from the acting deputy principal, during an interview, tells a story.

R Do you feel it was a fair dismissal?

DP I think it was unfair; it was supposed to have been the department offering the school and its management support so they didn't give him that support. Even within the school there are some things which are sensitive like, there are people (lot) from outside the province who buy posts so you have to keep quiet. A lot of us were appointed at the same time for these HOD posts. I struggled a lot, too many people were acting on that post; it was even worse for me because there was a lot sabotage.If people have accepted that I am here to work with them and we are going to make a progress though some were very naggy so I had to make my own observations , the management demanded that I must make a difference, so I told them to give me some time so that I could understand the people I'm working with Unfortunately two of them could not withstand the chemistry so they resigned. Somehow it made me feel so bad I wasn't harsh on them. It's just that they felt that they were miserable. (acting DP_int)

When I first entered the school in August 2006, the acting principal, a woman, was in control. The systems of the new management seemed to be in place and the school under control. From the moment one drove into the school, one could discern the signs of order, from a well-managed security gate, to a well-managed flower garden in front of the school building. It turned out that the gardens were in that state because of Lerato's Environmental Education project, on which she collaborated with Rhodes University.

The school reception was also very professional in appearance, with the window for the reception office placed on the left as one entered the administrative building. The office was resourced with modern office equipment (two computers, laser printer, fax machine, telephone), and a separate room with a heavy duty photocopying machine. The environment was clean, with very well maintained toilets, kitchen and staffroom. All learners seemed to be in class and there seemed to be order everywhere. But it turned out that I was not able to read the under-currents, because it was exam time and some of the learners had not come to school.

Within a period of three months, the school was again under new management as the acting principal and the deputy had resigned under clouds of controversy. The acting principal, a dynamic and self-assured looking man, was embroiled in an accusation of learner molestation.

> *In terms of (clears her throat) ehhh, human resources, we are a school that is about four years old and unfortunately we have been changing management over the past four years. Like, we are having our second principal, and we stayed for something like a year without a principal… an appointed principal* ***'ene le yona e o' (and that also)*** *in itself was a serious problem because every time somebody acts, the other person not acting, did not, could not cooperate, that was observation. You know like you are responsible so take charge, and there was no you know support system, and as a result it brought the problem into the SMTS as an entity...* (acting DP_int)

The excerpt below from an interview with the acting deputy principal, which was done in May 2007 when I was already disillusioned and ready to give up on the school, reveals the deeper dynamics characterising the school at the time, and some of the factors impacting on the learners in the school.

> *There were people who were within the school who didn't want to work and trusted their political affiliations and positions to protect them. You know COSAS [5]has its strong hold in our school. The president and the secretary of the whole province are our learners who will stay away from school for something like two weeks and I always have a problem with those learners. Some of the educators who were influential members of the Union as in SADTU[6], they come to school and stay in their offices for the whole week you*

[5] The Congress of South African Students (COSAS) is a national organization which was established in the late 70's in the wake of Soweto uprisings to represent the aspirations of Black school students when the apartheid government banned all the Black Consciousness political organisations.
[6] The South African Democratic Teachers Union (SADTU) is a trade union in South Africa

would think the person is not there, give the learners assignments and stuff and it was normal the principal who was acting wouldn't say anything to them because she needed their protection. They were very vocal people and whatever they say they are right and protected. So they will just sit there and not attend classes it was just chaotic. (acting DP_int)

What comes through and is very worrying, is that leadership and position are not perceived as avenues for progress, but instead as a vehicle for corruption and abuse of power.

You would have teachers and the COSAS learners once they attend their conference they will come back and go to the office and sit with those teachers the whole day as in the whole day and they really do come out only during break and five of them sent to town to buy food, during break or towards the end of the break and they will come back the next period and sit and enjoy their lunch and chat to those learners in their office. For me that was very scary and I could not understand a leader who could allow such. (acting DP_int)

The high school emerged as a system in survival mode, operating on no base at all and responding only to external pressures. There were no monitoring systems at whole school level, and no planning/reflections for teaching and learning at school and phase level. Planning at grade level was rudimentary and, although individual lesson-planning processes differed, they were mostly scanty.

We only do grade planning. We don't do school planning and this affects us because we do not do environmental analysis on topics that we need to do in grade 8 and 9 in natural science and this impedes integration. (Lerato plan & reflect-int)

We don't do planning in a whole school level, because we usually plan our learning and teaching departmentally. It affects me negatively because many a time if you need to give learners, tests, no teacher will invigilate for you even if sometimes you request before hand. (Mpho plan & reflect-int)

When asked to elaborate on why she thinks that level of planning was necessary, she responded with:

I think if we sit together and plan as a school, progression will be highly because all these learning areas are linking hence it will be easy and simple for a learner to grasp easier knowing that he has done this topic in NS and another educator of TECH[7] or MLMMS[8] come and do the same maybe calculations therefore it will be easier to remember calculations therefore it will be easier to understand. (Mpho plan & reflect-int)

On the question of whether whole school meetings were held to reflect on processes of teaching, the response was:

It was never done beforeas part of our school policy and this makes us unable to deal with shortcomings and strengths especially in assessment. (Lerato plan & reflect-int)

This was also confirmed by the acting deputy principal during an interview:

*The aspect 'ya' curriculum delivery. I think we know what is right, we all know what we are supposed to do but for me it's not like done properly. From the head of the institution because no monitoring is done, of the deputy principals and the DP also are not monitoring the HODs properly. We only do things when they are demanded by the district submission work of internal analysis of the ** we just do it you know in a very scanty manner bana it's not genuine, it's not genuine we say so many learners failed Biology what could have been the cause? How can we solve the problem? And we move with analysis that 1, 2, 3 we just do them*

[7] Acronym for technology which is one of the learning areas (subjects) offered the South Africa new Curriculum.
[8] Acronym for Mathematical Literacy, Mathematics and Mathematical Sciences which is one of the learning areas (subjects) offered in the new South African Curriculum.

in isolation. Term 1 analysis was done it stays there, we do nothing about it, term 2 analysis. So if maybe we can change the approach to say term 1 analysis is thoroughly done against term 2

R basically what you are saying is that there should be reflection phases.

DP Yes, and I think that's done because I was saying if things are not done properly like monitoring of educators. I have colleagues who are senior managers 'ko di'(Tswana for 'at the') primary schools and I feel small every time they say this week is submissions. All educators will be submitting their personal files. We don't do that in my school. I don't know whose fault is it but we all know that it suppose to be happening but it is not done I want to tell you the honest truth, it is not done. (acting DP_int)

Another comment by Lerato, when asked if she has any way of reflecting systematically by keeping records of reflections:

Not at all and we did not know that it was necessary. We actually destroy the report on systematic evaluation during the following year as GDE does not want last year reports to be in the current file. (Lerato plan & reflect-int)

The spirit of collegiality and collaboration also emerged as a problem at the high school. To the question of whether Mpho ever involved her other science colleagues in her lesson planning or lesson delivery or reflections, she responded with:

Not, truly in this school we don't work like a team, it's just lip service.

And to the question of whether she ever involved her colleagues in team teaching or invited them to observe her classrooms, her response was:

Not at all but I would like to do that through you because there are so many misconceptions amongst ourselves even learners because sometimes other learners told you that teacher teacher Y didn't teach us the way you are doing it so it will be fruitful for us and the learners. (Mpho plan & reflect-int)

This was also confirmed by the comment by the deputy principal.

The HODs they were not working like a collective, 'wa bona?' Ehhh, we have HODs who were skilled, who were empowered, who attended courses often. But they were unable to come back to school and say look this is what I have learned so that we move forward together; it was like an individual achievement and I don't know whether it was out of selfishness but I picked it up that there were programmes which were by the department of education and training that people went for and they achieved and were empowered but they came back and only implemented in their departments. That's why I say it was all selfishness. (acting DP_int)

Planning at grade level was rudimentary and, although individual lesson planning processes differed, they were mostly scanty.

There was a time somewhere last year, where I try my fortune by going not preparing and I was shocked when a learner asked me a question and not in position to answer that, why? Because I did not have a planning.

Does this mean that the teachers at the high school are not working? Are they lazy? The comment by the deputy principal explains the situation in greater depth:

*I must say this year when we had bad results last year ('**sheba, re ne re phenyitse**' – '**look, we were embarrassed'**) to an extent ('**ya gore' – 'that')** we came to school on the 3rd of January we were here we did our LTSM[9] with no principal. Around the 4th of January our Grade 12s were in class we started teaching without a principal we had just make-up our mind and said people no one from somewhere will come and*

[9] Learning and Teaching Support Materials

help us let us help ourselves; let us be what we want to achieve at the end and we started well very well and the grade 11 and 10s came in so did the other grades

DP Curriculum they expect us to be experts but, we are only theoretically but practically …

R But with this new curriculum we are all learners to be honest and its ideals of the curriculum itself are very ambitious and are far removed from our reality, the way we were schooled and trained so it's a learning curve.

DP It's quite hectic, that's another thing. There are so many things which are expected of us within a very short space of time and maybe, that's' why we hardly have time to do monitoring. Because I don't want to say to you people are doing nothing. People come to school and work, from the first minute they enter the school up to the last minute. But there are many other loopholes and unfortunately those are the very things we should be taking care of. So I don't know how best.. maybe after we are used to the NCS, the paper work, we will be able to[move] faster so that we are able to accommodate time for 'bo' monitoring and review, ***'wa bona' (you see)****. Because, I mean the time factor is very important, there are so many inconveniences, 'go tshwana le' when you have to be in the classroom you have many other activities like the principal's meetings, any time the district director wants to come because he wants to talk to you*.

R Ja, so many interferences and not coordinated.

DP Mmm sooo many because even the district we made them aware that sometimes you come to us to ask us for staff and three people from different offices want the same thing but in different formats. So it takes my time, I have to sit down and do the same thing in different formats for the same office but in different unit. It's not fair. (acting DP_int)

This other comment, from the teacher on whether she keeps a record of her reflections, highlights issues of unreasonable workload, if we bear in mind that we are talking of classes of about 50 learners on average.

Sometimes I do, but sometimes it's difficult for me to keep everything because of overloaded work that someone find herself in. For instance, I was having 9 classes: five in grade 12, two in grade 9 and two in grade 8. (Mpho plan & reflect-int)

Planning at the neighbouring primary school was much more elaborate and systematic. Comparing the quality of comments made by the teachers from the primary school, with those made by the teachers from high school, one gets the sense that the primary school teachers have a much deeper understanding of the curriculum, and their planning and reflection processes are much more in place.

Macro planning in our school cannot be done individually but is done by the whole staff. It is normally done on the fourth term of school calendar. All educators irrespective of which grades are they teaching, and other stakeholders such as SGB are allowed to form part of these activities.

Towards the end of the fourth term, educators come together for whole school planning. All phases are engaged in the planning. After developing the learning programmes which are based on the school's needs and surroundings, learning area educators converge together and start developing their work schedules. They identify themes from the whole school planning. (Kagiso plan & reflect-int)

When asked to elaborate on why she thinks it was important to do planning at that level, she responded with:

This type of planning gives the school a direction in terms of curriculum delivery. There is continuation of content delivery across the phases and grades. Educators have guideline to enhance their daily planning.

Grade educators normally convene meetings and during grade meetings a lot is shared based on method of teaching and assessment method and content delivery. Work schedules and lesson plans are developed at this stage. A standardised lesson plan is developed for every learning area and educators take part in the development of these lesson plans.

Educators in different phases meet to discuss the reflection together on the processes of their teaching to each other, they usually help and support each other. (Kagiso plan & reflect-int)

The primary school teachers seem to have systems and a working understanding of how to manage the new curriculum:

When planning the learning programme, what we normally do is that all teachers who teach the same learning area on the same phase meet each other to make planning for learning programme that would be used by each phase for a period of three years. After a three year cycle the learning programmes are reviewed. (Kagiso plan & reflect-int)

The following response to the question of whether the teacher finds the phase level planning useful and meaningful, also shows the presence of a collegial and collaborative spirit amongst the teachers at the primary school. It also reveals that such meetings are fruitful, with meaningful agenda:

The process is meaningful because it helps teachers who teach the same phase to be able to link our work. It also promotes good relationship among teachers as we work in groups... We do hold phase meetings with other phase educators to discuss which forms of assessment needs to be covered in each term At these meetings, teachers who attended CIF meetings also conduct mini workshops during phase meeting. (Thama plan & reflect-int)

Even though this looks good, there is also some level of its being more technical than meaningful. Also, there was only one grade 7 in the school and, therefore, Thama had to develop a work schedule alone

We as grade teachers, plan our own work schedule together, depending on what we teach at a particular grade. Work schedule should be related to phase level planning, that is, the learning programme. And as a teacher before I go to class, I decide what I will teach by checking how the learners would be able to benefit. As I plan the lesson, I decide which learning content, learning outcomes and assessment standards would learners benefit and how I am going to assess my learners. (Thama plan & reflect-int)

Clearly, the results revealed that the planning processes at the local primary school were much more substantive and extensive than at the high school. Another revelation was the knowledge and the vision the teachers have about the curriculum. The quality of the responses of the primary school teachers, as compared to those of high school teachers, reveals that they have a deeper working understanding and vision, that can sustain quality curriculum delivery. This is in line with the deputy principal's observation, and affirms her assertion below.

... and I think that's done because I was saying if things are not done properly like monitoring of educators. I have colleagues who are senior managers ***' ko di' (Tswana for 'at')*** *primary schools and I feel small every time they say this week is submissions. All educators will be submitting their personal files. We don't do that in my school. I don't know whose fault is it but we all know that it suppose to be happening but it is not done I want to tell you the honest truth, it is not done.* (acting DP_int)

When I eventually gave up on the high school, I first explored the possibility of just focusing on the primary school. However, the ground there also started shifting, in ways that were demoralising. Kagiso was seconded to the teachers' centre and only Thama was left at the primary school. I would have had to start working with two new willing teachers and start the process afresh to build a team. This was towards the end of 2007 and I felt that too much had happened and gone wrong, and there were no guarantees that it would work.

4.3.4 Teacher Factors (5)

As indicated in appendix G, these factors have to do with the teacher's own background, training, level of confidence and commitment to their task of teaching. In South Africa, as in the world at large, science teachers' subject matter knowledge is major problem. Other factors relate to how the teacher responds to the innovation. Is he or she open to the learning process? Is the teacher willing to take risks and be subjected to critical feedback as they experiment with new ideas and practices? Is he or she willing to collaborate and support other teachers in the process? The teacher's personal issues also emerged as factors within this category.

Ten science teachers from neighbouring primary and high school, participated to varying degrees in the programme. As explained in the previous chapter Lerato, Mpho and Molefe were the most enthusiastic and therefore richer data of on their activities was collected as compared to the rest of the teachers. The three teachers, Lerato, Mpho and Molefe were teaching science or technology in Grades 8, 9, 10, 11 and 12 at the time of the first cycle. Lerato had 21 years of teaching science. She held a Further Diploma in Education (FDE) in school management, a BEd Hons (maths and science), a Public certificate in Environmental Education and an ACE (science FET). Molefe had been working as a teacher for 18 years, initially having a language background before joining the science department. He held a degree in social sciences and a senior primary teacher diploma. He joined the Wits FDE Science programme for a period of a year, but dropped out of the programme. Mpho was from a nursing background and had only been a few years in the teaching field. She had done an upgrade course for teaching technology.

All the three teachers had undergone departmental training on the implementation of the new curriculum, and there was evidence in the learning and teaching materials they used that they were making efforts to integrate the training into their teaching strategies. Lerato was the

head of the department (HOD) and was part of the Advanced Certificate in Education (ACE) programme the researcher was coordinating at some stage.

When asked about what their challenges and fears were in teaching, this is what Molefe had to say:

My fears mam is if my learners can underachieve it will give a bad impression to say that I am not doing a good job. (Molefe backgrd_int)

One can pick up also, from Molefe's comment below, the pressure which the new curriculum placed on the teachers because of feelings of inadequacy. The only personal aspect of Molefe which surfaced is that he cherished his family and his children, and would never put his own aspirations above theirs.

I want to improve in terms of teaching, that is education wise. I wish I could go back and improve my qualifications and if an opportunity can arise I will take it. But you see I have a family and I have to take my children as a first priority. (Lerato backgrd_int)

Lerato also expressed her fears as being related to her learner achievements.

Yes, I am a teacher and the product that I am producing – I am giving more but there is less product. If I give more, let there be more not less. Those are my fears. (Lerato backgrd_int)

On a personal level, Lerato and Mpho were not in happy marriages. Lerato had a very beautiful and elegant home in the suburbs quite close to the school, but her relationship was both physically and emotionally abusive. She and her husband were both teachers, and, from her accounts, there were clear elements of jealousy from her partner because of her professional progress and academic passion. Over the years, she had learned to keep quiet and not provoke trouble during heated arguments. She would usually attract blows when found studying at her desk. Her husband was also having extra-marital affairs with women she felt were just too low.

Mpho's husband had become a burden because of his lack of contribution to the household income. She exhibited the tension of a woman, caught between the roles specified by culture and society, and the realities of her own circumstances. Another thorny issue in Mpho's life was that her son, a learner in one of the neighbouring schools, had been expelled from the school for unclear reasons. She was really not a very happy woman and tended to swing easily to negativity. She was feeling very insecure, and in the second cycle (at the beginning of 2007) had registered for 11 courses towards a teaching degree with Potchefstroom University (now University of North West) and this divided her focus. A text message she

sent, on one occasion when I was enquiring about her availability, typifies her prevailing mood at that time.

> *At the moment I'm not available, I even start to lose hope, the'r so many things happening & hurting me.* ***Ka setswana ra re madi-mabe ga a tlhapiwe & it's true, ke bona ka nna (in Setswana we say bad blood cannot be washed off, and it is true, I see this with me)****. I'll let u know if I'm available.* (Oct, 2007)

Salang and Malebo were originally from Limpopo and previously teaching in ABET and Elga (T5) is from Zimbabwe. Of the three teachers, Elga was the most experienced in teaching and this was reflected in the one lesson where she was observed. Her lesson reflected a very sound knowledge of content, as well as the use of strategies to develop learners' conceptual development, rather than rote learning. During classroom observation of Malebo and Salang, I could pick up that they were struggling with classroom management. Like most of the novice teachers, they were very teacher-centred in their approach and totally lost control of the class. Elga was much better and used more advanced strategies than even Lerato. She was on a par with Mpho and Molefe, in terms of engaging learners in the learning process.

Given Malebo and Salang's situation in relation to the other teachers, I was faced with two totally different groups of teachers and I didn't anticipate that this would pose a huge problem. They were relatively new in the teaching field and lacked teaching experience. Their concerns were more on surviving each lesson. I also noted to my dismay, during the workshop, that they had just a single science textbook between them, and when one had to take it home overnight, the other one did not have reference material she could take home for later use. This concurs with Luft's (2009) findings, that beginning science teachers need subject-focused mentoring support in their early years of teaching experience, in order for them to fortify their content knowledge, PCK and teaching repertoire.

Elga did embrace the programme and did attend almost all the remaining sessions and was very comfortable during the sessions. The two other teachers Salang (T4) and Malebo (T6) were very different, and had their own special needs and priorities which I did not appreciate fully at the time. It is also possible that one of the reasons they lost interest in the programme, was that they could not appreciate the meta-cognitive activities we were engaging in, because that was not their priority at the time. Since we were viewing classroom videos, it is possible that they felt, when their turn came, that they would feel exposed. Because we did not move further with the process (we only viewed Lerato's video), I did not think of it at that stage, but it might have helped if, at the beginning, I had made it a principle to give people an

option when they would like their classroom data to be viewed for feedback. This seems to be explained by Rogan and Grayson's first proposition that: *There is a zone of feasible innovation. Innovation is most likely to take place when it proceeds just ahead of existing practice. Implementation of an innovation should occur in manageable steps.*

The programme was geared towards using relevant content to deepen both cognitive and meta-cognitive skills of the participating teachers' practice. From the pre-interviews and the pre-lesson they were each observed in, it was evident that they did not have much experience in teaching, and were struggling with basic things, like keeping the classroom under control. They might have viewed the content of the programme as potentially revealing and not in their immediate interests and needs. The interview with the acting deputy principal shed light on the context and the background of Malebo and Salang.

> *The other challenge now became that most of the new educators were from ABET and these people were not grounded, basic things like classroom management they can't control their learners.* ***'o Utlwa' (You hear)*** *noise and we were forced to go to those classes and the learners would keep quiet. So they will change, they just need to be mentored like programmes which can empower them.*
>
> *... apparently most of them are from Limpopo and they are saying ABET in Limpopo is not paying as well as the Gauteng one.*

ABET stands for adult basic education and training. This is a flexible mode of training aimed at responding to the high illiteracy levels of most adults in the country. ABET provides access to nationally recognized certificates for a particular target audience. There are several ABET centres across the country; they informally employ interested teachers to run their programmes.

Fortunately, in the context of this study, the data collection was not in vain. There is a well-known saying – *if you want to understand a system, try to change it*. This case study provided me with insights into the practicalities faced by most of the teachers in the South African schooling system. The baseline data and emerging contextual issues contributed greatly to the conceptualisation of the intervention programme and the conceptual framework used in this study. The learning in this case study was transferred to a more functional and structured setting, outlined in the major case study described below.

4.4 Underpinning the Journeys in Institutionalised Context – Major Case Study

In this section of the chapter, I start by capturing the enveloping change environment by first giving an overview of the project and the background of the participants involved. The four teachers and their supervisor formed a collaborative team, but for reasons which will become

evident later, three of the teachers collaborated to a greater extent, while one of the teachers worked pretty much on her own. In the second section, I start by first considering and profiling the three teachers and then move on to profile the fourth teacher, according to the highlighted themes of the model. Each teacher's journey is given a title which captures what stood out for the researcher in terms of overall impressions.

4.4.1 Immobilised Potential – Who is to Blame?

Noma is an intelligent black female teacher in her mid 40s working at Mfondo High School, an underperforming township high school in Gauteng East. At the time of the study, she had been teaching science at the FET phase for 23 years. She was a head of department (HOD) in a school with 100% black learners, drawn from the neighbouring informal settlement with different cultural and very poor socio-economic backgrounds. As in most South African township schools, English is an additional language for all the learners in the school and they have difficulties with the language.

Noma is well qualified, holding a BA degree and a Further Diploma in Education (FDE) in science, and was doing a BSc Hons at Wits University at the time of the study. She was not proud of her 10 year experience as a science HOD, saying that it did not mean anything because the school was dysfunctional and under-performing. Her vivid descriptions of the conditions in her school give an overwhelming picture of the types of constraints and challenges ordinary South African teachers and learners experience. The school had a population of 1 478 learners with an average of 40 learners per class, with 8 science classes. This school was based on primary school premises and two empty classrooms with no benches and cupboards were designated as science laboratories.

As HOD, Noma did not have an office of her own. She related how the teachers competed for limited resources to a point where relationships were strained. She occupied the so-called laboratory and, when other teachers needed to use it, she had to relocate to their classrooms. This created frustration and instability for her because, after using the laboratory, most teachers just dumped used materials without proper washing or packing. She explained how chemicals continue to react with each other because of this.

The main challenge in Noma's school is more a lack of proper infrastructure and management of resources than a lack of science resources, because she did point out that the science resources were adequate. It is expecting too much from science teachers to organise

and manage the practical work without an assistant, such as a laboratory technician, and it is surely one of the reasons why practical work is not implemented in many schools.

The excerpt below about science resources reveals that Noma is not passive in her management. She is actually a very pro-active HOD, who is able to analyse and prioritise the needs of her department. She is assertive enough to take the initiative to direct the cause of action on what interventions should address, in response to the unique needs of her department.

I umm tell me about the practical work resources

N we do have, that we do have

I Ok so you have a working laboratory

N Aye, just the, it's not – so as we speak now – we made an application through the Impala – they are upgrading our laboratory – so meaning that they are putting benches and some form of basins

Because ehh what they were doing they do it for Kwa Thema schools and the Tsakane schools – so they fitted us into one package – to say go and put chairs for those laboratories and go and change floors.

I ehh ok

N So I said to them I do have floors and I do have tiles, I do have – they were removing these plastic things – and put the ceramic tiles – to me I don't think I need them. (N_bckgrnd_Int)

The excerpt below reveals the general school ecology and the types of constraints Noma and her colleagues have to operate under, in terms of infrastructure, as well as issues of collegiality.

I You needed basins

N Yes, I need basins, I need, you know – especially the cupboards – we are a secondary school but we placed in a primary school structure. (N_bckgrnd_Int)

Since she is an HOD, one would expect that she would yield a lot of power, but what comes through is a sense of powerlessness, in a situation where subordinates compete with, and sabotage leadership, and are very un-corporative.

N With those big numbers, so you know –

I So how does it work?

N – that am going to be honest with you, the laboratory thing is actually making my department – it is straining the relations (R:Mmhh) because even that laboratory we use for staff – so if somebody wants to use it I have to move out and go to his/her class – so until recently I have decided that OK, because it is straining relationships then everyone has to move out but – but as an HOD I am accountable – you know – you know – I'm, maybe people were thinking that I've got a privilege – I am always staying there, I am owning it – and anyone who want to use it here is the key. They are straining me in that once they done the experiments they leave all the things as they are.

I That's not fair at all – hectic – man -– and without a lab technician. (N_bckgrnd_Int)

It also reveals a *laissez-faire* attitude, where there is lack of respect and accountability structure. It also explains why Noma was resistant to suggestions that she rope in her

colleagues in her study. She anticipated that they would not commit to anything that required them to put in extra time, irrespective of how valuable it could be to their own professional growth.

> *N Aand the person will come you know – and say 'iphe nto e so'* (where can I find such a thing?) *and is expecting me to leave the class – so I've tried to say please people try to write down the things that you want and when you are not giving them – in other words you are not giving them access into the laboratory.*
>
> *I mmm, there is no understanding*
>
> *N So go in and take what you want – so even they take them out and – but if those apparatus come back they say go and give it to the teacher – just like that, they put them in boxes – so at times you find packs of boxes there – if you want something, you have to start in the boxes before you go – because at the end of the day I am not the laboratory assistant.*
>
> *I umm*
>
> *N At the end of the day – whereby after school I have to pack – I've got my own marking, I've got a whole lot of other responsibilities you know.* (N_bckgrnd_Int)

Clearly she was passionate about science and that passion is driving her. Hence she cared about the operation of the laboratory – otherwise in an environment where there is no support, one could easily give up and join those who don't care by only doing the bare minimum.

> *N So Impala now is giving ehh – they are going to put up some cupboards – so that they can actually – try and – you know – we have some planning have space for, glassware, chemicals – you know. We've got a very small cupboard, this size – to put our materials and when you go there – the substances are reacting on their own – yah I can – but when it comes to – resources we do have.*
>
> *I YAH it's just that the problem is in managing them.* (N_bckgrnd_Int)

In such trying circumstances, it can only be passion and love for her subject which sustains the enthusiasm and the optimism to press forward and play her part.

Overall, Noma was very much in control of her personal life. Like many unmarried women her age, she had struggles of relationships which she handled with utmost dignity in the process of trying to locate Mr Right. She had an ailing father she frequently worried about, as well as ongoing worries about her teenage son and his HIV status. She also has two strong, progressive, loving and supportive sisters whom she holds dearly.

What stood out and surfaced all the time in our interactions about Noma was that, when she decided to put focus on any academic task, her depth and insights far surpassed those of other team members, but the problem was that she was inconsistent. Hence the phrase: Immobilised potential – who to blame?

4.4.2 Hanging in There … Is it Worth the While? – Bongani's Enveloping Change Environment

Bongani is a black male in his 40s, working as a science teacher in one of the high schools east of Johannesburg. The school which was identified as an under-performing school, offered technical subjects, physical science, mathematics and accounting as key subjects. The school had a staff complement of 37 educators and a population of 1053 learners, drawn from the township and informal settlements with very poor socio-economic background.

At the time of the study, Bongani had been working as a teacher for 14 years. He trained as a technical subject teacher, and when his college was changed into an ordinary high school, he took the opportunity to retrain as a science teacher because they were in demand. So he had been a practising science teacher for about seven years. Before coming to Wits to do his BSc Hons,, he did a Further Diploma in Education (FDE) in science with Rand Afrikaans University, popularly known as RAU and currently called University of Johannesburg. Bongani struggled with his science, as well as other academic competencies.

At a personal level, Bongani was sickly and asthmatic. He had a nine year old son who had been diagnosed with Down's syndrome, and this was putting a lot of strain on him and his wife. There is no doubt that he is a dedicated and caring father because he talked very passionately and lovingly about his son and wife.

In addition to all these personal burdens, Bongani was not a strong student. Language seemed to be at the core of his academic challenges because he struggled a lot with comprehension in his reading and writing tasks, as well as comprehending the science concepts.

The school he was working in had serious problems of infrastructure because it used to be a technical college. It has workshops which are old and not well equipped, very few classrooms and a media centre with computers which are not working because of lack of electricity in most parts of the school. There is running water in the school but the only science laboratory in the school is not well equipped.

A lot about the school ecology and the management structure emerged in Bongani's background interview. Systems were in place, and regarding planning and monitoring, Bongani's school seemed to be doing well. There were also indications of genuine collective reflections on progress, and a meaningful review to try to address emerging problems. Why,

then, was the school not doing well? The excerpt below captures the type of monitoring and evaluation system operational in Bongani's school.

> *You are required to prepare on weekly basis. The head of the department is going to monitor the whole process and also weekly plan should include also weekly focus. In certain day which sub-topic are you going to handle and when to complete the topic. This process helps the teacher to be able to complete the syllabus in time. It is also simple to identify problem area where learners do not understand.* (B_bckgrnd_Int)

They regularly held meetings to reflect on their learners' performances, to identify those who needed remediation and to make commitments on what measures they will put in place to alleviate the problem.

> *This gives us teachers a task to help learners with difficulties through afternoon classes or morning classes ... We also hold subject meetings to discuss problems and results. When teachers are teaching the same subject at same grade, you need to do the same preparation and cover the work at same pace.* (B_bckgrnd_Int)

Collaboration and collegiality amongst teachers seemed to be very good because these meetings were also used to report about their teaching progress, to raise any challenges they experienced and to solicit and offer each other assistance in their teaching work. Even though not much was captured of how this worked, there seemed to be a support structure, as well as healthy spirit of collegiality, where teachers were able to draw from each other's strength to ensure quality inputs.

> *The head of the department will send notice to teachers to remind them of a meeting. The meeting is going to be minuted and the report on progress and difficulties you are facing on the subject are going to be dealt with. How are we going to help each other in the process? When you do have problem with a certain topic other teachers assist by teaching the topic.* (B_bckgrnd_Int)

Planning seems also to be meaningful and done timeously. It is a collaborative effort and assessment seems to be at the core of their plans.

> *The work schedule is planned at the end of each year when teachers are given their timetable for the following year. It may be individually or group of teacher preparing. They are going to incorporate even the assessment task and date to be written. Each individual should do his or her own schedule.* (B_bckgrnd_Int)

Bongani's elaboration on how he thought his learners learn best, revealed a lot about the type of context he is working under, the nature of learners he is dealing with, his knowledge of his learners and the practical strategies he employs to ensure quality intervention, using group work and peer engagement strategies.

> *B Err, my learners usually – it depends-it depends, because others, they learn while you are teaching them in class, others they need time, and eeh it is – sometimes – it is impossible, to even er, know individually how – how they cope with the work because of the numbers in class – but most – of the time, you see, learners they usually er if you give them err like homework – eeh, you give them ho – you – you teach them something, then ask them questions – they will say, they understand – and then after you when you give them, a task to do, that is where you discover that some of them – they don't understand*

the content, and in turn they will – borrow books from – from others, so, err my strategy, I usually – ehh when I enter the class I will, make sure that I check each and every individual that he has done the homework, before I can even, write on the board – the corrections or what (B_TB_Int)

The quote also reveals a lot about his knowledge of his learners and how he managed them to ensure order and progress in his situation.

I Ummh, ok, so – you referred to morning lessons, what do you do, with them during morning lessons.

B Morning lesson, ehh, ehh – more especially topics that are difficult – that I know – eeh they are not easy –for them to understand – I give them enough time; maybe early in the morning we do something then ehh – during our ehh, period – it then that I'm giving them maybe, a task – to find whether they do understand –if – they don't understand – even them they will say ukuthi, we don't understand this – give us time, we usually stay at, afternoon classes. Usually, they need to – sometimes –it become a problematic – because am studying – eeh, usually, I attend morning classes, usually I attend morning classes--afternoon classes it is a difficult process because – I need to attend even myself.

I umm, ok so morning classes, what time?

B Eeh, I arrive at school at, quarter to seven, learners arrive at – seven o'clock – then we have got that forty-five minutes.

To the question, *tell me how do you describe your role as a teacher* – Bongani's response below focuses on generic or moral aspects of the teacher's role, and does not touch on perceptions of the teacher role in terms of learners and learning (14). He raises very interesting points about role modelling which are centred around teacher-learner relationships, and this places him as a transitional teacher. The response is heart-warming in that it reveals a lot about his morally grounded perspective to life, as well as his pastoral attitude towards his profession.

B Eeer, a role of a teacher is like a father – or a role model, because as an educator–learners they, they, imitate some of the things that you are doing, and I don't think as a teacher – you need to do wrong things because – you will be misleading the very people –the – very learners that are – are imitating you as a teacher, or parents are – are entrust – entrusting you with their kids, and then you as a person, you – you behave in a wrong way. I think you need to behave properly err dress – properly, eeh manage your things – at school, like for an example – late coming –as a teacher it's a bad thing if you arrive late once learners arrive late, obviously they may say Mr so and so, will arrive late – usually arrive – early and late at school, so it is a bad thing even – to yourself

I Umm

B And to your colleagues, err language, insulting, learners, you know – so those are the things that you need to avoid as a role model, you are part of that community – you need to – show them – how to present themselves in a good manner, as learners. (B_TB_Int)

In other environments, certain things would be a norm and therefore not worth raising. So, in a way, his response revealed much about what takes precedence in the enveloping change environment (1), that is, the school ecology and the types of contextual dilemmas he faced as a teacher working in that environment. It also says something about the background of the learners, because the teacher, in such an environment, has a critical role to play, possibly because certain principles are not reinforced anywhere in the learners'

lives. It is also interesting that aspects which are directly related to learning, such as industriousness, conscientiousness, purposefulness etc. are not included in the response, which might be an indication of what takes precedence and explains the level of achievement of the school.

From the excerpt below, the school is clearly emerging as a troubled one with a very low culture of learning. No wonder it falls under the worst performing schools in the country. The level of teaching is disturbingly very low.

I so, you talked about Saturdays – are you able to – to keep on getting your, your

B This year it's difficult,

I Aha, aha

B this year it's difficult, that is why, I am saying last year, it was. ... – but after – after June, after – after that strike – it was not ok because – that year it was not okay, because even the very learners, that were attending classes – when I ask them – come and attend – they were not willing to – to come.

I Umm, and you talked about, eeh giving them task, but there, I mean for revision, is it different from – test, the task?

B – the task that I'm giving the – giving them, they are almost similar to – to tests – and class work

I Ok

B so – like for an example if – if I know that – I've done similar problems, and when I analyse –the test – only to find that there are – there are few –problems, most of them they – they didn't get those eeh problems – those are the problems that I highlight. (B_bckgrnd_Int)

The excerpt below indicates that the learners had a say in their own learning. This is a very good thing, but, unfortunately, the excerpt also shows that the learners set very low learning goals for themselves, showing very low expectations of their own capacities. The discussions were not focused on the understanding of concepts but were more about playing politics. What is even more worrying about this situation is that they were not shy to expose to their teacher their disturbingly low attitude towards learning. They appeared to be more interested in marks than learning, showing no culture of learning or hard work.

B And then I will – will always assist them first, then give them a similar problem, but what I have realised – about Mathematics – is that, err learners they will – in fact not Mathematics, learners, they will tend to – in fact I will talk about two things, first that is in Maths – when you give them a sum they will do that sum maybe – in a test – you give them a similar – eeh, eeh problem, some of them they didn't – understand they'll say, why can't you give us the one that you we – we've done in the class.

I Mmmh,

B Then – one – one learner – in my class err we wrote a test, then we were –doing some corrections – in fact I give them scripts – then in turn he raised up his hand, he said, meneer, eeh,eeh you know, I'm surprised that – you – you have, given us – this problem whilst we didn't do it in class – in this manner – I said, this is part of the language – a language, it a language barrier. (B_TB_Int)

It is quite interesting that the teacher's analysis of the situation did not point to the problem of rote learning, but to the problem of language. What is also very interesting is how fast the

teacher was able to transfer the problem to the language teacher. The excerpt also reveals issues of collegiality amongst teachers in this school. Another way to look at it is that, consistent with the prevailing SADTU climate in the learning and schooling affairs, there seems to be no room for learning from critical friendship amongst the teachers. The teachers cannot deliberate honestly on issues of learning, and this permeates across learning areas.

> *B – in fact because – It was – something that was straight forward – most of them, they've understood the problem, but, this one didn't understand the problem,*
> *I Umm*
> *B because, when we – we dealt with that problem, I've just indicated with a line, it was oxidation numbers – I said calculate – one – element, in that compound, so I said Mn – in – so it was a problem, now it is not my problem, it is a problem of language*
> *I Umm*
> *B So, shut things – if you – give them, that opportunity to raise those things – you are able to discover with those. – even the language part of it – whilst, then I wouldn't understand – and I wouldn't, eeh eeh go and say to – their English teachers – some – some people they – they will be offended – if you tell them that – eeh, learners are not coping with English, you know – so, it is a difficult, eeh problem.* (N_TB_Int)

4.4.3 Paradox in Excellence yet Lack of Recognition

Colleen is a white female in her early 50s, a mother of two academically successful girls, one having recently graduated in physiotherapy at Wits. She is also a professional squash player. After completing a BSc with a Chemistry major at Wits, she joined an American pharmaceutical company where she worked for three years, and then moved on to another company, which dealt with a whole range of consumer products, as well as pharmaceutical products. After a few years there she was promoted to a lab manager position, where she managed their main laboratory which had a microbiology, as well as a chemistry lab. She then left them and stayed at home for a couple of years to raise her two daughters.

Just as she was about ready to look for a job, she received a call from her previous employers. The two companies that she had worked for had merged, and since she was one of the few people who had worked for both companies, they head hunted her. Even though she was not a pharmacist, she served as one by re-registering a whole lot of drugs for them, a job she soon realised that she hated with a passion because as she puts it her own words:

> *It was like filling in technical forms. It was terrible, but I did it because it suited me I could come and go, I was on a cont- contract. So I was only paid for the hours that I worked. My kids were little so I came and went. But I really didn't enj – I liked the lab but I really didn't enjoy that.* (C_bckgrnd_Int)

Soon after, she got a job at Pro-Tech to teach Grades 11 and 12 science, and was with them until they closed down about three years down the line. She really enjoyed herself there; as she puts it: *And I really enjoyed it, in fact I think I am better with that than I am with children and I think*

ultimately I will go back to teaching adults. I really enjoyed it. That is where she had her first teaching experience, being involved in marking tests etc. for the first time. She then joined a Co-Educational government high school as a science teacher for 11 years. For reasons possibly related to not receiving any recognition of her experiences from the government, she left the school and took up a position at a private school where she stayed only for one year (before joining the present school) because as she puts it in her own words, she really did not like it.

> *I didn't enjoy it at all – the kids were too rowdy, spoiled and way too wealthy*.
>
> *As I have had no professional training I have always felt at a disadvantage although I have always achieved more than satisfactory results with grade 12 averages well above the National averages. Most of my learners have passed well and have gone on to achieve at tertiary level.* (C_bckgrnd_Int)

This was quite a sore point and morally discouraging in Colleen's teaching career, because she knew that, with her strong science content knowledge, she was a rare asset to the school education system but felt very alienated by the system in not only not taking cognisance of this strength, but also to want to classify her as an under-qualified teacher.

Colleen was quite new at the school where she was teaching at the beginning of the project, so it was not only about teaching a new topic within the new curriculum framework, but it was also in a very new school environment. She had started teaching at an English medium high school for girls, which we will refer to as Rainbow High School for Girls, situated east of Johannesburg, in January 2008. This school is one of the best government high schools in Gauteng, having achieved a 100% pass rate for the past 15 years in succession and in the recent matriculation examinations, a 96% University Bachelor's degree exemption. The school is also one of the best resourced government schools in the country with approximately 900 girls, a teaching staff complement of 52 and a teacher:pupil ratio of about 1:30. The school is very diverse because it draws learners from various racial and socio-cultural backgrounds.

Colleen, as a new teacher, was teaching two different learning areas in four different grades at GET/FET levels, and did not have an office space or a classroom allocated to her as a base. She taught physical science at grades 11 and 12, natural science at grade 9 and mathematics at grade 10. She decided to focus on her grade 12 class because they were the ones who would be doing chemistry at the time of her data collection, and her grade 11 would be busy with physics. This resulted in her being the only member of the group handling grade 12, and her possible working partner also being the only member focusing on grade 11. As a result of this project, Colleen ended up assuming the responsibility of planning the programme for

grade 12, which involved doing all the lesson plans and assessment tasks for the grade, and sharing them with her HOD who happened to be her partner teacher for grade 12.

4.4.4 The interface between the teacher factor such as work ethic and personal issues with management of resources and context

The school as an institution is very organised, with planning at different levels (school-, phase-, grade- and class- levels), efficiently coordinated and synchronised, and geared for success. Since Colleen was new to the school, she was not very conversant with the practicalities of planning and reflection processes at school level, but she was obviously highly involved in planning at phase as well as grade level.

> *This has not been done since I started at the school, but I have not been at the school long enough to know or it might take place in term 4.*

At phase level:

> *We hold discussions about what is in the curriculum for the phase, what is being taught and how at each phase.*

At grade level

> *Each grade has a person in charge of the planning and then all the teachers involved are invited to comment on it.*

When asked about reflection meetings with science teachers in the same grade:

> *We hold meetings to discuss progress and what is working and what isn't, whether we are coping etc. with the grade etc.* (C_bckgrnd_Int)

Colleen's professional background is a very interesting one and it brings to the fore rich and interesting dynamics underlying science teaching in South Africa. As expressed in her reflections above, even though she has about fifteen years of teaching experience at various education levels, she has always been frustrated and felt like a stranger in the teaching field because of her lack of a professional teaching qualification.

She however has a very rich professional background which declares her as her learning area specialist and accounts for her resourcefulness as a science teacher. Her experience of working in industry attests to her strong science content knowledge, as well as knowledge of industrial operations which translated well in her management of LO3.

The irony is, how a science teacher with such a background in this country where quality inputs in most science classrooms is just in the realm of dreams because of most teachers'

capacities, finds herself not being valued as a teacher. The statement below from an interview captures the core of Colleen's issues:

> *But the different kinds of – I can't get registered, I'm struggling to get reg – a registered with SACE But in spite of all my teaching experience, they don't recognise anything that I've done. … I thought of doing PGCE after my daughter matriculated, and when I looked at the programme, I thought I'm too old and this is really too basic, I'm way past that. My work experience has taken me way past where a student having their first school experience is, and I'm not willing to do it and that is why I registered for this instead. But this does not give me a professional qualification.* (C_bckgrnd_Int)

Colleen's background as a pure science graduate with no teaching qualification, coupled with experience of working in industry, is unique and confers a unique advantage on this study. Her dilemmas provide rich data in several debates, including those on how the knowledge of pure scientists differs from the knowledge of science teachers. At the time when Colleen got involved in this project, she had only been at her current school for a few weeks, and therefore another area her experiences elucidate is how knowledge of the teaching context affects all other aspects of PCK.

Colleen works in an exceptionally functioning and well managed school. The excerpt below reveals a lot about the interface of time constraints and school management and ecology in the enveloping change environment impacts of the teacher's time to focus on science teaching.

> *Staff meeting today and then there are parents evenings the whole week. Will battle to get much done. Will have to leave Wits early on Thurs for maths – grade 10*

From the reflections below, it is clear that Colleen as a new teacher in that school had to hit the ground running.

> *I have spent the whole holiday doing the preparation for chemical systems as well as preparing term planners for grade 12, maths prep and prep for grade 9*
>
> *I have to catch up with 'Lara (co-teacher and HOD) and finished the section the Doppler effect and colour and colour mixing.* (C_refl_journal)

It is also clear that the pressure was far too intense and was now spilling into Colleen's personal life.

> *Am tired after grade 11 parents evening and then a squash match last night. Had to drive to Parkview on my own.*
>
> *I needed more time for all the different aspects of my life. My husband is not happy about the amount of time I am working and our home is neglected. Next year should be better when all the prep is done.* (C_refl_journal)

At the same time, it is a reflection of her own resilience as a professional teacher that she is able to absorb this pressure, and still excel and produce quality in what she is doing in the classroom.

The excerpt below indicates a clear sign of tenacity, and being new but daring enough to take a content and curriculum specialist role:

> *I have gone through the plans with Anita. She seems to be happy with all the planning. I am to prepare both the cycle test and the exam which will take place in May*. (C_refl_journal)

As a new teacher, Colleen was also learning and exploring the school context, the possibilities and the constraints it can have on her teaching plans:

> *I have to let Jane (Technician) know about the video, The Busy Electron and see if she can set it up in the computer room*
> *Need to show the learners a video for their practical – am not sure how video streaming happens. Difficult to set up with all the extra murals*
> *Video is worth seeing but there are pauses in transmission. Stella will see what she can do about it.*
>
> *Maybe I can get Rainbow to buy some more up-to-date videos and computer software for next year.* (C_refl_journal)

The following is a reflection of how constraints of time and resources in the enveloping change environment impacts on effective management of resources and the context for learning:

> *I have organized with the computer teacher to let the girls watch the video in the centre. I have not managed to get a data projector for the lessons as the deputy in charge of equipment is on a school tour.* (C_refl_journal)

This is a reflection of a sigh, due to overwhelming professional pressures and demands:

> *My prep for this term is enormous and I am not sure how I am going to manage everything. I am helping with the major production at the school, I have to set and type exams for grade 12 science, grade 10 maths and grade 9 natural science. This is on top of all the marking and the grade excursion to Sci Bono. The grade 12s are also entered into the Mintek quiz.* (C_refl_journal)

At the core of all these dynamics is the reflection of how Colleen's vast and secure content knowledge is able to support her versatility to delve deeply and broadly in addressing the topic with such quality, while at the same time being able to take on other critical pastoral roles aimed at ensuring learners' personal development beyond academic learning. What is noteworthy is the courage she has, to take on a content and curriculum leadership for her colleague, who was not just an ordinary colleague but actually her superior, while at the same time being a very new teacher in the school.

4.4.5 Underneath the Silence, the Humility, the Unstable Support base lies Greatness

At the time of the research, Sipho was a male teacher in his early 40s who had been in the teaching field for twenty-one years. Over this period, he had taught in five different schools and had been with the current school for 16 years. Throughout his career, he had been teaching physical science, biology and mathematics in different grades. He was heading the

science department in not only one of the worst performing schools in Soweto, but also one of the most notorious and violent, where learners bring marijuana, alcohol and weapons such as knives to school.

Because of his broad and flexible knowledge of the field, he was regarded as a resource person who could be allocated any grade in any of the science subjects, if urgent need arose. At the time, Sipho held a Senior Certificate Diploma in teaching with Physical Science, Biology and Mathematics as majors, a diploma in Education management from the University of Pretoria and an FDE in secondary science teaching from Wits University.

Sipho has a very good command of English and his content knowledge for teaching science was very well grounded. Not much of Sipho's personal life surfaced except that he missed several sessions due to ill health, and at times due to professional battles levelled at him by school management and the department. Sipho was married with three sons. He did not divulge much about his personal or professional life and seemed to be a bit reserved. He did not seem to have a good support base for his studies, especially from his school. Irrespective of all this, Sipho's enthusiasm and passion for his subject and his firm content knowledge, left no doubt in one's mind that he was a very hardworking and committed teacher and HOD. Nonetheless, these issues recurred too frequently, leading to inconsistencies which culminated in Sipho's not submitting his research report.

Infrastructure and resource wise, the school was situated in a relatively new building, housing about 650 learners from grades 8 to 12, with a complement of about 32 educators. There were shortages because not all learners had desks or chairs and there were a few windows broken here and there. There is a library and about four science laboratories, which are not very well equipped. This is what Sipho had to say when asked whether he thought his school was well resourced

S: Ehhh – it's not sufficient – it is there, but not sufficient – yah, yah, in that, whenever we have to do practicals with learners – there is a group of forty learners in a class – and the material, I want to divide it into groups, I can't, rather it ends with a demonstration or – with only some of the learners participation, yah

I: so there are constraints, yeh.

S: Yes

I: What resources do you think you need?

S: Eh, especially those – that eh – help me to – to do a practical lesson—successfully. Chemicals and laboratory equipments – etc. All the equipment – that has to do with the practicals. (S_bckgrnd_Int)

Another thing is that Sipho seemed to appreciate the resources he was exposed to in the programme and drew them strategically into his own teaching. In the excerpt below, he seems to be quite excited as he explains how the new science teaching strategies and resources he is exposed to are improving his classroom strategies, and helping him to make science meaningful to his learners.

S: Ehhh I use textbooks, policy document, and eh – lately – I use this experiment I got here from the course materials that I think is relevant – I use some of it – and they are proving to be working.

I: Okay, Ummh, you have good feedback about them.. Yah, I think so because – eh – I tried it, and I just given them a test yesterday, and eh – I marked half of it – half the number of learners –and – I'm quite happy – that the – at least they are grasping – those things, especially, that, microscopic representation.

I: mmh

S: You see when we – teach for instant immiscible liquids – in mixture – okay, we end by telling them – sometimes if they are lucky – we do have those eh – chemicals – we try to show them – there they can see that –its not eh – heavily – they are immiscible the liquids.

I: Ummh

S: The new thing that I learnt from here is – representing now – those molecules of those liquids, say in a container – in a picture form – and I find it quite interesting, I showed it to them, I asked them in a test –and they did well. (N_bckgrnd_Int)

When it comes to issues of teacher collaboration and planning, Sipho's department seemed to be doing reasonably well, even though there could be a lot of room for improvement. From the concerns he showed, and the passion he exuded while consulting about issues of teaching and learning, one could gather that he was passionate about science as a learning area, concerned about his learners' progress and a very supportive and progressive HOD. As indicated in his response below, lesson planning was done as a matter of formality, but not for improving the quality of inputs. When asked to share how he normally goes about preparation for his lessons his response was:

Okay, eh, I would look at the policy document, what is it that must I stress about that particular topic I'm eh preparing for – and then consult the textbook, look at the content – but most of it is in my head – so I tell myself, and then – I would – draft a lesson plan – there's a – template that we use there – just for formality, and put it in a file — for anybody who could request to see it and eh, well as I tell you – the content – I think – I tell myself – it in my head, so, eh – that's how I go about – yah then I just – instead of –

When it came to issues of reflection, from the excerpt below, it is quite evident that even though the lesson plan formats were merely done for procedure's sake, at some superficial level, it did begin to foster a culture of reflective practice.

Yah – – in a way it is standard practice in our school – that's why we have what –eh template –eh lesson plan template for each – learning area – and for each department – eh – the reason is –to reflect on those lessons, but, you see we don't – do it the correct way, in that eh – yes you – try to – determine the constraints that made your lesson not to be successful or successful, eh – we discuss we – with department, and – but we don't go deep – as I said so. (S_bckgrnd_Int)

From the excerpt below, clearly there were some genuine levels of collaboration and collegiality existing in the interactions of teachers in Sipho's department. Even though reflection sessions were not formalised and the teachers did their own reflections on their lessons individually and not in any formal way, the collaborative spirit was good and the teachers helped each other in their teaching efforts.

S: On the reflection part, but on the – planning part, I think – no, yah we do it individually—

R: Okay, weekly reviews, what do you do – there?

S eh, it's like a – departmental meeting—we not many – eh we are about four science teachers, yah, and we – just check on each other – how are we coping –

R okay, okay, and you share – strategies – and all that –

S yah, in a way—

R aha, how is the spirit – how is the spirit, is it collaborative spirit, is a helpful spirit—supportive or you think there is room for improvement –

S I think there is room for improvement – anyone who started this year – yah – it was my initiative I think – (S_bckgrnd_Int)

From the excerpt below, when asked whether he ever invites colleagues to observe him during his teaching, it is clear that there is collaboration and support but it happens naturally within the constraints and affordances of the enveloping school environment.

Eh – well they are free to come – but because – we are over loaded with work – they – don't normally come, yah, except where – say for instance – I have challenges in electromagnetic – teaching – for instance – then the colleague……. Microbiology is a – challenge to me – can you do it for me – we know our strengths – so we use each other – (S_bckgrnd_Int)

4.5 SMK Base from Concept Challenge – for both Case Studies

In this section, I discuss part of the participating teachers' SMK of the chemical change topic with the aim of identifying their conceptual starting point so as to be able to map it along with other knowledge domains as a factor in their professional growth. Another interest is to diagnose the types of conceptual challenges and see if there are any emerging patterns across the teachers' varying backgrounds.

Even though the topic of chemical systems at the FET level involves new topics in the curriculum, it is based on the application of known topics in science, society and the environment, and therefore involves some unfamiliar as well as more familiar concepts. Therefore, the SMK sub-domain entails the teachers' foundational knowledge of teaching chemistry topics, as well as their knowledge of some specific topics of chemical systems at a specific grade at FET level. The data informing this sub-domain were collected using the chemistry concept inventory/challenge, concept maps and the CoRe.

In addition to determining the teachers' SMK, the concept challenge was also used to introduce the role played by alternative learner conceptions in learning, so the ideas were further explored during reflection and planning sessions as a means of focusing teacher discussions on lesson planning. The questionnaire was discussed in chapter 3 and can be found in Appendix I and raw data analysis in appendix J.

To get a full impression of the foundational knowledge of science teachers who participated in both case studies, data for 15 out of 16 teachers involved were analysed together. The teachers were allocated numbers from T1 to T16 (Figure 7). T6's data were missing because she did not hand in the concept challenge. As discussed in chapter 3, the 29 questions were put into nine categories (see table 9), according to similar areas of difficulties revealed by research. These were ratified against categorisation of an expert (chemistry professor), with only two discrepancies (on which consensus was reached through consultation).

The teachers were also put into two levels of categories, with the first level distinguishing Senior phase from FET teachers and the second level, with three categories, distinguishing primary school from high school teachers, as well as senior phase high school from primary school and FET teachers. The three teachers who became the main focus of the minor case study because of their extensive involvement in the research process, are identified by their pseudonyms: Lerato (T1), Mpho (T2) and Molefe (T3). The four teachers in the major case study were: Bongani (T13), Noma (T14), Sipho (T15) and Colleen (T16). Their performance in the challenge is shown in table 7 below.

Table 9: Concept Challenge Scheme of Analysis

Molecular distinction between gases, liquids and solids (Q1 a, d, g, j, m, p)	molState
Molecular distinction between mixtures and pure substances (Q1 b, e, h, k, n, q)	molM&P
Molecular distinction between elements and compounds (Q1 c, f, I, l, o, r)	molE&C
Conservation of mass & atoms during chemical reaction (Q2,6,8,9,13, 14,19,20)	ConsMcc
Conservation of mass, atoms & molecules during physical change (Q3,4,5, 7)	ConsMpc
Macroscopic v/s sub-microscopic descriptions (Q11, 12, 15, 23, 24)	mac-mic
Energy during physical & chemical change (Q10, 17 &18)	EnP&CC
Solution & concentration (Q16, 21, 22)	sol&conc
Word equations for acids-base reactions (25, 26, 27, 28, 29)	Wrd-eqn

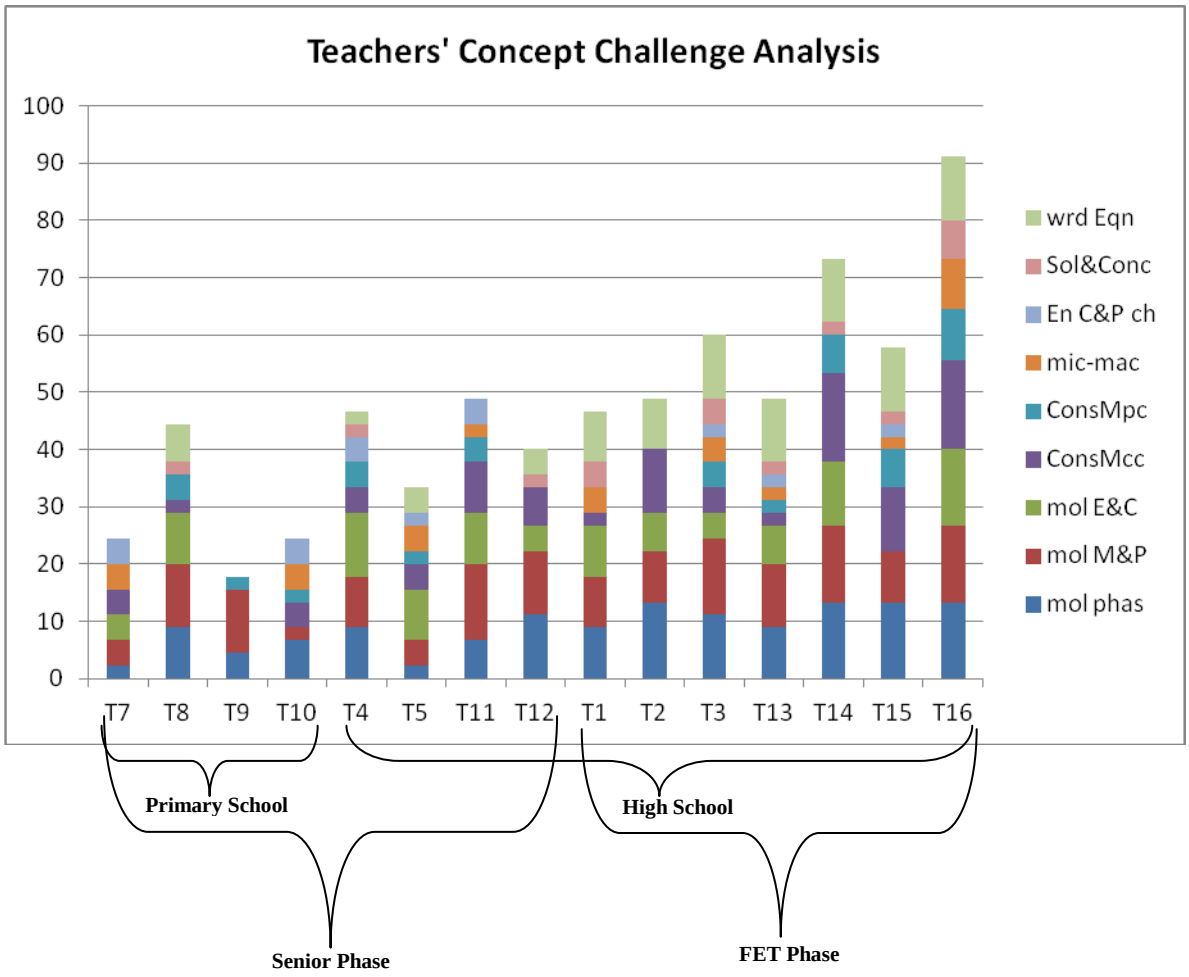


Figure 7: Concept Challenge Analysis Codes

The pattern that emerges is that T16 (Colleen), in the main case study, stands apart from the other 14 teachers who seem to lack basic understanding of fundamental concepts which form the foundation for clear thinking in chemistry. Generally, looking at the totals, it is also clear that the high school teachers have a slightly higher content knowledge than the primary school teachers, and the FET teachers also generally have higher content knowledge than the GET teachers. Another distinct pattern is that of the 15 teachers only T3 and the four teachers from the major case study performed above 50%. Another very distinct pattern is that there is clearly a higher understanding of word equations by the FET teachers and very low understanding by the GET teachers. Besides this category, three FET teachers, T1 (Lerato), T2 (Mpho) and T13 (Bongani) seem to fare as badly as the primary school teachers.

Mpho's results are also unique in that her score is distributed between only two categories, revealing that of all the six categories, she only has some understanding in two aspects which are: the *word equations* and the *Conservation of mass & atoms during chemical reaction.*

Table 9 and Figure 7 reveal that with the exception of T16 (Colleen), all seem to have problems with the *mac-mic* cluster of questions. This point to most of the teachers as having conceptual challenges in making shifts between microscopic and macroscopic descriptions which is a critical aspect in establishing clear thinking in chemistry.

On the issue of *energy during physical & chemical change* (Q10, 17 &18), the senior phase teachers seem to have a better understanding than the FET teachers. This is one area which Colleen (T16) also seemed to encounter difficulties.

Question 10

Heat is given off when hydrogen burns in air according to the equation

$$2H_2 + O_2 \rightarrow 2H_2O$$

Which of the following is responsible for the heat?

a. *Breaking hydrogen bonds gives off energy.*
b. *Breaking oxygen bonds gives off energy.*
c. *Forming hydrogen-oxygen bonds gives off energy.*
d. *Both (a) and (b) are responsible.*
e. *(a), (b), and (c) are responsible.*

There are also levels of confusion concerning microscopic categorisation of substances as mixtures, pure substances, compounds or elements, as well as issues around conservation of matter.

The following conceptual challenges which inform the category of *content knowledge* general profile emerged from analysis of concept challenge questionnaire.

- Difficulty distinguishing between particle diagrams of gases and liquids;
- Confusion between crystalline compounds and mixtures
- Confusion between mixtures and compounds at the microscopic level
- Difficulty distinguishing between physical and chemical changes
- Inability to conserve mass and matter during chemical change
- Attribution of macroscopic attributes to microscopic entities, e.g. "particles evaporate"

- Belief that breaking chemical bonds results in release of energy

4.6 Discussion

The main aim of this study was to explore cognitive, meta-cognitive and pedagogical aspects in the participating teachers' responses to the challenges of enacting new practices in their classrooms, in order to identify support strategies. What emerged points to the overwhelming role played by contextual issues in the learning and teaching processes. I was left with very thin data on the intentions of the study but a large amount of data on what was not sought. The struggle became one of how to pull the pieces together, with the main challenge being how to report the deficiencies revealed in the minor case study.

In this minor case study, it is clear that the quality of learning and teaching in the classroom is affected by a range of factors which could either be extrinsic or intrinsic. One insight I really appreciate about this case study, is a window into the negativity at the root of a system which, on the surface, seems normal and thriving. The reality unfolded gradually. I initially thought I had encountered issues of professional jealousy leading to sabotage which I could deal with, to foster healthy, cohesive relations where everyone feels appreciated and open to constructive inputs.

The range of issues which plagued the management were enormous: school fund embezzlement, teacher–learner molestation, intimidation, political corruption such as buying of posts, union backed corruption and incompetence. All these rendered the school dysfunctional. These issues provided a window into how efforts of strong and committed teachers can be undermined by factors in the enveloping change environment. Also in politics, the notion of leadership can be misconstrued as an opportunity to abuse power and protect corruption. The story of the acting deputy principal also points to the fact that no matter how gloomy and disheartening state of affairs can be, it can take one bold individual to break the cycle and initiate a chain of constructive change. It is, however, a painful route to use power to work against a corrupt system because people naturally collude, as opposed to facing the issues.

The four indicators (teacher factors, learner factors, school ecology and management; time and resource constraints) used in this study, together give a picture of the capacity of a school to be able to support and carry out an innovation. Rogan & Grayson (2003) hypothesise that the relative contribution of these four factors to this construct are likely to be dynamic as well as changing over time depending both on level of the school and the implementation stage. A

good case to illustrate this is a study by Malcolm et al. (2000) where schools with relatively similar resources produced strikingly different matriculation results. The Malcolm et al. (2000) findings suggest that teacher factors as well as school ecology and management factors could be the largest contributors to the capacity to support innovation construct.

Even though I never went to visit the schools involved in the major study, the types of issues which emerged point to the fact that, with the exception of Colleen's working context, the teachers were operating in contexts which were not immune to the types of issues that assailed Bojanala high school. As if these extrinsic issues are not enough, the results of the concept challenge reveals that, with the exception of Colleen whose junior degree was in pure science, at a personal and professional level, the teachers lack knowledge of the content area they are supposed to teach.

It takes unique resilience, courage and willpower to work professionally in contexts these teachers have to work in on a daily basis, and this is what declares them as the heroines and heroes of our nation. The national strike really put a nail in the coffin of the minor case study. When making the decision to abandon the study, I was deeply challenged because the big question for me remained whether, as education researchers, we can really afford to neglect moral issues and claim to be focusing on the teaching of science in the classroom.

4.7 Conclusions

The journey within the minor case study was a frustrating, dynamic and steep learning curve, especially in trying to sustain commitment and cohesion among the team of science teachers who participated in the study. The minor case study provided insights into the practicalities faced by most teachers in the South African schooling system. The findings show that the school is not an island and the prevailing political climate can engulf all efforts to improve the system.

To the research sub-question 2.2 *what dynamics serve to afford or constrain the teachers' efforts in effecting curriculum aligned changes in their practice* – five findings can be claimed. Firstly, the results of this case study suggest a cycle, where the two sub-constructs, *school ecology and management* as well as *learner factors* are intertwined and not easily separated because one breeds and leads into another. The socio-economic background of the learners presents certain challenges and opportunities for the school and its management and how the school managements respond to these challenges, breeds certain types of school ethos and ecology which either reinforces or discourages certain behaviours from the

learners' backgrounds which in turn breeds certain types of learners. Secondly, the two prominent factors at the heart of the breakdown suggest that the results of this study concur with Rogan & Grayson's (2000) suggestion that teacher factors as well as school ecology and management factors could be the largest contributors to the school's capacity to support innovation. Thirdly, the results of the concept challenge suggest that most teachers across GET and FET were operating from a very shakey chemistry content knowledge with FET teachers achieving slightly above the GET.

Fourthly, besides the four factors, the results suggest two more factors which have a strong influence on the school's capacity to support innovation. The first factor which I refer to as *school collegiality* became apparent in the types of collegial issues which were raised by the acting deputy principal, and those which arose from the efforts of trying to integrate the new science teachers who joined the school later on. The second factor which I refer to as *external factors*, became strongly apparent but was somehow conflated with the *school management and ecology* factors. By external factors is meant factors that originate outside the school, such as policies, agencies, departments of education and the local community and either supportive or hindering the on-going processes within the school. Lerato's move, in the minor case to force her subordinates to be part of the programme against their wishes is an example of effects from external factors. Her coercion was clearly an outcome of external pressures which she herself faced as an HOD, during the meeting with the MEC where all HODs were expected to present their turn-around strategies of improving their matric results.

The results of the concept challenge partially address the research question 1.1 by revealing the chemistry conceptual challenges of the participating teachers and showing that FET teachers generally had stronger content knowledge than GET teachers. The results also show a link between qualification and performance where Colleen, who holds a qualification in pure sciences far outcompetes the rest of the teachers and the teachers in the major case study who were registered for their honours degree performed better than the other FET teachers.

CHAPTER 5
NATURE AND PROFILE OF SUPPORT AND THE DOMINANT CHANGE FORCE DRIVING LEARNING

5.1 Introduction

Although no longer in use, the South African Norms and Standards for Educators (DoE, 1998) called for reflective practitioners. Research on reflective practice (Roth, 2007; Schön, 1983) argues that teacher reflection should form a critical part of professional educator responsibility, as it provides an avenue for the teacher to consider the many factors which should inform the decision on how to act in particular and varied situations. Loughran, Berry, & Mulhall (2006) assert that for teachers, thinking about teaching is a complex task, and that it is important to promote ways of sharing teachers' professional knowledge of teaching, to further enhance understanding of teaching and learning in science.

In this chapter, I present an analysis of the intervention programmes of the minor and the major case studies. I used the Rogan & Grayson's *profile of outside support* construct (see appendix F) to critique and contrast the designs in the minor and major case studies through the intentions and actions underpinning the interventions. Part of the aim was to highlight the types of challenges experienced in the two processes and the types of strategies employed to mitigate the problems. The *profile of outside support* construct consists of five sub-constructs which are: *physical resources, design of professional development, direct support to learners, dominant change force evoked by agency* and *monitoring mechanism and accountability*. The construct of professional development design has two which are: *the underlying purpose or focus of professional development* and *the extent and duration of the support*.

In this study the Rogan and Grayson construct is modified to put focus on the nature and profile of the professional development intervention and the learning that happens as themes a result. All four of the sub-constructs with the exception of *direct support to learners*, are of relevance to this study. Within this study, the *nature and profile of support* is the main construct which serves to describe the nature of intentions and actions underlying the professional development programmes attached to the minor and major case studies.

The sections and discussions of this chapter are arranged according to these four modified sub-constructs. As discussed in chapter 3, the profile of outside support is directly linked to the stimulation and challenge domain of the LTtP model. This construct accounts for the type of *stimulation and challenge* that arises and forms one of the three *domains* of the LTtP model. In the section that follows I use figure 8 below to show how the LTtP model served to organise the activities of the intervention programmes of the minor and the major case studies.

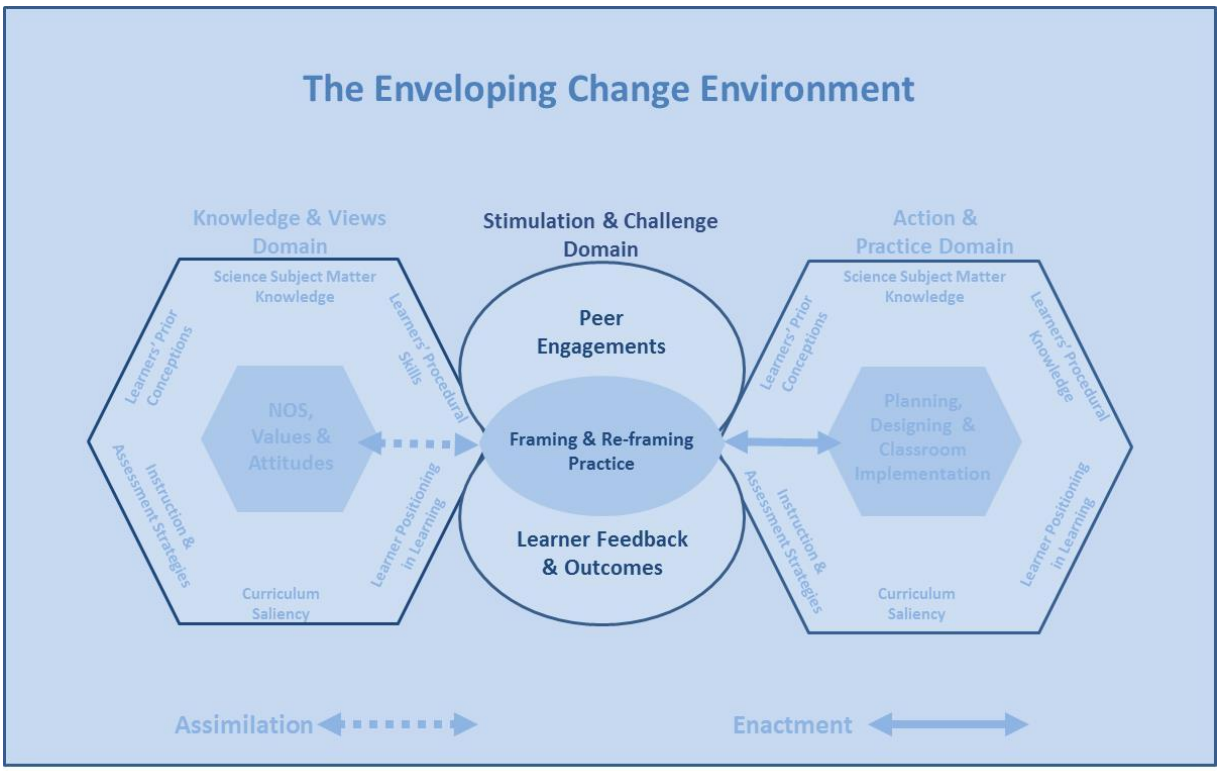


Figure 8: LTtP Chapter 5 Analytic Framework

As illustrated in figure 8, the Stimulation and Challenge Domain consists of two sub-domains: the *peer engagement* and *learner feedback and classroom outcomes*. What the model suggests is that the merging of these two sub-domains is what provides each teacher with the content for framing and re-framing, which crystallises into deep insights, which are, in turn, assimilated into teachers' repertoire of knowledge and views, as well as their practice in the classroom.

Feedback comes from learners in the form of performance, and the behaviour and classroom culture engendered as a result. The teachers also actively elicited feedback from the learners

about the process and how they experience it. Feedback also comes from personal impressions the teacher has about the experiences during the reflection process.

Outcomes are of two types, the product-based and the process-based outcomes. The product-based are the constructed CoRes, the lesson plans and the investigation tasks that come out of the process, and the process-based outcomes would be the procedural skills, classroom changes (culture), meta-cognitive skills gained etc.

At the intersection of these two sub-domains are the processes and activities, consisting of a series of presentation and reflection sessions. The latter systematically drew from accomplished research-based strategies, and feedback and outcomes from classroom implementation and peer engagement, to support and engage each teacher in a cycle of *framing and re-framing* their classroom practices, as well as in gaining deeper insights about themselves. The insights and sets of competences gained during these processes would, in turn, be assimilated into the knowledge and views domain, and consequently into the action and practice domain as soon as the opportunity arises.

5.2 Analysis through Nature and Profile of Support

Data that informed this chapter were drawn from the semi structured interviews and the planning and reflection sessions held with teachers. Even though the same instruments were used during the data collection phase for the two case studies, the process took very different courses because of the different nature of the two case studies. The *nature and profile of support* construct is described by four sub-constructs which capture the types of activities and processes that drove learning and change within the programmes. These are used to structure discussions in this chapter and are referred to as: *the purpose, design and extent of professional development*; *physical resources provisioning*; *monitoring and accounting for learning* as well as *collaborations and the dominant force driving learning*. The physical resource provision deals with resources made available by the professional development programme and differs from the resources and time constraints sub-construct of the enveloping change environment which were discussed in the previous chapter.

In the sections that follow, I discuss aspects of the minor and major case studies related to each of the four aspects. As discussed in detail in the next chapter, the activities of the minor case study were arrested by contextual issues leading to its premature halt which resulted in thin data related to the focus of this study.

5.2.1 Purpose, Design and Extent of Professional Development

This sub-construct is about the purpose, the design and the extent of the professional development intervention. The four levels range from Level 1 which could be a one-shot workshop in a form of presentation which is aimed at informing school-based personnel about new policy and the envisaged changes. Level 2 could involve a series of workshops lasting for a year geared at introducing curriculum aligned teaching and learning strategies to school-based personnel who are also given an opportunity to practise in simulated situations. A typical Level 3 would be a 2 to 3 year programme, initiated and designed by the school-based personnel with the aim of implementing new practices aligned with the curriculum by invoking outside support. A typical Level 4 which is the highest form would be an on-going long term, sustained school-based professional development where communities of practice have taken root and full responsibility for their own continued professional growth.

A. The Minor Case Study

The minor case study was conceptualised as a school-based action research programme, which aimed at promoting and supporting teachers to take an experiential approach to their practice through collaborative interactions. Considering the delicacy of this study, especially in seeking to reveal the conceptual understanding of teachers, video-taping their lessons, as well as demanding total commitment to the dynamic processes which it involved, there was need for rapport and complete trust to be established between the teachers and the researcher. Therefore sampling was purposeful with the researcher relying on teachers and schools known to the researcher and willing, as well as enthusiastic, to participate in the activities of the research process.

The team which was established consisted of ten science teachers in two schools, neighbouring high school and primary schools in a newly established formal settlement (RDP houses) 74 km South of Johannesburg. Lerato was once part of the ACE programme which I was coordinating at RADMASTE and was the science HOD at the high school. She was very keen on the suggested collaboration and opened the doors of her school and department to me. I then approached the neighbouring primary school to invite the science teachers to join the programme, so six of the participating teachers, including Lerato, were from the high school and four from the primary school.

Since the programme was aimed at entrenching a new culture of practice, inputs by the researcher had to be intensive, requiring a lot of dedication and commitment from the

participating teachers. This programme took off but was difficult to sustain and was aborted at the beginning of its second cycle. The core of this initiative was the building of a school-based community of practice. It was undermined by technical and contextual issues. The commitment by and participation level of the nine teachers in the programme varied greatly. Consequently, the research data which could be collected also varied.

In this case study, I assumed the role of a constructive intervener (an observer and a friend who could offer support for improving practice) during classroom observation. This enabled me to engage in interactive data collection, as well as to offer support if needed. The study was to be carried out in three main phases which are pre-testing, intervention and post-testing phases. Furthermore, the intervention phase was to happen in three cyclic stages employing participatory action research approaches referred to as action learning, collaborative inquiry and critical emancipatory at the different stages. `

The first cycle happened in the last term during the year 2006. It involved three science teachers working in the same high school. The three teachers who, for the sake of anonymity, will be referred to as Lerato, Mpho and Thabo, are well qualified, all holding at least a degree in education, and were teaching science or technology in grades 8, 9, 10, 11 and 12 at the time of the first cycle. They had all undergone departmental training on the implementation of the new curriculum, and there was evidence in their learning and teaching materials that they were making efforts to integrate the training into their teaching strategies. These three teachers remained enthusiastic and committed to the programme.

The findings from data generated during the first cycle informed both the development of the intervention programme, as well as the focus and implementation strategies for the second cycle. In the second cycle, five more science teachers, three new ones from the same high school (T4, T5, and T6) and two (T7 and T8) from the neighbouring primary school, were enlisted in the programme. T7 is the deputy principal and T8 was also part of the ACE programme I coordinated at RADMASTE. The baseline study was aimed at

- forming a picture of the school context, which then informed the planning process by offering insights of the teachers' personal practical knowledge as well as their challenges and gaps in their day to day teaching and learning efforts.
- gathering baseline data as a starting point for mapping teacher development and growth as they continue to participate in the programme.

- gaining insights and experiences to inform the development of a school-based action research framework, that integrates research and teacher development, and which would be used and continue to be modified throughout the study.
- establishing praxis through engagement in critical reflection about my facilitation role in exhibiting flexibility and adaptability during the AR process.
- gaining expertise in effectively keeping and maintaining a reflective journal throughout the process of monitoring aspects of the project and in collecting data as a tool to clarify my thoughts in terms of
    - critically analysing what is happening throughout the project,
    - constantly identifying the changing needs of individuals, as well as the whole group,
    - deliberating on how to interpret the data and report the findings of the study
    - constantly questioning and reflecting upon my changing roles throughout the process.

As indicated before, because of unforeseen contextual issues, the activities of this case study were interrupted, and therefore most data collected were baseline data, which were meant to establish where the teachers were at the beginning, so as to inform the development of a more relevant intervention programme.

The research process had two distinguishable cycles. The first cycle happened from the last term of 2006 up to January 2007. This involved three science teachers (Lerato, Mpho and Molefe) working in the Bojanala high school, and the introduction of the programme to the neighbouring middle primary schools. Pre-classroom observations and interviews in the primary school happened in January 2007. From the second week of February to the first week of April, I was on maternity leave and used that period to study the pre-data and put together an intervention programme.

The results from the *pre-testing, interview & (pre-lesson observations)* phase served to clarify the context and inform the planning process, by offering insights into where the teachers were and the challenges and gaps in their teaching and learning efforts. They also informed the starting point for mapping teacher development and growth, and even more important, informed the development of a school-based action research framework, that would integrate research and a responsive teacher development programme based on the

identified needs. The full programme is included in Appendix D. Below is the table which captures the critical events in the research process:

Table 10: Research Process of the Minor Case Study

Phase	Activities	Participants	Period
Cycle 1	Introduction, Pre- testing & Ethics clearance phase at the High school (4 days) Introduction, proposal and negotiations Pre-testing and pre-interviews with individual teachers Pre-classroom observations	Lerato, Mpho and Molefe	Sept – Nov 2006
	Classroom learning/teaching strategies workshop (2 hours) Exploring practical work with microscience equipment Exploring the three learning outcomes	Lerato, Mpho and Molefe	02 Oct 2006
	Introduction, Pre- testing & Ethics clearance phase at the middle primary school(2 days) Introduction, proposal and negotiations Pre-testing and pre-interviews with individual teachers Pre-classroom observations	Kagiso and Thama	October 2006 and 15th – 19th January 2007
	My maternity leave and Easter Break		9th Feb – 10th April
Cycle 2	Introduction, Pre-testing & Ethics clearance phase of the three new teachers at the High school (2 days) Introduction, proposal and negotiations Pre-testing and pre-interviews with individual teachers Pre-classroom observations	Elga, Salang, Malebo	April 17th (morning)
	Classroom learning/teaching strategies workshop (2 hours) Confronting own misconceptions Exploration of common learner misconceptions Exploration of useful teaching & learning strategies Exploring the three learning outcomes	Lerato, Elga, Salang, Malebo, Kagiso, Thama Lerato, Molefe, Elga, Malebo, Kagiso, Thama, Sello	17th April (afternoon) 19th April (afternoon)
	Classroom learning & Teaching strategies + Planning & Reflective Practice Exploration of useful teaching & learning strategies Exploring the three learning outcomes Exploration of experiential reflection Cycle Classroom reflective practice tools	Lerato, Molefe, Mpho and Elga	5th May (Saturday)
Cycle 3	Pre-reflection & Planning session (4 hours) Outline of the research agenda, processes and goals Consult & Agree on implementation schedule Exploration of Rogan & Grayson classroom implementation levels Teacher brief of lesson & its aims Viewing of video lessons. Discussions and feedback.	Lerato, Molefe, Mpho, Elga, Malebo, Thama	21st May

Phase	Activities	Participants	Period
	General National Strike		June – 1st September 2007

The pre-testing, interviews and lesson observations took place over a period of four days, to try and establish where the teachers were at, in terms of conceptual understanding of the topic, their learning and teaching planning/reflection strategies and the management of learning and teaching in their classrooms. As part of the study, the teachers also participated in a two hour reflection session, as well as four hour in-service training session. Two of the teachers were then observed twice in their classrooms, dealing with some aspect of the *chemical change* theme.

B. The Major Case Study

This case study involved four teachers who undertook self-studies on learning and teaching *chemical systems* in their FET classrooms as research projects towards their BSc honours degree. Self-studies as a research strategy have the following special nature and methodological requirements which make it a powerful pedagogical training strategy. Self-studies have to

- be situated and self-initiated, because they have to focus on self and its development.
- take place within interactive and collaborative set-ups,
- employ multiple qualitative methods because they require continuous monitoring and justification of pedagogical strategies used in one's practices

As mentioned in chapter 3, honours projects are aimed at offering students basic research skills with the support of a supervisor, to plan, carry out and write up a small research project in an area of their specialisation within a period of six months. The programme involved 14 weekly three hour sessions with supervisors, with six of these sessions starting with a plenary session on a topical aspect of research in line with the stage of research the students were scheduled to embark on at that particular time. The six month schedule is included in Appendix C. Within this programme, students had a choice of five topics. The four teachers chose the one which is investigated in this PhD study and was entitled: *Building a Community of Practice around the Teaching of Chemical Systems in FET classrooms – Personal Journeys.* Copy of the brief is included in Appendix D.

The projects were conceptualised within the framework of this PhD study, to explore the types of resource systems that are useful to support FET teachers as they grapple with the challenges of implementing a new topic in their classroom. *Chemical Systems* was a new topic in the curriculum and therefore unfamiliar to many teachers. The project drew from research based strategies and relevant teaching and learning resources to support the teachers in their endeavours of addressing a new topic. The project included the following activities:

- Identify and refine problem statement through a reflective collaborative process
- Study provided materials and develop CoRes
- Explore effective science teaching strategies
- Adapt or develop a series of lesson plans addressing at least two of the science learning outcomes 1, 2 and 3
- Present to collaborative team and get feedback
- Use feedback to refine the CoRes, other curriculum materials developed or strategies and approaches adopted
- Implement the lessons in the classroom

Right from the beginning, the process was intense, following a very tight schedule which involved 15 weekly three hour sessions with 6 of these starting with a 30 minutes plenary session on the key research process. The students were expected to complete and present tasks towards their projects at all the sessions, except for the first session. The CoRe was used in this case study to capture, portray and monitor changes in the PCK of the participating teachers, as well as a training tool for reflective practice, while the PaPeRs offered a window into that PCK in action.

5.2.2 Physical Resource Provision

Level 1 of the Rogan framework includes supplementing what already exists but still not sufficient to cover and support the intended changes. At level 2, provision draws from what already exists and is partly sufficient to cover the most critical aspect required to effect change. At level 3, provision draws from what already exists and is fully sufficient to cover all the most critical aspect required to effect change. At level 4, provision is driven by the

intended change and responds to draw from the existing and outside resources to cover fully and sufficiently all the requirements for full effect of the intended change.

A. Resource Provision for the Minor Case Study

Since this was a school-based programme, one other challenge which emerged for the facilitation role was around resources for both data collection and teacher development. During the first cycle, micro-science equipment which was supposed to have been delivered as part of the NBI-RADMASTE program had not reached the school. I followed up on this to make sure that the school received the equipment. Plans were already under way from RADMASTE to send the equipment to the schools, as well as to train the teachers. Lerato had already attended training on how to use the equipment. In the neighbouring primary school, the science teacher who was part of the ACE programme, had passed away, so the primary school was about to forfeit receipt of its micro-science equipment because nobody reported why she did not turn up for training. I had to intervene to ensure that the school received the equipment.

Each teacher was also provided with a file of Matter and Materials coursework which we use in our GET ACE programme. The following are the topics covered in the module: Matter and its States; Mixtures and pure substances; Exploring Chemical Change; The Acids and Bases in our Lives

Another challenge was in securing a private space to hold workshops and interview sessions. There were not enough rooms, and all science teachers, including the HOD, shared the one science laboratory. It was a very awkward situation because there was literally no privacy. There was endless interference from learners, parents and other colleagues who were sharing the same room, and it was just not working because my time spent at the school was of the essence. This was resolved by looking for a venue outside the school premises for running workshops. A teacher centre, which was located right next to the school, was more than willing to host us.

B. Resource Provision in the Major Study

The researcher approached Heinemann Publishers to supply the research team with copies of the RADMASTE Heinemann Grades 10, 11 and 12 textbooks series (Bradley, et al., 2005; Bradley, Lycoudi, Ovens, & Stanton, 2006), as well as to lift the copyright clause and grant the team permission to use and draw from the chemical change and chemical systems section

in the textbook for preparation of their teaching materials as they saw fit. So for the duration of the project, the team was at liberty to copy any part of these two sections, and use it in the development of the curriculum materials.

All the teachers received copies of the books relevant to the grade they were teaching, as well as photocopies of the sections in the other two grades, to familiarise themselves with what others were doing, and be in a position to give constructive feedback during presentation and reflective sessions. The teachers also themselves brought different resources, which turned out to be useful, or brought copies which were then copied and made available to others.

All the four teachers were sponsored fully to attend and participate at the national science teachers' conference which took place in Johannesburg in 2008 and Noma and Colleen were also further sponsored to attend and share their work at a continental science teacher conference which took place in 2009 at Rhodes University in Grahamstown.

As indicated above, in both minor and major case studies, material and resource provisioning was done on a needs basis to meet the requirements of the programmes. This puts the two intervention modes on this aspect at level 4 of the Rogan and Grayson's categories.

5.2.3 Monitoring and Accounting for Learning

At level 1 of the Rogan framework, monitoring and accountability is done exclusively through inspection by authorities. At level 2, this is done by the authorities in collaboration with the teachers themselves. At level 3, monitoring and accountability has as its aim engaging teachers at the individual and collective level in processes aimed at developing an experiential outlook to their practices through monitoring of their own learning and growth using powerful research-based metacognitive tools and thereby taking full ownership of their own learning. Level 4 was modified to reflect self-monitoring by individual teachers involved in collaboration with their peers (within a community of practice). At level 4 monitoring meets all the level 3 criteria as well as engaging teachers in formal research where their findings in the form of insights and learning are formalised by opening their processes for public scrutiny and peer engagements within community of practice

A. Accounting in the Minor Case study

Due to unforeseen contextual issues which were discussed fully in the previous chapter, the activities of the minor case study were interrupted and therefore the data of this case study,

on these aspects which formed the core interest of this study, were very thin, compared to that of the major case study. The minor case study is rich in contextual issues which just emerged and brought the project to a halt, and not much of a process on aspects of teacher shifting knowledge and practice could be discerned from the data. As was already mentioned in the earlier section, the teachers engaged with the process to differing degrees, and the one teacher who took the process a bit further before it stopped, was Lerato. Therefore, data which inform the *framing and re-framing* domain for the minor case study is derived mainly around Lerato's experiences of the process.

The strategy was to use the pre-lesson session as the starting point, to help each teacher to identify and set out their own problem statement and the area they wanted to focus on and improve through a framing and reframing process. The whole aim of this exercise was not only to help the teachers to develop an experiential outlook on their practice, but also to deepen the types of exchanges that happen between the teachers, to foster a critical eye, and assist them to develop a language for representing the subtleties of their practice. Part of the strategy to achieve this was to expose the teachers to various powerful meta-cognitive tools for analysing classroom episodes, as well as to experiment with these during reflection sessions, with the hope that they would develop a critical eye towards their practice.

Since all the teachers, except for Lerato, were observed only once, with the aim of deriving content for the initial reflection sessions and practising on how to use the lesson analysis tools, the formal analysis of these lessons is not included in this thesis. The idea was to view each teacher's classroom data, but before doing that, to have the teacher expressing himself or herself by giving an outline of what he or she set out to achieve in that lesson, and giving his or her impressions of how he or she thought the lesson went, and where he or she felt she needed to improve. The reflection session was held with Lerato and four of her science colleagues also teaching senior and FET classes. The aim of the session was to develop more effective and meaningful approaches to judging ideas about teaching and learning, based on shared experiences during the classroom implementation phase.

Lerato was the most confident, brave and open to new learning and constructive criticism, as she offered to be the first point of focus. We started the process by viewing and reflecting on a video of her lesson, using levels of progression designed by Rogan & Grayson (2003). Lerato trusted the process and was actually very impressive, displaying an exceptionally mature attitude, to be able to open herself up to her subordinates in the ways that she did.

This went a long way to help set the scene and demonstrate to her subordinates that the process was not about judging each other, but was about learning to develop tools to communicate important intellectual aspects of teaching, as well as to engage in constructive exchanges about the learning and teaching process.

Good and effective teaching in a specific learning area is a very abstract process, yet those, who have never taught, may underestimate this task, and fail to appreciate its dynamic and abstract nature until they themselves are faced with the challenge and the responsibility of doing it. The lack of appreciation of this intellectually demanding task is what leads to ineffective methods being employed by many teachers in their classrooms.

Since the whole idea of the reflection sessions in this case study was to develop teachers' abilities to recognise and be able to judge effective and good practice, rather than destructive criticism of each others' teaching efforts, Rogan and Grayson's levels of progression were used without allocating any levels. These were used by the teachers to place the lesson and offer constructive feedback on Lerato's lesson.

After receiving positive feedback on the strengths of her lesson, more constructive feedback was given. It was interesting that all participants, including Lerato herself, placed her lesson at the lowest level of the profile of implementation in most aspects, but even lower in terms of learner participation. A valuable comment:

> *You know mam your lesson is good but the problem is that you try to do everything in one lesson. Try to focus on only a few concepts and build on them so that learners can understand. You go too broad within one lesson and this can confuse learners.* (Molefe – comment)

This comment above by Molefe raises a critical observation which points to both his and Lerato's curriculum saliency (12).

> *Another thing is your learners were not active. During the whole lesson your learners never commented or asked any questions. They only answered the questions you asked them. It [is] like they were not free.* (Mpho – comment)

> *Yes, think of ways you can use to try to engage your learners more so that they become active participants in their own learning. One important way you can use to improve engagements and interactions in your lessons is through the types of questions you ask. Just check the types of questions you asked. They were all low ordered requiring learners to respond with one word. To get discussions going during your lessons, try to integrate more higher order questions when engaging your learners so that they are not required to give one word as a response. You have to think about these questions carefully as you plan your lesson. Another strategy to get discussions going is to frame your inputs on learner's everyday context. Link the science concepts to what is familiar to them in their daily experiences and ask them to share their experiences of the phenomena under discussion.* (researcher)

Unlike the other teachers, Lerato was observed four times. These two issues stood out as her main challenge, and it would have made sense for her to focus on one of these at a time. Leou, Abder, Riordan, & Zoller (2006) argue that, even though many educators consider

their questions to students to be one of their most powerful teaching tools, research suggests that most classroom practice involves lower-order cognitive skills (LOCS), such as memorisation, recall and application of algorithms to familiar situations rather than encouraging inquiry and problem solving.

These are comments which Lerato herself made, later on during an interview on her views about learners and learning. It illustrates seeds of starting the framing and re-framing (8) of her practice.

> *And the other times before when I was conducting my classroom lessons, I only gave learners knowledge about learning outcomes etc. etc. I did not allow learners to ask questions. Learner participation was very limited. But due to this programme I discovered during reflections that learners must also be encouraged to ask questions. Teachers are not the only ones who should ask questions. And another thing is that we must avoid asking factual questions only. We must also ask learners higher order questions. This is what I have been implementing in my classroom.* (Lerato Post lesson –int)

B. Accounting for Learning in the Major Case-study

This study focused on how PCK of the participating teachers changed as they carried out self-studies, towards their BEd honours qualification, under the supervision of the author. The study involved mapping the participating teachers' changing perceptions and their PCK as they actively engaged with strategies to systematise the planning, designing, classroom implementation and peer engagement processes of curriculum aligned lessons. The studies were complex and very demanding for the teachers because of their two-pronged agenda. Two parallel processes of support were factored in, with one focusing on development of research and writing skills and the other on the development of PCK in teaching a new topic.

Self-study as a research design should employ interactive methods which are responsive to what we teach and capture the complexity of what we do. It is personal in that it is about the self in the journey of development, therefore it has to be formalised by making its processes open and available for public scrutiny. Validation is acquired through systematic processes of construction, testing, sharing and re-testing.

In this case study, the process involved engagement with peers, which was a forum that served not only to offer support and critical inputs, but also to validate their findings as part of the requirement of carrying out a self-study. *Peer engagements* did not only involve activities within research group sessions but the teachers also presented their work at a local teacher's workshop, with Noma and Colleen also taking their work to a National Teachers' conference (SAASTE 2008 Bi-annual Conference) and a regional conference (SAARMSTE, 2009).

The CoRe was used in this study to capture, portray and monitor changes in PCK of the participating teachers and as a training tool for reflective practice, while the PaPeRs offered a window into that PCK in action. The four teachers engaged in the process of planning and reflection in preparation for teaching the topic. They developed high quality curriculum-based tasks which ensured creation of rich learning environments for learners. As part of their preparations and planning they constructed the pre-CoRes which were consolidated at strategic stages as the process unfolded. The modified versions were referred to as post-CoRes.

In this case study, I did not do the classroom observation personally. Each teacher developed their own lesson plans through a collaborative effort, implemented them in their classrooms and arranged for video recording of those sessions on their own, as part of their Honours projects. These video records were shared with me for subsequent analysis in this study. The four teachers formed a collaborative team and met every week over seven weeks for 3 hour sessions. The first meeting was on the 5th February 2008. Through this process, these teachers used research-based strategies to generate high quality lesson plans and associated resources, which could be shared with other teachers. The teachers also presented their work at teacher workshops, and local and national conferences.

5.2.4 Collaborations and the Dominant Force Driving Learning

Like all other constructs, the levels range from level 1 to level 4 with driving force at level 1 using a *bureaucratic* style where change is driven by top-down directives. Level 2 style is referred to as *charismatic* where change is still driven from top to bottom but this time through inspiration and encouragement rather than demands. The third is a professional style where change is brought about through appeals to the moral conscience to adhere to professional codes of conduct and standards for teaching and learning. The fourth which is the highest level is driven by the concept of learning communities which involves development of communities of practice with shared values and goals regarding the standards of learning teaching as well as individual and collective commitment to put them into practice.

A. Learning Driving Force in the Minor Case-Study

The context of what is discussed under this section was addressed in details in the previous chapter. This is because in this case study, there is a lot of overlap between this sub-construct and the school ecology and management which is discussed in the next chapter.

The claim below by the acting deputy principal captures the complexities of the dynamics at play as well as the spirit that prevailed in the school which could pose threat to efforts of forging collaboration amongst teachers.

> *The HODs they were not working like a collective, 'wa bona' (Tswana for you see)?' Ehhh, we have HODs who were skilled, who were empowered, who attended courses often. But they were unable to come back to school and say look this is what I have learned so that we move forward together, it was like an individual achievement and I don't know whether it was out of selfishness but I picked it up that there were programmes which were by the department of education and training that people went for and they achieved and were empowered but they came back and only implemented in their departments. That's why I say it was all selfishness.* (Acting DP-int)

Constructive collaborations and a spirit of collegiality amongst the team members were critical in ensuring sustainability of the programme. One other aspect which emerged as a dilemma concerned the issues of handling and reporting on privileged information divulged or observed on incompetence, irresponsible acts, insights into professional jealousy, sabotage and back stabbing. While I understood the gravity of such acts in undermining a collaborative spirit, I really did not know what to do with such information, other than to put a positive spin on all discussions. I later realised that I should preferably have used it strategically in forums, to try to highlight how it undermines collaboration. In one of our meetings, I used this information to encourage and foster group cohesion by actively guiding the group from an informed position.

> *People, you need to try to work together, there is no other better place out there where you can run to. Places of productivity and progress are cultivated and created and it would be a very fulfilling thing for each one of you if you can achieve it amongst yourselves. You can decide to work together and support each other and make your school a best place you want it to be for all of you, or you can decide to work against each other and make this place an unbearable place for all of you. The choice is yours and the power lies within each one of you. As an outsider I see so much potential between and within each one of you and only you can decide to nurture and exploit it for your own good and progress, or you can decide to undermine it with your in-fights.* (R comment – reflect session 1)

The level of motivation and collegial relations between Lerato, Mpho and Molefe was great. They together with Elga participated enthusiastically and were even willing to come in on Saturdays, when we worked on the different micro-science experiments and different strategies of addressing the three learning outcomes in the classroom.

Another issue was the demand, in terms of time and effort, the programme placed on the teachers. The extensive engagement which the programme demanded, posed the challenge of ensuring the teachers' commitment, passion and sustained interest. It became clear that the continuity of the programme would depend on my capacity to sustain the teachers' interest throughout the process, and that the flexibility and adaptability in carrying through the interests of each and every individual was critical. The strategy which was employed was to ensure that the process was rewarding, as well as responsive to the teachers' day to day learning and teaching issues. Throughout the process and especially during reflection meetings, I strove to create a learning environment where all participants were comfortable enough to express their ideas, were receptive to critical feedback, motivated to stay on track and committed to offering constructive feedback to others. This was achieved by being vigilant and taking every opportunity to highlight the unique strengths each individual possesses and encouraging them to make their contributions.

An outburst from Lerato during one of the reflection meetings:

You know, people are not cooperative here and I think I am going to leave this place. Rorisang (pseudonym) was a much better school and when I was still there people were much more serious and appreciated the help they got from programmes like this one. I am very frustrated here and I am going to leave this place for another job somewhere. (Lerato reflect_session)

One of the central aims of the programme was to promote teacher autonomy and emancipation where teachers collaborate with each other to take ownership of their own learning. Therefore easy and typical power strategies (e.g. prescription, mandatory or coercive) went against the spirit of the programme, as well as Wits ethics requirements (learning community change). This became a challenge when the school decided to adopt the programme as their turnaround strategy, because Lerato (T1) kept on insisting that the new teachers should become part of the programme whether they liked it or not (bureaucratic). Besides these challenges, there was also tension between the Wits ethics principles agreed to for this study, and the realities on the ground. My dilemma was how to handle issues of coercion from the school senior management, aimed at forcing the teachers to participate in the programme while, at the same time, honouring the ethical requirement of ensuring that all participants should participate voluntarily, and could withdraw from the process any time they wished. I kept on insisting that all teachers should participate voluntarily from an informed position without feeling compelled to take part.

Anybody who is in my department will have to be part of this programme. When the MEC visited our school to get our plans on a strategy of turn around, I presented this programme as a strategy. So as long as you are part

of my department you have no choice, whether you like or not you have to be part of this programme. The principal also knows. (Lerato reflection session)

Lerato was under great pressure and at that stage I did not understand where she was coming from. It was only after I had an interview with the acting deputy principal which is discussed fully in the next chapter, that I understood the troubled nature of the school I was trying to service. As discussed fully in the next chapter, this also explains how the ground shifted between the first cycle and the second, and led to yet another challenge I had to face, that of the fluidity of staff and the necessity of integrating new teachers into the programme at a late stage. As discussed fully in the next chapter, this attitude of compulsory participation, the four new teachers were not enthused about the programme, and they ultimately withdrew.

B. Learning Driving Force in the Major Case-study

Given the nature of self-studies, the project was a collaborative effort with the four teachers and myself as the supervisor and the researcher, forming a collaborative team. Noma, Sipho and Bongani worked together more closely during the development of curriculum materials. Noma and Sipho focused on the grade 10 water cycle and even though Sipho's attendance was erratic and he ultimately dropped from the programme, his participation when he could make it were substantial. Bongani focused on grade 11 chemical systems and Noma and Sipho also collaborated with Bongani in the development of the grade 11 CoRe which had a focus on atmospheric chemistry. Colleen also participated in the collaborative process and received feedback from the team, but she worked independently to develop her CoRe and other curriculum materials.

At the beginning of the programme, we hit what was initially perceived as a logistical problem in terms of when the Chemical Systems theme had to be phased in according to the plans proposed by the department and adopted by all schools. In the case of Colleen, consultation on this issue as discussed fully in the next chapter, revealed how her strategic knowledge related to curricular saliency.

At one level, registration into a formalised programme of higher learning means special kinds of pressure and force are driven by the participants' intrinsic motivation. It meant that in the first place, the participants, out of their own intrinsic motivation were moved to pursue a higher education qualification. To this end their commitment went beyond just participation in the programme because they were willing to align their lives, set aside financial resources and time to acquire the qualification.

At another level, the extent of participation and the quality and time the participants were willing to put into the programme said something about the types of forces that moved them. As evidenced in chapter 6, the teachers in this case study were driven and worked very much on their own as individuals and also collaborated very well with each other, sharing resources as well as contributing their ideas to enhance each other's work. The spirit of collaboration and cohesion was great and closer analysis of their deliberations as done in chapter 6 reveals high quality knowledge driven exchanges and interactions.

Analysis of the forces at play reveals several sources of pressure to heighten the teachers' commitment to learn. First of all from the exchanges the teachers engaged with during their sessions one can discern that their arguments were constructive and knowledge driven. They were driven to participate because they were eager to learn. Another force which was evident in Colleen's case was the conscience and eagerness to align her efforts in response to the DoE requirements. Commitment to the group as well as the individual's commitment towards achieving their qualification seemed to be at the core of what drove the teachers.

5.3 Discussions

In terms of design and purpose both the minor and major case study professional programmes could be rated at level 4 of Rogan and Grayson's construct. Both programmes were designed with an overall aim of supporting evolution of participating teachers' PCK, by drawing from powerful research-based strategies and available learning and teaching resources. Part of the aim was to stimulate the teachers to take an experiential outlook to their practice by systematising their learning and teaching efforts, while at the same time deepening their understanding of specific science concepts, within the framework of the new curriculum.

While both case studies targeted the classroom and the teacher's practice as a focus for learning, the difference, which led to distinct pressures and modes of accountability, was that the minor case study was an informal school based programme, while the major case study was a formal university based programme leading to a formal qualification. As this was discussed in the last chapter, the working contexts of the three teachers in the major case study with the exception of Colleen closely resembled the working contexts in the minor case study. What is then apparent is that the stability and commitment which enabled the teachers in the major case study to achieve such laudable goals was due to their working towards a formal qualification.

Within an informal set-up, there are flexibilities and unpredictable interferences which need to be managed carefully in the interest of sustainability of the programme. Amongst all other challenges the minor case study faced as discussed fully in the previous chapter, I believe that the main one was when we tried to integrate new teachers at a late stage into the programme. During the first cycle, good rapport was firmly established with Lerato, Mpho and Molefe, and was still taking root when incorporating and forging collaborations with the two teachers Kagiso (T7) and Thama (T8) from the neighbouring primary school. At that stage of the programme the change force was more *professional* and *learning community* driven which are levels 3 and 4 of Rogan and Grayson's construct.

To some degree, Lerato's insistence on making the programme compulsory which categorises the strategy as *bureaucratic*, stifled its collaborative and autonomous spirit. Even though it could be seen as a desirable move towards formalising the programme, there was clearly need for a different approach in handling this. A more of a *charismatic* approach where teachers are inspired and encouraged to embrace the plans to bring about change rather than a *bureaucratic* approach would work better.

Rogan and Grayson (2003) in one of their six propositions argue that all critical role players in a programme, should be granted the opportunity to establish their own understanding of the vision of the programme as well as reconceptualising the envisaged changes in their own terms within the limits of their own context. It could also be argued that Lerato herself as an HOD, was pressurised by the demand from the MEC to come up with a turnaround strategy to adopt the programme. The change force in that case would partly also be bureaucratic in nature.

The type of professional development strategy this study aimed at is in line with professional learning communities (PLC) and Cochran-Smith & Lytle (1999) in the quote below captures the essence:

> *It is assumed that the knowledge teachers need to teach well is generated when teachers treat their own classrooms and schools as sites for intentional investigation at the same time that they treat the knowledge and theory produced by others as generative material for interrogation and interpretation''* (p. 272)

In this study, the Rogan and Grayson's professional development construct is modified extensively because its descriptions are too generic and focus mainly on the duration rather than the nature of the programme. Another limitation is that professional development should have focus on teacher learning yet the Rogan and Grayson descriptions on this construct do not capture that. Borko (2004) proposes that, for us to be able to understand teacher learning,

we must consider it within its multiple contexts that put sharper focus and account for both, the individual teacher, learners and the social systems in which they are participants. She argues for simultaneous use of the individual as well as group as units of analysis within professional teacher development programmes. Drawing from these perspectives I identified and modified the Rogan & Grayson's professional development construct into the following three sub-constructs which capture the teacher's learning, the nature of their participation and experiences as well as the contexts in which they operate within the professional development programmes: the *individual teacher* to put focus on each teacher's individual learning, the *community of practice* to capture their learning through collaboration within a social system and the *prevailing institutions* to capture the context in which their practice prevails.

5.4 Conclusions

The intensity and magnitude in terms of time, insights gained as well as learning accrued in the two case studies are of different scales and therefore incomparable. Carrying out self-studies as well as tracing development of one's PCK through a meta-cognitive tool such as a CoRe, is a very demanding as well as intellectually taxing exercise. From a comparison of the two case studies, it is clear that stability and commitment in the major case study were guaranteed mainly because the participating teachers were enrolled in a formal programme, working towards a qualification.

As already alluded, three of the teachers in the major case study were working in school contexts which were as dysfunctional as the high school in the minor case study. This is clear because irrespective of their working contexts, the teachers' uptake and productivity were quite substantial, compared to the teachers in the minor case study. They struggled, but managed to keep a balance between their work and the demands of their studies. The findings in this chapter concur with Rogan & Grayson's (2003) argument, that professional development needs in schools should be institutionalized and approached in a systematic way or otherwise it becomes a futile exercise.

CHAPTER 6

PLANNED ACTIONS, REFLECTIVE PRACTICE AND THE SHIFTING KNOWLEDGE BASE

6.1 Introduction

The literature shows that the role of on-going teacher reflection in the development of the teachers' knowledge base for teaching is central to meeting the demands of a curriculum as complex as South Africa's. In this chapter, I report on the findings of the main case study, which involved four teachers who undertook self-studies as part of their honours projects. This chapter focuses mainly on analysis of data from the CoRe and the processes of its construction. Figure 9 below serves as a framework for this study and, for easy reference, all the different aspects of the model are allocated numbers and those aspects of focus and discussions in this chapter are highlighted.

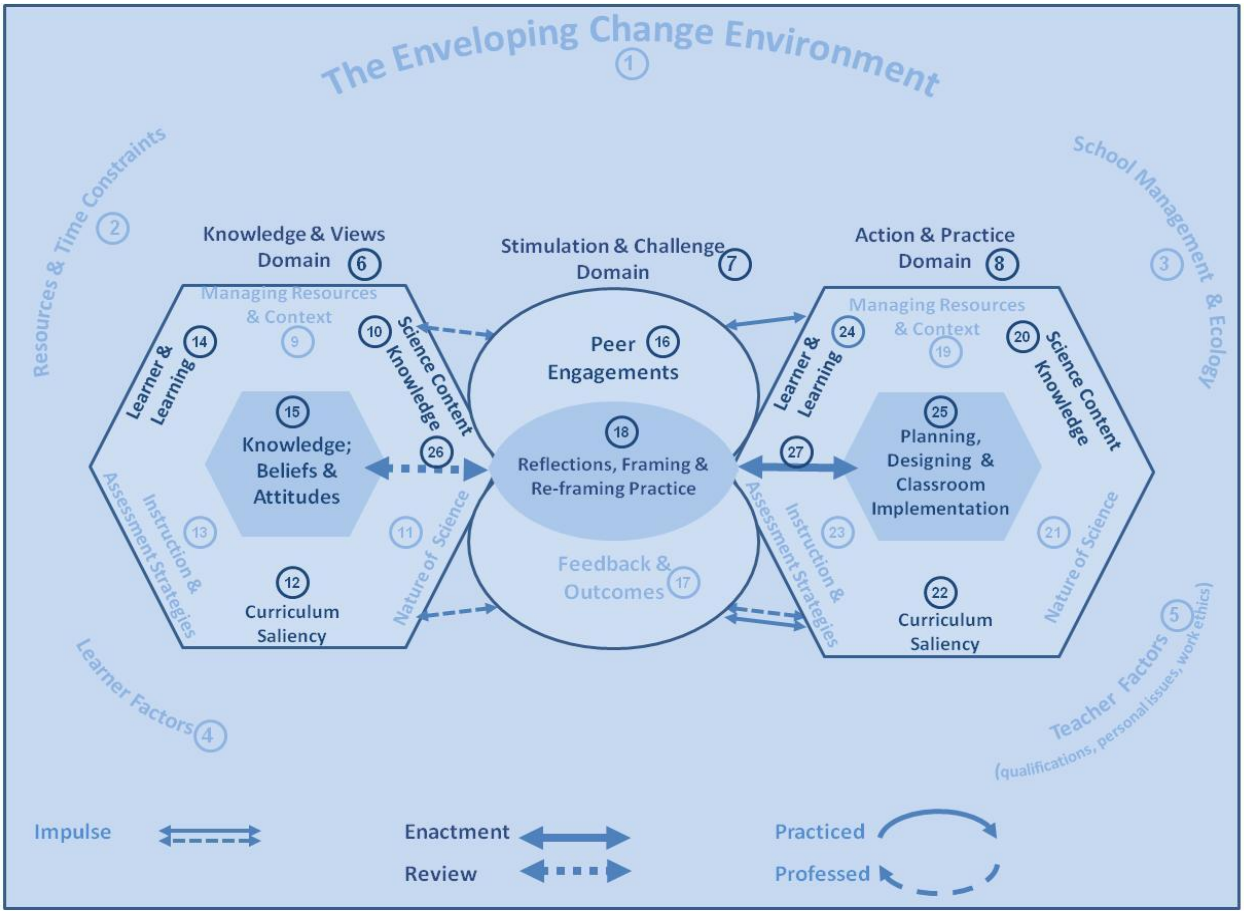


Figure 9: LTtP Chapter 6 Analytic Framework

This chapter traces how the knowledge base of each participating teacher shifted by focusing on selected aspects of the three domains (6, 7, 8) that encompass each teacher's professional world.

Two of these domains, the knowledge and views (6) and the action and practice (8), respectively represent the teachers' internal and external milieus. Profound shifts in each teacher's knowledge base on three aspects of their PCK highlighted in bold in 6 (10, 12, 14) and in 8 (20, 22, 24) in figure 9 are located at the centre of the *challenge, synthesis and enculturation domain* (7), which represents the intra- and inter-psychological planes. This helps to trace how these aspects are shifting, as they engage with the process of systematic and deliberate planning, designing and reflecting on their actions within the constraints of their working contexts.

According to LTtP model (fig 9), engagement of the participating teachers in framing and re-framing their practice (18) resulted in a shift in knowledge base at the planning and designing stage. This enabled them to review and add to their existing knowledge base, as well as engaging in reasoned action in producing the plans for their classroom teaching (right hand hexagon). This chapter addresses the following related research questions:

1) What knowledge base do the participating science FET teachers have about the new curriculum and the topic of chemical change, chemical system?
2) How is their knowledge base for teaching science shifting, as they plan, design, teach and reflect on their practice?
3) How are their meta-cognitive capacities evolving, as they plan, design, teach and reflect on their practice?

This study aims to explore the insights that come about from the use of reflective practice and meta-cognitive tools as strategies of enhancing the teachers' practice at multiple levels. Thus, a wide variety of qualitative data sources, such as mind maps, classroom videotaped lessons, journals, and Content Representations (CoRes) were used. Data which inform this chapter are drawn from analysis of pre- and post-CoRes, the concept maps, reflective journals, the curriculum materials developed or modified, the audio-taped research group sessions, as well as from the teachers' honours project research reports.

One can appreciate the importance of meta-cognition to empower people to be able to predict their own performance in various tasks. There is a shift of focus in science of learning developments to rather help people to take control of their own learning in order for them to

be able to recognise what leads to their own understanding and the type of assistance they need to facilitate their own understanding. Meta-cognitive approaches to learning give focus to sense making, self-assessment and reflection on what worked and what needs improvement (Bransford et al., 2000). This chapter focuses on the analysis of the pre and post CoRes produced by the four teachers and the inputs they made in the honours project mentoring sessions, to depict how their content knowledge and meta-cognitive skills for teaching chemical systems developed.

Each teacher's journey is profiled on each of the two domains of the framework (fig 9), i.e. the views and knowledge domain (6) and the action and practice domain (8), to see how the processes of review (26) and enactment (27) mediate shift in their science content knowledge (10, 20), their knowledge of their learners and learning (14, 24), as well as their curriculum saliency (12, 22) is shifting, as portrayed in the plans and the designs (25) they produce for teaching. In this chapter, the consideration of learners and learning (14, 24) only focuses on the teachers' knowledge of their learners' conceptions. The generic elements of learners and learning are picked up in the next chapter. Formulation of each teacher's individual profile varies significantly not only because it is drawn from a variety of data sources for each teacher, but also because of their unique responses to the process, as well as their unique experiences in their involvement with continuous enactment and reflections during the process.

The findings discussed in this chapter are based on analysis of the pre- and post CoRes and PaPeRs produced by these teachers, their CoRe presentations during the honours research team session, the curriculum materials they produced, as well as the research report they produced for their honours projects, to depict how their content knowledge for teaching chemical systems developed throughout the process.

In the second section, I start by considering and profiling the three teachers and then move on to profile the fourth teacher, according to the highlighted themes of the model.

6.2 Peer Engagements and the Three Teachers' Collective Learning

The teachers' CoRes were analysed to get further information about the teachers' subject matter knowledge base for teaching that particular topic. This involved using three of the six aspects provided by the conceptual framework (highlighted in fig 9): science content knowledge (10), learners and learning (14) and curricular saliency (12). The teacher's pre-

CoRe was used to map their starting points and the preceding CoRes provided evidence on how the teachers' PCK on these four aspects developed as they engaged with the process.

The four teachers and their supervisor formed a collaborative team, but for reasons which will become evident later, three of the teachers collaborated to a greater extent while one of the teachers worked pretty much on her own. The teachers engaged in the process of planning and reflection in preparation for teaching the topic. They developed high quality curriculum-based tasks which ensured creation of rich learning environments for the learners. As part of their preparations and planning, they constructed the pre-CoRe, which was further consolidated at strategic stages as the process unfolded. The CoRe was used in this study to capture, portray and monitor changes in the participating teachers' PCK as well as a training tool for reflective practice. Typical data of teachers' initial knowledge in teaching the topic was collected through construction of a CoRe which was consolidated at different stages of the process to capture each teacher's growing content knowledge.

The construction of the CoRe is an intellectually taxing process which depends on the teachers' deep knowledge of the topic. It begins with the process of dissecting the topic into big ideas, which requires deep knowledge, but may be perceived as just dividing the topic into sub-topics. Big ideas are those ideas that hold the topic together, and have a profound impact on how scientists view and conceptualise the world. From a pedagogical perspective, big ideas can be explained as ideas that deal with the relationship between some class of *natural phenomena* and the *explanatory model* that helps us understand why that class of phenomena unfolds the way it does. Hence, for pedagogical purposes, big ideas would be regarded as underpinning and crucial to the understanding of any topic. At the pedagogical level, their abstraction is a crucial, highly intellectual and difficult task, without which the whole topic falls apart.

Noma and Sipho were both teaching grade 10 and therefore focused on the water cycle in grade 10, while also collaborating with Bongani who was addressing chemical systems at grade 11, with a specific focus on atmospheric chemistry. Both Sipho and Noma made extensive inputs to Bogani's work. Actually, the preparation of the grade 11 CoRe on atmospheric chemistry was a collaborative effort of these three teachers.

Even though Colleen participated in the collaborative process, and did receive feedback and inputs from other team members, the production of all her CoRes was not a collaborative effort. She went away during school holidays and worked alone on her preparation. As will

be discussed later, Colleen focused on the whole of grade 12 chemical systems, which includes four case studies of chemical industries: Sasol, which deals with organic chemistry concepts fuels, monomers and polymers and polymerisation; the chloroalkali industry, which deals with concepts, such as saponification; the fertilizer industry, which deals with N, P, K macronutrients and synthesis processes used in industry; and the fourth case study, which deals with electrochemical cells. Before the April school break, Noma and Colleen attended almost all sessions, while Sipho and Bongani missed quite a number of them.

6.2.1 Preparation of Atmospheric Chemistry CoRe

Before coming up with the post-CoRe, each teacher received the Heinnemann chapter on Atmospheric Chemistry to study individually. The process of constructing the CoRe started with Bongani and me only, because Noma and Sipho were absent. This was the session where the big ideas were identified. They were: *The structure and composition of the atmosphere*; *The chemistry of the atmosphere and its role in nature* and *Human impact on the atmosphere*. Bongani's contribution was minimal; he did not contribute anything constructive. This was very frustrating, so I asked him to go and study the topic from the resources which were provided and prepare a presentation for the collaborative team, both for his own preparation, as well as to bring everybody on board about the topic before we proceeded to develop the CoRe.

In the next session, only Bongani and Noma could make it. I invited Bongani to start with his presentation of the atmospheric chemistry section so as to brief Noma. The only contribution he made was to mention the names of the different layers of the atmosphere. Even with this, he incorrectly mentioned lithosphere, instead of thermosphere, as the fourth layer. I tried to help him by probing but ultimately I had to take over. Noma, who was initially quiet and passive (possibly due to her absence from the previous session), became animated and started asking questions, commenting about her prior misconceptions about the topic. They both said that they learned a lot from the presentation, and the discussions we had about the grade 11 atmospheric chemistry section.

This session really served as a stimulation to begin work on construction of the CoRe. Noma said that she always thought that ozone depletion and greenhouse effect were linked, and happening in the same parts of the atmosphere. Before telling Noma about the big ideas we came up with in the previous session, I asked her to come up with her own big ideas. She suggested the following three: *The composition of the atmosphere*; *the structure of the*

atmosphere and *the relationship between energy and chemical change*. It was interesting, because her first and second big ideas corresponded to what we identified in the previous session as our first big idea, and her third big idea was very closely related to our second big idea, but more profound. With hindsight, I realise that we could have used her third big idea to modify our first big idea as follows: *Energy as the driving force in the chemical composition of the atmosphere and its role in nature*.

From the presentation, it was clear that the teachers also had misconceptions which were partially addressed during our discussions. From identifying big ideas, we moved to *Knowledge about learners' thinking which influences your teaching of this idea,* the fourth of Loughran, Berry and Mulhall's (2006) prompts. This proved to be a good strategic move to ensure consolidation of Bongani and Noma's content knowledge of the topic. This was a deliberate move because I thought it could be a futile exercise to try to engage them on the different aspects of the CoRe while they were not on top of the topic. A discussion on learners' misconceptions was a good way of helping them to clear up their own misconceptions, without feeling embarrassed and losing their confidence as teachers. When we considered possible learner difficulties, Bongani contributed the position of ozone layer in the atmosphere as an example, because he also had experienced problems with it, and anticipated that it would be an area of difficulty for learners too. It was a very interesting exercise because, during the atmospheric chemistry content presentation (honours session which was presented by myself and Bongani), it was apparent from the questions, the comments and the "aha's", that lots of light bulbs were lit as the presentation proceeded. When we considered the learners' possible difficulties, the following was suggested as possible learner barriers, coming, as they did, from their own prior ideas:

- Global warming is caused by the hole in the ozone layer;
- Global warming, due to the greenhouse effect, results in ozone depletion;
- Both the ozone hole and greenhouse effect are caused by cars;
- The greenhouse effect and ozone formation are essential natural phenomena which have been occurring for millions of years;
- The holes in the ozone layer trigger the greenhouse effect;
- Difficult to appreciate that global warming and ozone depletion are two independent, distinctive phenomena with separate causes

Since Bongani's study focused on the grade 11 atmospheric chemistry. I challenged him by requesting inputs from him directly and I requested him to lead the process by reading out the possible misconceptions from the diagnostic test we were working with (Appendix X). This proved to be a very fruitful process, as both Bongani and Noma also identified areas where they themselves had confusion. Even though Bongani was leading with the reading, he still made minimal independent contributions compared to Noma. In the data analysis that follows, his uptake from that process and from the product will be primarily deduced from the extent to which he managed to integrate the inputs in his own practice, and will be discussed in the next chapter. Both Noma and Bongani were very motivated, and that they learned a lot is evidenced by the following comments they made, as we were busy with the process:

> *N: You know, I learned a lot here. Actually I realise that all these misconceptions we are discussing here, I also had the same confusions and mainly because I did know anything about global warming and ozone depletion except what I got from the media. And in the media every time they report about climate change they always put the two together as if they are related and one causing the other.*
>
> *I: Yes, I like that and I think it's a very good observation which can enrich your approach to your learners. You are identifying one possible source of these misconception and we know that media reports at times are not scientifically sound and they can perpetuate misconceptions. Or even it might be the way of reporting and they might not be wrong in what they are reporting but, if they are – the fact that they always refer to the three phenomena together, then this can make learners to think that three have a causal relationship.*
>
> *B: Ja, I also agree with Noma, there is where my confusions came from and with learners if these two phenomena are discussed together they will stick to them as one thing. Even myself I always thought that CFCs cause global warning.* (atm CoRe_construction)

Their final CoRe is in Appendix M and, although its construction was a collaborative effort, Colleen was not there to participate and Bongani's inputs were quite minimal.

6.2.2 From the Inconvenient Truth reflection session

During the April school break, Sipho, Noma, Bongani and I met for about 10 hours over three days, when we viewed the DVD of the film *An Inconvenient Truth* together, held a reflection session on how its contents can be used as a resource and continued work on the grade 10 water cycle and the grade 11 atmospheric chemistry CoRes. Noma attended all three days and Sipho and Bongani each missed one of the days.

Both the 30 minute reflection session on *An Inconvenient Truth* and the process of construction of the CoRe, were audio recorded. During the reflection session, all three teachers were present but Sipho made the most substantial and succinct inputs by far. These are captured under his shifting content knowledge base section (6.3.1). Noma was there but

never uttered a word. I don't think she had nothing to say, but for reasons that are not evident, she chose not to participate.

Although science content is critical, the framework of the three science learning outcomes from the curriculum dictates that attention should also be paid to socio-political and moral dimensions of the debates. Therefore, all comments which indicate some level of critical thinking in moral debates are seen as very relevant. Sipho's comments during the *An Inconvenient Truth* reflection session, in preparation for the construction of the CoRe, were substantial, reflecting a great uptake on his part – he was able to capture the socio-political and moral dimensions of the debates, as well as the underpinning scientific knowledge. Below, he captures the concept of the *albedo effect* and the role of polar ice in regulating the Earth's temperature variations very clearly.

> *Sipho: The other thing that we heard was that as more of that polar ice is melting and that we are facing the challenge about the sun's rays – because they say that polar ice is the greatest contributor to the reflection of the ultraviolet rays which are – which we don't need – and if that polar ice is now diminishing – where will that big reflection take place from – then we will end up with a serious problem – ja, besides the impact of the rise in temperatures – just the diminishing of that iceberg is contributing to all these things in climate condition.* (atm CoRe_construction)

He is also quite analytic, as he moves on to the socio-political debate, and states what strikes him as parallels between education efforts, aimed at eradicating illiteracy, and the potential role of a literate citizenry in addressing global issues facing humanity today, such as global warming.

> *S: (Bongani tries to intervene but withdraws) the idea that this problem is a new terrorist the world is facing and I, you see it made me think of the missionaries of the world today. I am trying to think that America is trying to propose project 2061 that every American child should be literate – so that they are not left behind as the economies are progressing – and you see beside that vision – that idea, that problem of global warming made me realise that, that problem is not only for America, it's for the entire world – everybody must become literate so that we can get rid of the problem the world is facing – because if you only have captains of industry or whatever who are making profit, then they will not want to deal with the problem and the majority of people will be passive.*
>
> *I: So one realises that science knowledge is no more for the privileged few – really it has to be for everybody, we need a scientifically literate society – otherwise its application can be monopolised and then a – especially if those who have a moral conscience are not in the scientific debates – then these issues can send the world in directions which are self- destructive.* (atm CoRe_construction)

Some of Bongani's inputs were superficial and lacking in scientific focus.

> *Bongani: And I am wondering what would have happened if Al Gore became the president? Because I think the focus would not have been on war only because the very country is the one that is orchestrating war on other countries – if a person like him would be the president, the world would shift and we would not be having the problems that we are having now –*
>
> *R: Ja, you are raising a good point and maybe you are right. But it is also possible that as the president, his focus and energies would be diverted to other things. We don't know but it is certainly very helpful to have a leader with such sharp moral conscience.*
>
> *B: I thinking because the very leader who is shown there is somebody who is greedy. Those people are greedy, they are just thinking of money only.*

Sipho: Ja, that's why they are not interested in the Kyoto Protocol or whatever, that issue about countries pledging to reduce their contribution of carbon dioxide into the atmosphere. They are just mindful of their economy and nothing else because their economies depend on those industries.

Bongani: And they contributed a lot, 30% is so much, is so much. (atm CoRe_construction)

In the next excerpt, Bongani tried to bring in some science content, but he is still very vague:

B: You know there is something that is mentioned about industry. ... the way they explained ehh, the earth and the atmosphere where the boundaries are moving away from each other, and the explanation about the carbon dioxide, I didn't figure it out, but now I know how to explain that.

R: Ja, ok, that was a very powerful analogy, that one of the earth breathing in some periods and out in others to explain the patterns in variations of carbon dioxide percentages.

B: Yes and it helped me with a clear understanding as the teacher on how to teach it.

In the discussion on how to use the debates raised for teaching, Sipho went to the core of the challenge of contextualised tasks, in making sure that science content is not diluted but remains central to the content of the debate. I also interjected to bring their attention to how the 5Es (Bybee et al, 2006) teaching strategy could be incorporated to ensure that a good content knowledge foundation is laid before the learners enter into debates.

S: But I think the problem in addressing such a part of the curriculum using role play because I understand that here you already have the knowledge base that we have – (R: Exactly, that's the challenge. You have to build the knowledge base before giving such a task.) – their role has to be clearly defined – (R: mhhm) like if I say that you are in the role of the American government.

R: For them to be ready to engage with this, you need to do spade work as the teacher, give them assignments and resources to read, or tasks to research, or if you are using the 5Es you need to have a series of lessons that are gonna ensure that, the misconceptions that they have are cleared, establish enough content base to ensure that they are not gonna be lost in the socio-economic issues which are not underpinned by the knowledge of science, the science concepts in the debates should not be lost, and should come through. Basically that's the challenge of the science teacher. Just like when you were approaching the open-ended investigation, it means that work should be scaffolded through tasks that will ensure that they are clear, all of them and not necessarily only the one who will be assuming a certain role, and the assessment rubric or assessment criteria, should emphasise scientific literacy and the use of scientifically grounded arguments.

B: I think also it relies on the research which means if you are going to be doing research, it is important that you read and will be able to answer questions in class. Because most of the time they will dwell on the political issues so you must have enough content to be able to guide them. (atm CoRe_construction)

The excerpt below also shows Sipho's analytic mind, where he is pointing to the moral dimension of the debates. He is a teacher in one of the most notorious high schools in Soweto so, given the issues engulfing South African communities, especially the youth, I was not only deeply impressed with his analysis of issues, but also gratified and excited at what stood out for him. I took his interest as a sign that he will not only care about his learners' academic progress, but that he will also care enough to try and influence their moral decisions and guide them towards positive life styles.

S: There is one other thing that relates to the research knowledge we are trying to gather – and it's about Al Gore himself. I saw him trying to relate an incident that happened to him naturally when his son was involved in an accident and relating it to the natural disaster, and our tendencies to view things which are near to us and take them for granted – forgetting that in just one minute we can lose it all. So I captured that it was a personal journey for him.

R: Yes, issues of moral courage and actually it is not only that incident of near loss of his son's life, but also the incident earlier on in his life when his family owned a tobacco farm and his beloved sister ironically died of tuberculosis. So for him he had already experienced issues of moral dilemma where you are looking at something that is valuable because it is a source of income and in the process losing something even more precious and irreplaceable like a big sister you were so fond of and so close to, because as a family you did not react and change your ways fast enough. From those experiences you can see very clearly how he would be the one to advocate what he was advocating and you can also see that he was actually propelled naturally to assume the role that he assumed.

S: Yes the frog one was very interesting (everybody laughs).

R: Yes, as Sipho has said earlier, is it not also so true in all other aspects of our lives – how collectively we can feel so safe in some habits which are actually so detrimental to our lives and refuse to wake up from those comfort zones until it's too late? Ja, that's how we lose our moral nerve as a society and end up faced with all the difficult, complex and painful issues we are now facing either individually and as communities. (atm CoRe_construction)

6.3 Teacher's Shifting Knowledge Base

The construction of the water cycle CoRe was done in eight hours of concerted effort over two days. On the first day, Bongani was not in and joined the following day. Noma was very active during the construction of the team-generated water cycle CoRe, and made substantial inputs which marked a shift in her knowledge base of teaching the topic. The 3C-3S Concept Map Scheme of analysis, discussed fully in section 3.5.4 of chapter 3was used to analyse the concept maps and the CoRes.

Noma and Bongani's pre-CoRes did not have a good structure, because they did not identify the big ideas. They are included in the sections where I consider their individual shifting knowledge base. In the cross-case analysis matrix in Appendix E, I included Sipho's pre-CoRe, the team generated consolidated (post-) CoRe, with indications of the levels of contributions of each participant during the construction process. Each teacher is allocated a colour code to highlight their level of contribution during the construction process and the analysis of their contributions is discussed together with their pre-concept maps, under the sections of their shifting knowledge base.

6.3.1 Sipho's shifting Knowledge Base - Content Knowledge and Curriculum Saliency

Sipho's semi-concept map (see figure 10) below lacks a lot of detail, and only includes phase changes involved in the water cycle. It does not include cloud formation, the sun as the driving source of energy or the type of solar radiation responsible for the changes involved in the water cycle. Other important aspects which could have been included are the indication

that the atmosphere has layers and in particular the layer where the water cycle is confined, as well as the temperature and pressure variations in those lower layers.

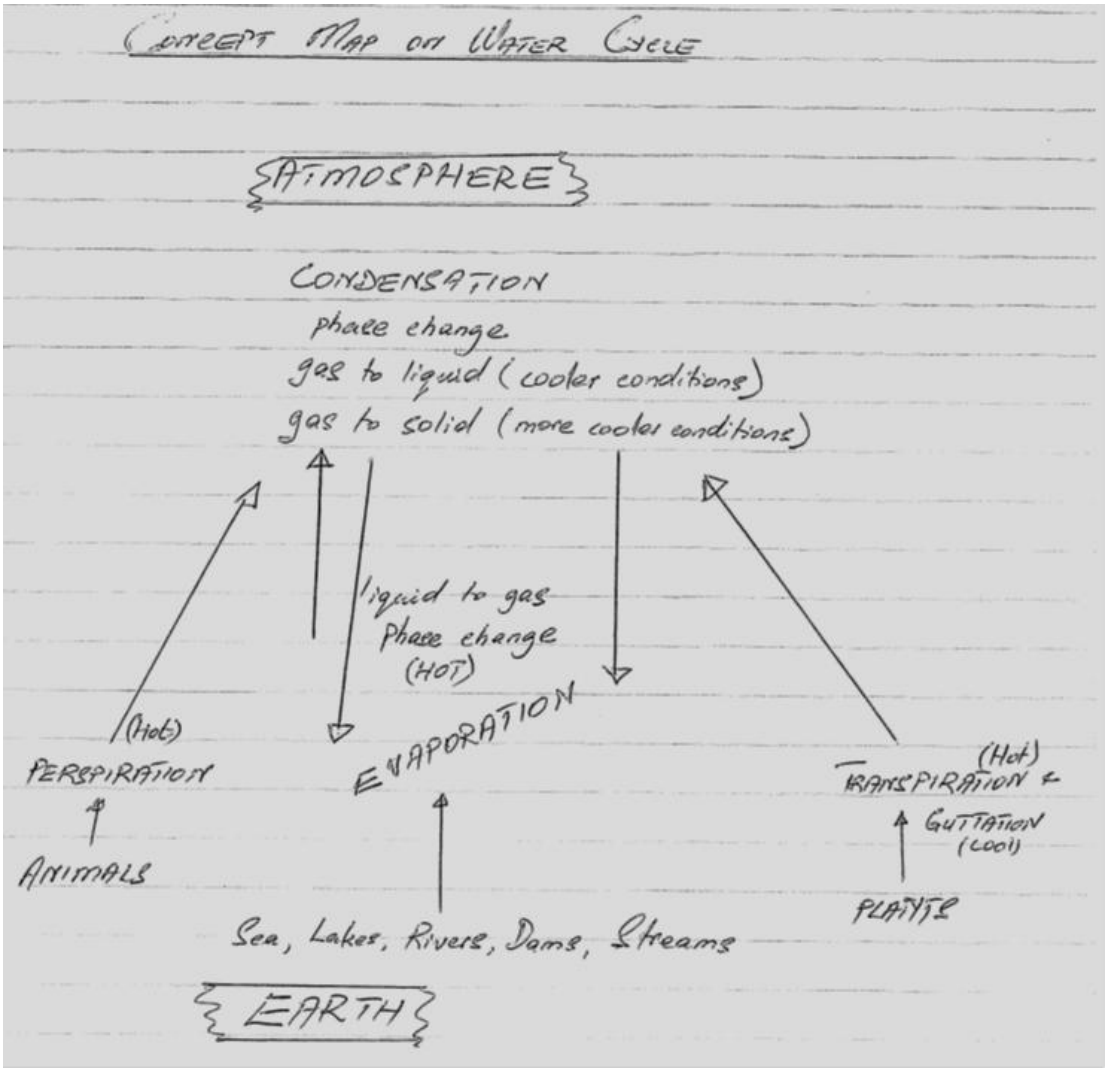


Figure 10: Sipho's Water Cycle Concept Map

Even though the map does not have errors but using the 3C-3S scheme of analysis, it can be rated as simplistic and vague in terms of conceptual depth and connectedness. At grade 10 this topic dealt with how energy transfer (the sun) drives water cycle and therefore the weather, through the physical changes it undergoes and how this interfaces with the chemistry of the atmosphere. Another aspect is the chemistry of the water molecule and how its polar nature and the strong intermolecular bonds it forms leads to its special properties and the special role it plays in nature. These include among others its high latent heat; high specific heat, high heat of vaporisation and large difference between its melting and boiling points.

As part of the teachers' curriculum saliency and knowledge about learners and learning, a slight modification was made to the Loughran, et al's CoRe, to include the prompt *what the teacher would expect her/his learners to know already about this idea*.

Table 11: Extract from Sipho's pre-CoRe - big ideas, prompts 1 & 2

Important Science Concepts	CHEMICAL ~~CHANGE~~ CoRe			
Big idea / Prompts	Phases of water	Particulate theory	Properties of water	Conservation of water
1. What you expect learners to know already about this idea	Water has three phases	Basic shape of a water molecule	Water remains at 100°C/(0°C-4°C) during boiling and freezing until all water molecules has evaporated or frozen	Water is not 'lost' during phase change
2. What you intend students to learn about this idea	Bonding causes different phases of water	The shape of H_2O molecule does not change despite the phase water is in	Temperature remains constant until all water molecules have vaporized/frozen	Water is conserved

By the time Sipho produced his second pre-CoRe, he had already read widely and researched the topic, so unlike his pre-concept map, the ideas contained in it are ideas gleaned from discussion as well as his own. A lot of learning for Sipho happened during the preparation for the construction of the CoRe, and during the process of the construction of the CoRe itself, discussed above. As compared to Noma and Bongani's pre-CoRe, Sipho's CoRe has some structure and phrases which are reasonable, that he identified as big ideas. According to the 3C-3S sheme of analysis (Table 4 in chapter 3), Sipho's CoRe can be said to be sound and adequate. From figure 10, we can discern Sipho's growth pattern by looking at the way

his initial ideas expressed in the pre-CoRes and pre-semi-concept maps he produced were consolidated during peer engagement within the challenge, synthesis and enculturation domain. It takes a deep knowledge of both content and strategic curriculum knowledge for a teacher to come up with sound big ideas for any topic. Compared to Noma's (Table 17) and Bongani's (table 18), Sipho's first pre-CoRe in Appendix V was substantial in both structure and conceptual depth.

As reflected in Table 11 above, he identified what he regarded as the four big ideas, which were closely related to the big ideas we settled for as a team during the construction of the post-CoRe (Appendix L).

The difference is that his first (phases of water) and second (particulate theory) big ideas were collapsed into one big idea, number 2 in the team generated CoRe as follows: *The relationship between macroscopic phase changes and microscopic energy transfers of water*. His list of big ideas also did not incorporate what emerged as the 5th big idea, *human impact on the water cycle* in the consolidated post-CoRe.

Analysis of the team generated CoRe (Appendix L) reflects that he made the most substantial inputs during the process which suggests a very good uptake and that his knowledge of the topic deepened substantially during the process.

It also takes deep content and strategic curriculum knowledge for the teacher to determine what to expect the learners to know already about each big idea, what he or she intends that particular group of learners to know about that aspect of the topic, why it is important for them to know it and what advanced knowledge the teacher him or herself knows about that aspect which he or she does not intend the learners to know yet. From Sipho's pre-CoRe (Appendix V) and the team generated post-CoRe (table 12 below), which is reflecting each teacher's individual contributions, one can discern a substantial shift in those areas of knowledge.

Sipho code **Noma code** **Bongani code**

Table 12: Top part of the Team generated Post CoRe

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
Big idea	Phases of water (S-pre) Sun as major source of energy (N-plan) The sun as the main source of energy that drives physical and	Particulate theory (S-pre) Polarisation??? (N-plan) The relationship between macroscopic phase changes and microscopic energy	Properties of water (S-pre) Movement of water from the ocean and land controlled by	Conservation of water (S-pre) Intermolecular forces & polar nature of water	Human Impact on water cycle (R)

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
Prompts	chemical changes (N & R)	transfers of water (S & R)	energy and sunlight (N-plan) The unique and special properties of water and its effects in nature (S & N)	(N-plan) The abundance and conservation of water in the cycle (S & R)	
1. What you expect learners to know already about this idea	Water has three phases (S-pre) Speed of light (N) They would know that the sun is the main source of energy (it gives them warmth, provides light etc) (S) The sun provides energy for photosynthesis; (S) *Energy is transferred through biological or physical systems, from energy sources.* They know that the sun rays move through the atmosphere before reaching the ground; (N) When energy is transferred, it causes changes in the system and the system's surroundings; When the energy has gone into heating the surroundings, we can no longer use that energy to do work for us; Hot objects transfer their energy, as heat, in three ways: by conduction, by convection and by radiation. These transfers may be useful or wasteful; Light travels away from a light-giving body until it strikes an object. The object may then absorb the light, or refract it or reflect it. Light transfers energy to other objects; Dark-coloured surfaces get hotter than light-coloured surfaces when exposed to radiating sources of energy like the sun; Dark coloured objects radiate their energy as heat more readily than shiny light-coloured objects The sun is the major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and	Basic shape of a water molecule (S-pre) They should know energy can be stored in a system as potential energy, either by the positions of the bulk parts of the system or by its particles (atoms and molecules) which have the potential to react with each other and release energy; Water changes its form as it moves in a cycle between the hydrosphere, atmosphere and lithosphere in what is known as the 'water cycle'; Some changes to materials are temporary but other changes are permanent. (water & nitrogen cycles) Substances change when they receive or lose energy as heat. These changes include contraction and expansion, melting, evaporation, condensation and solidification; A particle model of matter can explain physical changes of substances such as melting, evaporation, condensation, solidification, diffusion and heating by conduction; The dissolving of a substance in a solvent depends on variables which affect the rate of dissolving; (hydrosphere);	Water remains at 100^{o}C (0 – 4 ^{o}C) during boiling and freezing until all water molecules has evaporated or has frozen (S-pre) Water plays an important role in ecosystems, sustaining both plant and animal life; The atmosphere is a mixture of nitrogen and oxygen in fairly constant proportions, and small quantities of other gases that include water vapour. The atmosphere has different properties at different elevations. (nitrogen cycle & Grade 11) The atmosphere is the most important factor in keeping the earth's surface temperature from falling too low or rising too high to sustain life. (Grade 11)	Water is not lost during phase change (S-pre) *With each energy transfer, some of the energy becomes less available for our use, and therefore we need to know how to control energy transfers;* Energy sources such as wind, sun, and water in high dams are renewable *the atmosphere is a system which interacts* *with the land, lakes and oceans and which transfers energy and* *water from place to place;* Most of planet earth is covered by water in the oceans. A small portion of the planet is covered by land that is separated into continents. At the poles there are ice caps. Only a small amount of the water is available for living things on land to use and only a small portion of the land is easily habitable by humans.	Industrial, agricultural and domestic activities may have a serious impact on the quality and quantity of water available in an area; Human activities and natural events can slightly change the composition and temperature of the atmosphere. Some effects of these small changes may be changes in annual weather patterns and long-term changes in rainfall and climate.

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
	the water cycle; The atmosphere protects the earth from harmful radiation and from most objects from outer space that would otherwise strike the earth's surface; *Our planet is a small part of a vast solar system in an immense galaxy.*				

In essence, this section in table 13 below should constitute what the teachers know about their learners' existing conceptual knowledge, in relation to each particular big idea, as well as the foundational knowledge related to that big idea as stated in the curriculum. Coming up with this proved to be a very interesting and worthwhile exercise in terms of the teachers' content knowledge development, as the teachers did not know much about what to expect from their learners. Since grade 10 is the first grade at the FET level, the teachers had to consult two policy documents (GET and FET) to identify the necessary foundational knowledge. This exercise also served to expose the teachers to the GET policy document, as well as empower them on how to engage with the policy documents critically and fruitfully.

Table 13: Team generated Post CoRe - Prompts 2 & 3

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
Big Idea / Prompts	The sun as the main source of energy that drives physical and chemical changes	The relationship between macroscopic phase changes and microscopic energy transfers of water	The unique and special properties of water and its effects in nature	The abundance and conservation of water in the cycle	Human Impact on water cycle
2. What you intend students to learn about this idea	Solar energy drives the weather ; the movement of water from the ocean and land surface to the atmosphere is controlled by energy in the sunlight; The types of radiation constituting solar energy (IR, UV & visible light); UV and visible light are radiations with high energy and IR radiation with low energy Absorption of IR is responsible for the water cycle/weather conditions Water cycle is a cycle of physical changes Absorption of UV and visible light leads to chemical changes	The shape of the water molecule does not change irrespective of the phase in which water might be in. The absorption of IR (low energy) does not lead to change in chemical composition of water molecules. At water's melting point, irrespective of the heat supplied, its temperature will remain constant until all the ice has melted. To understand and differentiate between internal, kinetic and potential energy and their relationship to macroscopic changes	Polar nature of water molecule ensure that it absorbs infrared radiation and therefore leading to the sea being a reservoir of heat therefore serving as the Earth's thermostat .strong hydrogen bonds (intra-molecular) leading water to have high specific heat capacity, The solid state of water is less dense than its liquid and therefore water serves as an insulator for aquatic life during adverse weather. Water expands when it changes from liquid to solid (freezing) therefore contributes to mechanical weathering of	80% Earth is water yet we have to use energy to purify water because only 1% is fit for drinking. Water exist in nature as a mixture of substances Water is a universal solvent Water molecules are neither destroyed nor created and we therefore have same number of water molecules being recycled over and over again. The inter-phasing of water cycle with all other	

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
			rocks.	global spheres	
3. Why is it important for students to know this?	Understand and appreciate the vital contribution of the sun in our daily life; that all life is linked and sustained by the sun's energy To understand and appreciate that the movement of water through global systems is as the result of the sun's energy. To appreciate and understand the nature of the different solar radiation and their positive and negative impact in their lives. To understand and appreciate the roles played by different types of solar radiations in their environment.	So that they can understand and appreciate that the chemical composition of water does not change during phase change. To appreciate and understand that the absorption of IR radiation does not lead to chemical decomposition but only leads to increasing the kinetic energy of the molecules. To understand and appreciate that water has the capacity to absorb and release large quantities of energy during phase change (e.g. at melting and boiling points)	They need to understand and appreciate that size of the water molecules remains constant during expansion		

The section below represents the ideas which Sipho had about the water cycle (see table 14 below) and considered them beyond the scope of his grade 10 learners. We did not get to complete this whole section as a team but Sipho's pre-CoRe (appendix V) was more complete. Even though quite limited compared to those we were able to put together as a team, they are substantial and relevant. Learners would be expected to deal with the ideas he has under his third and fourth big ideas in grade 10.

Table 14: Extract from Sipho's pre-Core - prompt 4

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe				
Big Idea / **Prompts**	Phases of water	Particulate theory	Properties of water	Conservation of water
4. What else do you know about this idea (which you do not intend your learners to know	The 4th phase (plasma)	The water molecule can accommodate the 3rd H atom	Water is capable of withholding/absorbing energy for longer periods because there are many hydrogen	Dynamic equilibrium. During precipitation some water is deposited deep under the

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe				
yet)?			bonds to be broken	layer of soil but later resurfaces as ground water that flows into streams while the other water is trapped in wells.

Since the team also participated in the generation of the grade 11 atmospheric chemistry CoRe (see table 15) , this section of the water cycle CoRe was greatly influenced by that work, as well as what was learned during the viewing of the *Inconvenient Truth* DVD. The grade 11 policy document was also consulted to see how the topic evolves in grade 11, but because of time constraints, this process was not completed.

Table 15: Team generated Post CoRe - Prompt 4

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
Big Idea / Prompts	The sun as the main source of energy that drives physical and chemical changes	The relationship between macroscopic phase changes and microscopic energy transfers of water	The unique and special properties of water and its effects in nature	The abundance and conservation of water in the cycle	Human Impact on water cycle
4. What else do you know about this idea (which you do not intend your learners to know yet)?	Photo-electric effect (nature of frequency of different types of materials); dual nature of light; diffraction, interference, polarisation. Grade 11 sound and light (scattering and absorption of light) Grade 11 Exothermic and endothermic reactions All other types of radiation other than solar radiation Ideal gas and thermal properties	The chemistry of the atmosphere (tropo-, strato-, meso- & thermo- and the fact that the water cycle happens between the first layer of the atmosphere, the lithosphere and hydrosphere.			global warming, greenhouse effect, ozone depletion GW and OD are two separate unrelated phenomena Advancements in industry lead to more pollution to the environment Relations between population growth and demand

Knowledge of Learners' Science Conceptions

Even though there is evidence of new inputs generated in the post-CoRe (appendix L), Sipho's second pre-CoRe also shows that a lot of thought went into the generation of his CoRe and his knowledge was good.

Table 16: Extract from Sipho's second pre-Core - prompts 5 - 8

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
Big Idea / Prompts	The sun as the main source of energy that drives physical and chemical changes	The relationship between macroscopic phase changes and microscopic energy transfers of water	The unique and special properties of water and its effects in nature	The abundance and conservation of water in the cycle	Human Impact on water cycle
5.Difficulties/limitations connected with teaching this idea	Learners' difficulty in relating micro and macroscopic changes	Learners find it difficult to relate micro and macroscopic changes	If taught theoretically	Measuring and comparing water that has evaporated with water that precipitated.	
6. Knowledge about learners' thinking which influences your teaching of this idea	Water disappears	Water separates into H and O atoms when heated and both combine during/ when temperature decreases	Temperature continues to rise and drop during boiling/freezing Boiling is the same as evaporating	Accounting for water that has evaporated	
7.Teaching models and procedures (and particular reasons for using these to engage the idea)	Using plant and covering it with transparent plastic	Building models of water molecules and indicating the points of hydrogen bonding	Do experiment on temperature reading during boiling and freezing	Heating water in a closed system	
8. Specific ways of ascertaining learners' understanding or clearing confusion around the idea (teaching & assessment strategies)	Questioning them about the origin of water droplets	Letting them disengage individual molecules from a sample of 5 bonded water molecules	Letting learners take and compare temperature readings during boiling/freezing over a time interval	Comparing original water before and after then account for the difference	

Sipho did not study the sections from the Heineman book and data reveal that much of his learning happened during the preparation stage, when the four of us watched and reflected on

the *Inconvenient Truth* DVD and through Noma's brief introduction of the section, as well during the process of the CoRe construction itself. Unfortunately Sipho did not take the process forward because he dropped out of the process before implementing his ideas in the classroom.

Of the four teachers, Sipho's participation in the process was minimal because he missed most of the collaborative activities and also ended up not implementing his classroom plans or submitting his final report. It was therefore, not easy to discern patterns of shifts in his knowledge base. However, in the activities where he did participate, his uptake and contributions were substantial compared to the other teachers, Noma and Bongani. Nothing can however be said about the framing and reframing of his practice for classroom implementation, and clearly shifts in his knowledge base came as a result of his participation in specific peer engagement activity during construction of the water cycle CoRe.

6.3.2 Noma's Shifting Knowledge Base

Evidence of Noma's knowledge shifts are quite integrated within excerpts referred to in this section, and cannot easily be pulled out into the three aspects (science content knowledge, knowledge of learners' conceptions and strategic curriculum knowledge), as shown in figure 8; therefore discussions in this section will also be presented in an integrated form. Her knowledge of learners and how they learn, surfaced throughout the process.

Knowledge of Content and Meta-cognitive skills

Noma's pre-CoRe reflected in table 17 below is very rudimentary and simplistic in terms of its structure, comprehensiveness, complexity and conceptual depth. There are no big ideas identified, which is a reflection of a lack of understanding of the topic at hand, as well as what the CoRe, as a pedagogical construct, is.

Table 17: Noma's Water Cycle Pre-Core

BIG IDEAS / PROMPTS	INTRODUCTION
1. What you expect learners to know already about this idea	I will expect my learners to have an idea about the earth and its composition
2. What you intend students to learn about this idea	The learners should know about the levels that the earth is made up of
3. Why is it important for students to know this?	
4. What else do you know about this idea (which you do	How the earth was formed according to the big

not intend your learners to know yet)?	bang theory
5. Difficulties/limitations connected with teaching this idea	
7.Teaching models & procedures (and particular reasons for using these to engage the idea)	
8. Specific ways of ascertaining learners' understanding or clearing confusion around the idea (teaching & assessment strategies)	Make use of appropriate models
9. other factors that influence teaching of this concept	Various sources textbooks, TV programmes, internet

Explaining this pre-CoRe in terms of the 3C-3S scheme of analysis (Table 4 in chapter 3) it can be said to be simplistic and vague as far as structure, correctness, conceptual depth and connectedness goes.

As is revealed in Noma's comment below, the construction of the team generated post-CoRe (Appendix L) was a collaborative effort in which she learned a lot about what the CoRe is and its value, as well as about the water cycle as a topic within the grade 10 curriculum. Comparing her pre-CoRe and the team generated post-CoRes discussed above in section 6.3, one notes substantial knowledge growth on her part.

> *Doing some reading on what she gave us from emm Heinemann that had been evolved and then we came together; it was myself, Sipho and Mpunki and we started going through the big ideas trying to identify what the big ideas were, even with that one I was a bit, you know slow, 'cause I couldn't actually pick it up from the onset, I should think with help of Sipho I was able to start making my contributions. We identified the following as the big ideas on the water cycle to be the sun, the main source of energy that drives the physical and chemical changes. We have got the relationship between macroscopic changes and microscopic energy transfer of water. The uniqueness and special properties of water and it's… the abundance and the conservation of water in the cycle. And then the human input…so those are the main big ideas that we actually picked up.* (N & C CoRe pres)

The following excerpt from Noma's research report reveals her evolved understanding of what the CoRe is. It also captures the scope and the depth of the processes and the activities of the research team during the time of planning for their teaching.

> *In addressing the issue of new content, we read quite a number of resource materials with focus on the water cycle. We held a number of meetings (3 hours per week) over a period of 4 months. With the assistance of our supervisor, we discussed and shared our individual models and developed a consolidated CoRe. The structure of the CoRe informs the content knowledge of the water cycle. The structure provides an intellectual way of organising content knowledge. Before engaging in the process, I thought the CoRe was based on employing the sub-topics in structuring the content knowledge. However, the big idea entails underpinning concepts without which the topic will fall apart and the prompts help the educator to have an insight about the learners and the knowledge of the learners. We also engaged with the grade 11 educator in the process of developing content knowledge on chemical systems.* (Noma, Research report)

Noma clearly understands what the CoRe is and where it fits in as a tool to expand her repertoire of pedagogical strategies:

At macro-planning it is a useful tool. It helped me to think about the content in terms of how it should be taught and can be easily shared with other educators. It is a flexible framework that can be changed to suit the context of educators as well as that of learners. Prompts outline fundamental things that an educator should consider when planning to teach a certain topic. Prompts give as insight about learners and learners' knowledge, in a way it also suggest to an educator to always have a broader knowledge of the topic beyond what learners know. (Noma, SAARMSTE, 2009 pres)

During the construction of the team-generated water cycle CoRe, Noma was very active. Sipho had not studied the chapters and sections they had agreed to study, so Noma started by giving a logical and comprehensive summary presentation on her understanding of what the sections entailed. She started by discussing the nature of solar radiation as the energy that drives both physical and chemical changes, and the special nature of water molecules etc. I only had a few inputs to make which involved discussions on how the special nature of water molecules makes it to serve as nature's thermostat and heat sink, to sustain life on earth.

The excerpt below from her opening statement during one of the research group sessions where she was presenting her CoRe, captures the uncomfortable state she was in at the beginning of the process, when she had to confront the content gaps she had as she approached a fairly new topic in the curriculum. This again highlights that the construction of a sound CoRe is a complex and intellectually demanding exercise which cannot be underestimated. The excerpt also reveals how unfair it is to have such high expectations of teachers without proper and ongoing support, as well as the types of coping strategies a teacher calls on when put in such a difficult position of being the all-knowing. This can actually prevent teachers from engaging in reflective practices, or opening up during in-service training and the importance of openness as the starting point in the learning journey cannot be understated.

When we started with this chemical systems and the development of the CoRe, I want to say it was very difficult for me because really ah, I didn't know what I was supposed to do and how I was supposed to maybe structurise the whole thing, but with the support of the team – okay we started doing the – it was an individual work whereby we were supposed to do the core and I should think on the templates that you gave us, more or less there was nothing that I could write because, it's a new topic to me, so whenever I look at it I associate it with Geography section so I didn't know anything about it and really I didn't feel good because as an educator whenever you are given work people have those expectations that you sort of know everything but, eh Mpunki struggled a lot with me because I was trying to dodge her (laugh from everybody) …but the reality, until she approached me and told me that it's part of my data collection process and I should relax as I learn more, that learning can only be reflected when I know where I started from. (Noma, research group session 4)

The excerpt below confirms that Noma appreciated and felt much empowered by the process.

This process gave me an opportunity to expand my knowledge beyond what my learners will learn in grade 10 and helped me to consolidate the prompts such as 'what else do you know about this idea which you do not intend your students to know yet?' Engaging in this process had a positive impact on my content knowledge on chemical systems which I hope will be a developing model as I proceed with my teaching even in other years to come. (Noma, SAARMSTE, 2009 pres)

From analysis of Noma's pre-CoRe (Table 17) and the team-generated post-CoRe (Appendix L), there is a clear progression from simplistic to sophistication of representation of their structural knowledge in terms of comprehensiveness, complexity and conceptual depth, as expounded in the scheme of analysis above.

As expressed in the excerpt below during presentation of her CoRe in one of the honours project sessions, her learning and appreciation of possible learners' misconceptions not only alerted her to the role of misconception in teaching and learning, but also addressed her own misconceptions about the topic:

> *Noma: Yah and then we came on to the difficulties or the limitations connected with these ideas, so also on this one they gave some (not audible)… on the misconceptions that learners have and not only learners misconceptions it's also misconceptions by the teachers or (not audible) … so whilst developing this we had to sit down through our discussion and I was able to understand myself; my previous failures when I approached this idea that maybe this concept was supposed to be explained in this format only to find out, I also had some misconceptions on that, using the general knowledge that I had, since this is still a new topic, so besides developing the core, learning also truthfully, I sort of learned a lot, especially the water cycle because there is a lot that I didn't know about it…* (N & C CoRe pres)

Curriculum Saliency (12)

Revealed beneath the expression of frustrations, and dilemma of how she is going to ensure that her learners catch up and cover the work expected, is Noma's sense of curriculum saliency. It is also very interesting how knowledge of one group of learners enables her to ensure that meaningful learning happens at a faster pace.

> *I Ok, tell me, what work have you covered with your learners in science so far?*
>
> *L In grade 11– and then in grade 10 – mathematics*
>
> *I Err how far into matter and materials?*
>
> *L I'm behind, I am actually behind – I am actually worried in that ehh – ok with my grade 11 class I have tried using morning classes – Ja and I don't think it's a difficult group – the grade 11. I've got two classes but they are not really difficult because they already know me – I think I'm able to push through …*

What is revealed below is strong curriculum saliency springing from continuous growth in her knowledge of the curriculum (particularly LO1), as Noma reviews and adjusts her teaching and assessment strategies to ensure that she addresses the science learning outcomes adequately. There are clear signs that Noma has some working understanding of what learning outcome 1 entails, and it is quite impressive because it is a very complex Learning Outcome, underpinned by complex combinations of high-order procedural skill. She is also very aware that, to inculcate those skills in learners, will require special and concerted effort.

... and actually let me say what makes me to slow down in grade 10 is that – I've started realising what I have to cover in terms of covering the assessment standards –instead of the classwork that we do – so you find that err yes I've taught the atom and all those things – but learners have not been given – that this is in terms of LO 1 – so that is the problem so actually – yah you do your lesson plan and I haven't been clear about that one that I've been empowered a lot – so for each and every activity there must be a marking rubric – so I was also focusing on the skills – Ja, I don't know. (Noma practice-int)

This I thought was powerful and it attests to the impact of training on practice. It may definitely have a negative immediate impact as she adjusts her practice, but it will certainly have a long lasting effect. This is what is referred to as 'implementation dip' (Fullan, 2001). Below, Noma is expressing her uncertainties and how intimidated she feels about the whole change management. It is also very interesting that she consulted her learners as she went through with the process.

L Umm, I was also focusing on the skills yah, I don't know so am, am it's scary when it comes to what we are supposed to do there – but I have discussed with my learners in that, there is this section of work whereby I am going to pump them up with reading materials – but I will be able to take them through that (not audible) ... (Noma practice-int)

On the challenge expressed below, one could argue that it might be due to poor planning, but on the other, it might also be due to infrastructure that fails to support the rising expectations of teacher performance and innovation.

... and one other challenge although they say we must finish putting the goal (not audible) because for each and every piece of work which you have to do, you have to go for photocopying whereby you have to queue. But with my grade 11 I am pushing the work because they have that experience – so it is open on page so and so, look at that paragraph and then they start to – (Noma practice-int)

The excerpt below is an evidence of curriculum saliency, where Noma's strategic knowledge of the curriculum comes to the fore as she reviews her conventional teaching approach in the light of the new knowledge she had just gained about science leaning outcomes, especially learning outcome 1 which involves the carrying out of scientific investigations. From this rich knowledge, she was able to arrive at the conclusion that her teaching approaches thus far had only been catering for LO2, which is about the substantive structure of scientific knowledge, excluding the syntactic as the other important structure. It is evidence of strong curriculum saliency because, as soon as she became aware of the lack of her teaching strategies, she decided to cut the flow of her inputs and strategically interjected to incorporate the knowledge and skill needed to engage with LO1.

I: What I've actually done now because I had that challenge of the practical investigation, I've started by teaching the content as in the old method but now I realise that ok, that one is actually LO2 because I'm focusing on the core knowledge but now I'm having a challenge of this LO1 now that I was almost done with mechanics that chapter of these laws, what I've actually done. I have taken all the four practicals and I'm drilling a skill of planning – the planning phase whereby I sort of put a scenario for

the learners to say – this is the situation come up with a problem statement on that one so, I'm informing them that we are doing LO1 and what is my expectations on that one – so for the four of them instead of doing them simultaneously because I'm also drilling a certain skill so that in the other areas I'm not going to have a problem so for each and every one they identify the problem statement and they give an answer for that one. (Noma practice-int)

In the excerpt below, it is interesting and exciting that Noma has moved on to try to overcome the limitations imposed by textbooks in addressing the science learning outcomes. She seems to be using her knowledge and understanding of what scientific inquiry means to her, and align her teaching strategies to assist learners in gaining knowledge of procedural skills involved in planning a scientific investigation.

Ok the textbook normally gives them the apparatus; they tabulate the apparatus but they have to check whether they have given the accurate number. For example let's say they have to talk about Newton's law. Do they say one, two or whatever and then they carry on to the variables? so I was actually introducing them to this thing of variables – the one that you control – the one that you change – the one that you – ja, measure. So what they've actually done – they have done one with frictional force and the normal force – they have to know because what is frictional force? Because I don't see frictional and normal force. (Noma practice-int)

Below, she admits that her knowledge of LO3 is still very fuzzy and lacking, and that she has not made as much progress to incorporate it in her teaching as she has done with LO2. It is exciting to see the clarity she has about what she knows and what she does not know yet about the curriculum. This helps a great deal to lessen the confusion and ensure that there is no breakdown in the inputs that the teacher is making in her classroom, while ensuring that she remains open to the further inputs she needs to improve her practice.

I'm still struggling with LO3 about that in that I don't know whether we are linking it to the society. At some stage I've commented about wearing of the safety belt. Why do you have to wear the safety belt? The modern cars have the airbags so why do you have airbags? So I'm not really clear whether I'm linking it correctly. Is it applying to our everyday experiences? I don't know. (Noma practice-int)

Of all four teachers, Noma is the one who engaged with most of the collaborative activities which went on during the process. She also seems to have made more holistic and major strides, in terms of shifting her own content knowledge, knowledge of her learners' conceptions and strategic curriculum knowledge. The framing and reframing of her practice for classroom implementation was influenced by the knowledge she gained through peer engagement, rather than from her own individual study of the materials or from her learners' feedback. Noma engaged fully in most of these peer engagements, and in instances where she had to take a lead and present something, she prepared very well for such activities. So she learned a lot throughout the various stages. However, data indicates that her most profound insights and learning happened during the construction of both the water cycle and the atmospheric chemistry CoRes.

6.3.3 Bongani's Conceptual Challenges

All told, Bongani struggled the most of the four teachers and, as discussed in this section, his uptake throughout the process was minimal.

In the previous chapter, the concept challenge data of the minor and major case studies were analysed together to get an impression of how the GET and FET fared. The results revealed that, even though most FET teachers fared much better than the GET teachers, Bongani was one of the two FET teachers who fared as badly as the GET teachers. The results revealed that Bongani had challenges in all the concepts which were targeted. This implies that he had challenges in:

- distinguishing between particle diagrams of gases and liquids
- distinguishing between crystalline compounds and mixtures
- distinguishing between mixtures and compounds at the microscopic level
- distinguishing between physical and chemical changes
- conserving mass and matter during chemical change
- resulting in attribution of macroscopic attributes to microscopic entities, e.g. "particles evaporate"
- and believing that breaking chemical bonds results in release of energy

Even though Bongani was doing his BSc Honours, he was really struggling with his content courses as well, and this could be attributed to the fact that he was never trained as a science teacher. He was initially trained as a technical subject teacher and later retrained as a science teacher, by pursuing FDE with Rand Afrikaans University before coming to do his honours. Bongani's two concept maps were analysed and presented in the next section using the 3C-3S scheme of analysis (Table 4 in chapter 3).

From the Concept maps

Bongani produced two maps: pre- and post- semi-concept maps (see figures 11 & 12). These were analysed to show how his conceptual understanding of the topic of atmospheric chemistry changed as he engaged with the process.

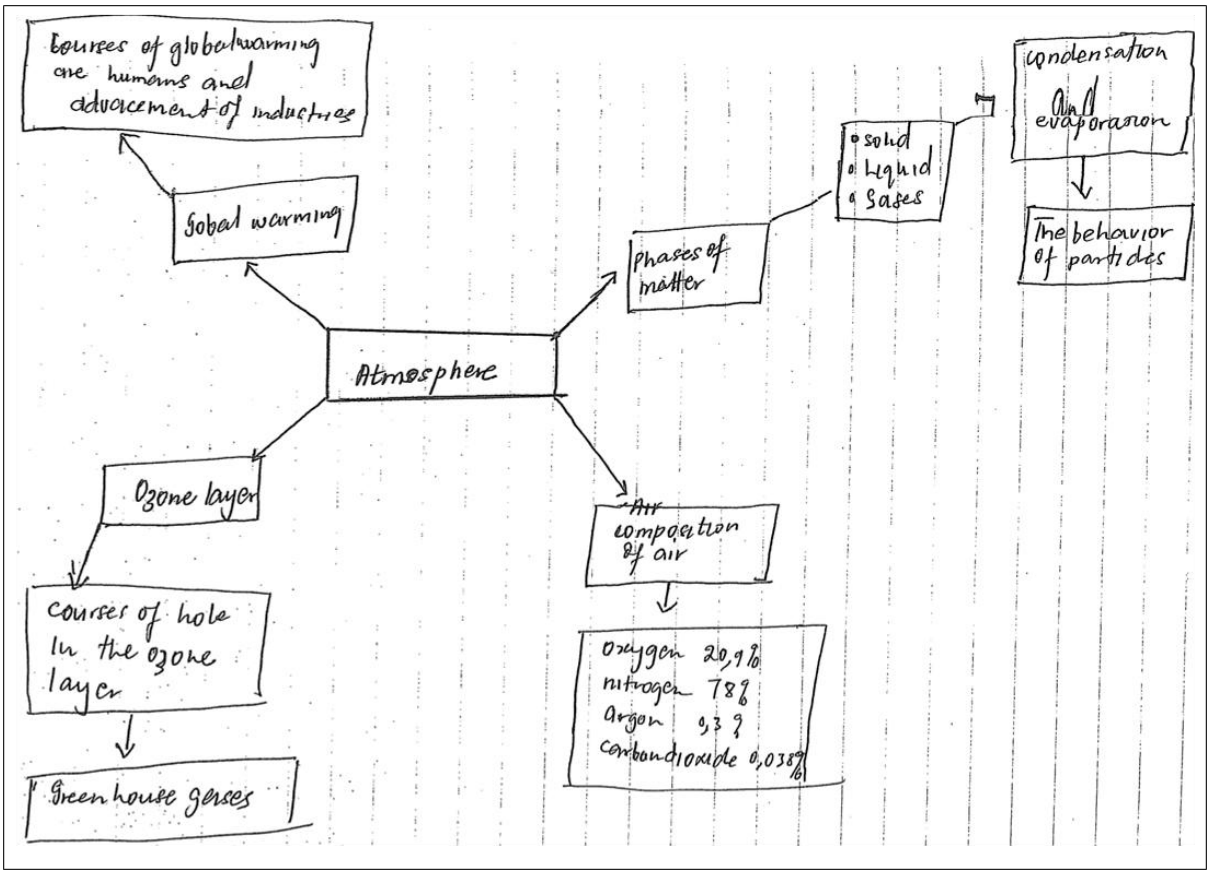


Figure 11: Bongani's Atmospheric Chemistry Pre-Concept Map

The pre-semi concept map was generated right at the beginning of the programme, while the post semi-concept map was generated right at the end, after teaching the topic in class. The teaching itself happened after researching, learning and planning for teaching. No training on concept mapping was provided, so not all the maps follow the acceptable structure of concept maps in having linking words. Hence his concept maps could better be referred to as mind maps or graphic organisers, but they do give an idea of how the content hangs together.

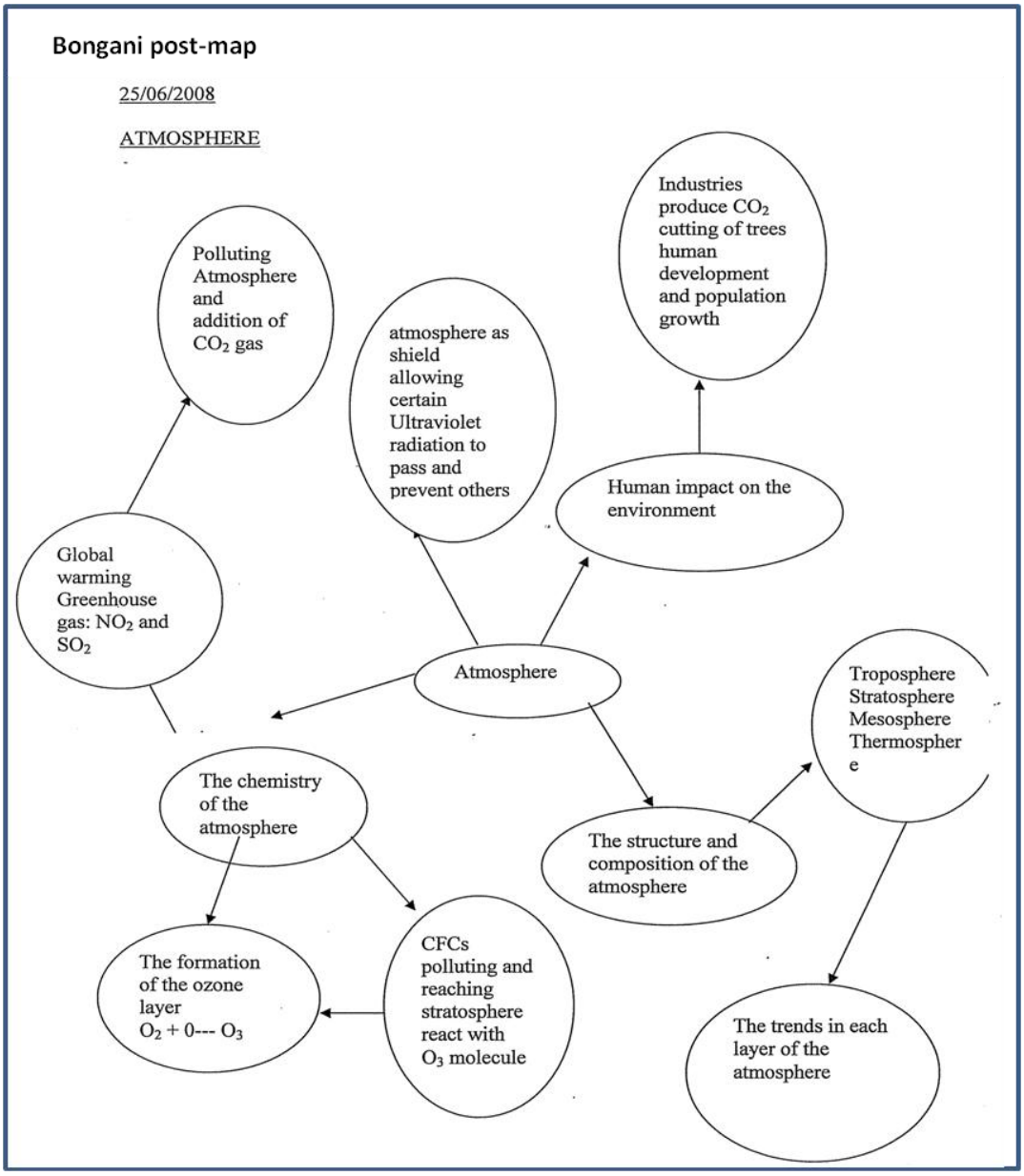


Figure 12: Bongani's Atmospheric Chemistry Post Concept Map

Conceptual depth, Correctness and Connectedness

Analysis of the two maps (fig 11 & 12) reveals a substantial growth in both depth and breadth of conceptual understanding of the topic before and after he engaged in the process. The pre-concept map is constituted of only 5 relevant concepts, reflecting very narrow, segregated and superficial knowledge of the topic. The structure he produced was very simplistic and does not reveal much about the nature of gaps he has about the topic. Two misconceptions which can be discerned from the pre-map which Bongani had were firstly about ozone

depletion. He claimed that greenhouse gases are the cause of the hole in the ozone layer. This is a typical misconception,, resulting from confusing global warming and ozone depletion, which is normally held by many learners (Kerr & Walz, 2007; Cordero, 2002; Toby, 1997). Secondly, he ragarded CO_2 as being a pollutant and this is actually not true. The message which can be discerned from the pre-map is that the atmosphere is directly related to 4 concepts which are:

- **composition of air,** made up of 20.9% oxygen, 78% nitrogen, 0.3% argon and 0.003% carbon dioxide.
- **phases of matte**r as solid, liquid and gases related to condensation, evaporation which results from behaviour of particles
- **global warming** which is caused by humans and industries
- **ozone layer** with greenhouse gases causing the hole in the ozone layer

Within Bongani's post-map (fig 12), one can identify 27 relevant concepts as compared to the 5, in the pre-map, which indicates growth and sound conceptual depth. The post-map is also a much more detailed, scientifically rich representation, which shows a much better understanding of the topic. However, a closer look at the map reveals poor association of some of the concepts, reflecting a narrow and less integrated understanding of the topic.

In terms of connectedness, it can be classified as sound and adequate because even though the post-map is much more structured and contains basic features, it lacks integrity in terms of coping with additions, because of incorrect links in some parts. The concept map shows no link between "the shielding role of the atmosphere" and "the ozone layer"; neither is "the human impact on the atmosphere" associated with "global warming or ozone depletion". What is very gratifying is the correction of the misconception noted in the pre-map, that greenhouse gases are responsible for ozone depletion. In this post-map, it is clear that Bongani understands that global warming and ozone depletion are two distinct environmental issues, and rightly associates global warming with greenhouse gases.

From the pre-CoRe

Bongani's pre-CoRe below (table 18) did not have big ideas and it reflects strong commonalities of content with his pre-concept map. The misconception which was identified in the concept map is also present here. What is different is that under what he expects learners to already know, when approaching the topic of atmospheric chemistry, are the *water*

and nitrogen cycles, as well as *the uses of nitrogen*, and under what he intends students to know is *the disturbance of natural cycle*.

The Grade 11 atmospheric chemistry post-CoRe (Appendix M) was generated from a collaborative effort, to which Bongani made minimal contributions, compared to other team members. His uptake from that process and from the product produced can only be deduced from the extent to which he integrates the inputs in his own practice and will be discussed in the next chapter.

Overall, Bongani did engage and learn, but his engagement with the process and his uptake from that process was superficial. If there is any substantial uptake, it can only be deduced

Table 18: Sections of Bongani's pre-Core

Bongani Atmosphere pre- CoRe

SYSTEM

Important Science Concepts	CHEMICAL ~~CHANGE~~ CoRe			
Big idea / Prompts	The movement of particles on the three phases of matter			
1. What you expect learners to know already about this idea	Matter consists of three phases of; • Solid • Liquid • Gases	The behavior of particles in each phase • Solid - particles are closely packed and at the fixed position • Liquid - particles are close but there are space between • Gases - particles are far apart from each other	• The condensation of water • The evaporation ~~expansion~~ of water	• The water cycle • nitrogen cycle • The use of nitrogen
2. What you intend students to learn about this idea	• The composition of air • The disturbance of the natural cycle. • Ozone layer • Global warming	The disturbance of natural cycle	• Ozone layer • courses of the hole on the zone • The green house gases	Global warming • courses of the the global warming are human beings and the ~~advance~~ advacement of industries

from the extent to which he integrates the inputs in his own practice and will be discussed in the next chapter.

6.3.4 Colleen's Shifting Content Knowledge for Teaching Science

From the Concept Challenge

Because of her qualifications and her background in chemical industry, Colleen has a solid knowledge of science content (CK), which is confirmed by how she faired with the concept challenge. The pattern that emerges from the concept challenge data which was analysed in chapter 4, is that Colleen stood apart from the other 14 teachers who seem to lack basic understanding of fundamental concepts, which form the foundation for clear thinking in chemistry.

From the CoRe

Even though Colleen participated in the collaborative process, and did receive limited feedback and inputs from other team members for some special circumstances, the production of her CoRe (see appendix P) was not a collaborative effort. From Colleen's CoRe, which is a three stage *planning content for teaching* product, one can deduce the development and growth of her content for teaching the topic of chemical systems at grade 12. In this section, I begin the process by focusing on an analysis of the pre-CoRe, which reflects her limited knowledge of the topic at the beginning, before teaching the topic to her learners. This information has both her beginning ideas and ideas she picked up during the preparation phase.

From Colleen's CoRe which is a three staged *planning content for teaching* product one can deduce the development and growth of her content for teaching the topic of chemical systems at grade 12. In this section I begin the process by focusing on analysis of the pre-CoRe which reflects her limited knowledge of the topic at the beginning before teaching the topic to her learners. This information has both her beginning ideas and ideas she picked up during preparation phase.

As discussed in the next section, Colleen ignored advice that she should focus her research project on only one topic of Chemical Systems. She decided to focus on the entire grade 12 Chemical Systems. This meant that her whole research project became extraordinarily

difficult, as became apparent in the construction of a CoRe as a topic specific cognitive framework.

As a consequence, she had to deal with a large range of topics resulting in her not being able to come up with appropriate *big ideas*. What she identified as big ideas were just too broad; each should be an independent topic with its own CoRe and *big ideas*. These, however, were also not just ill-conceived topics, but her original conception themes, around which the knowledge area of chemical systems could be built in grade 12. An overall view of Colleen's CoRe over the three stages reveals a pattern of progression, from generic addressing of the concepts to more specific details, which encapsulates knowledge of the learners' understanding of the concepts.

Table 19: Sections of Colleen's CoRe - Big ideas & Prompts 1

CoRe PRIOR TO TEACHING, PREPARATION STAGE
CoRe DURING TEACHING PHASE
CoRe AFTER TEACHING PHASE

BIG IDEA/ PROMPTS	ECONOMICS AND THE CHEMICAL INDUSTRY	THE FERTILIZER INDUSTRY	THE CHLOR-ALKALI INDUSTRY	ENERGY FROM THE CHEMICAL INDUSTRY
1. What you expect your learners to already know about this idea?	Exploiting the lithosphere-mining and environmental impacts [Sections from grade 10 and 11 – Matter and Materials, Chemical Change and Chemical Systems] Global warming, photochemical smog, production of iron and steel, gold and phosphate, Kinetic theory and gas Laws, mole ratios. Writing and balancing chemical equations, understanding how to write chemical formulae, understanding charges on ions, chemical calculations, and stoichiometry.	Nitrogen cycle (Biological and geographical systems, Industrial fixation of nitrogen, atmospheric chemistry [Sections from grade 10 and 11-Matter and Materials, Chemical Change and Chemical Systems Composition of the atmosphere, global warming, Kinetic theory and the Gas Laws, air pollution, phosphate mining and production of superphosphates, use of catalysts. Writing and balancing chemical equations, understanding how to write chemical formulae, understanding charges on ions, how distillation works, chemical equilibrium and rates of reaction. Chemical calculations, stoichiometry. Link to grade 10 chemical systems; grade 11 mining and mineral processing, acid base reactions, neutralization and grade 12 rate and extent of reactions, chemical systems, SASOL and the manufacture of fertilizers.	Acids and bases, laboratory acids and standard solutions [Sections from grade 10 and 11-Matter and Materials, Chemical Change and Chemical Systems Electrolysis, oxidation numbers Writing and balancing chemical equations, understanding how to write chemical formulae, understanding charges on ions, shape of molecules, electro negativity, polarity of bonds and molecules, difference between oxidation and reduction, strengths of oxidizing and reducing agents.	Electrolytes in solution, redox reactions, ionization and conductivity, substitution, elimination and addition reactions, energy and chemical change, electrochemistry, galvanic cells, standard electrode potentials [Sections from grade 10 and 11-Matter and Materials, Chemical Change and Chemical Systems. Production of coal, oil, alkanes, alkenes and alkynes, other energy resources- bio-fuels, hydro-electric power, nuclear power, solar power, wind power and wave power. Writing and balancing chemical equations, understanding how to write chemical formulae, understanding charges on ions, difference between oxidation and reduction. Chemical calculations, stoichiometry, industrial processes that use elimination reactions [cracking], solubility of salts. Link to grade 11-mining and mineral processing.

Pitjeng (2011) in her MSc report identified two big ideas for Chloralkali industry as: *Electrolysis of sodium chloride involves a redox reaction* and *the chloralkali industry plant has impact on the societal, economic and environmental issues*. Big ideas are those ideas that relate what is observable at macroscopic phenomena level about a class of phenomena with the types of explanations scientist construct at microscopic level help with understanding how that class of phenomena unfold in nature. Therefore each big idea should cluster together a group of related concepts. One can also argue for a third big idea to complement Pitjeng's big ideas as *the role of energy in the chloralkali industrial processes* and this would relate with Colleen's fourth big idea.

Analysis of the CoRe, through comparison of its three stages, reveals progression of Colleen's conceptual understanding of the topic, as well as a deepening knowledge of teaching this topic to her specific group of learners. Deeper analysis of the CoRe with a focus on one of its sub-sections (what you expect your learners to know) and only two of the big ideas identified as *Chloro-alkali Industry* and *Energy from the Chemical Industry* as represented below, reveals confusion about what the topic entailed. This confusion cleared up, as the process progressed.

Colleen's entry on what she expected her learners to know at the preparation and planning stage were too general reveals that she was still not clear about the foundational concepts related to the different sub-topics she presented as big ideas. She was also still confused about the focus of chloro-alkali industry as a topic. She thought the topic had a focus on acids and base reactions instead of oxidation–reduction reactions, a confusion that reveals initial unfamiliarity with the topic and might have been the result of the word "alkali" in the title. Even though a strong base (NaOH) and a strong acid (HCl) are produced, the processes of production involve oxidation–reduction reactions.

At the teaching phase, Colleen was a lot clearer about the focus of the topic and at the post-teaching stage, it is evident that she had become much more familiar with the topic and was much clearer about the types of conceptual gaps the learners brought to this topic.

> *I have spent the whole holiday doing the preparation for chemical systems as well as preparing term planners for grade 12, maths prep and prep for grade 9.*
>
> *I think I am ready to teach chemical systems – a lot of work has gone into the prep and it should be worthwhile.*
>
> *Feel more confident about the content – especially the new content, e.g. SASOL process which I was not very sure of.* (Colleen RJ-14/4/2008)

In the exception of the first and second prompts, the rest of Colleen's prompts are generic and do not focus on any content or concepts. Closer look at prompt 2 with a focus on Colleeen's big ideas 3 and 4 reveals that her choice of big ideas do not pull together related concepts under one idea and hence cannot lead to coherence in planning for learning of these topics. Indeed some content of the fourth big idea could be suitable under the suggested third idea to complement Pitjeng (2011)'s two big ideas.

Table 20: Section of Colleen's CoRe - Prompt 2

BIG IDEA/ PROMPTS	ECONOMICS AND THE CHEMICAL INDUSTRY	THE FERTILIZER INDUSTRY	THE CHLOR-ALKALI INDUSTRY	ENERGY FROM THE CHEMICAL INDUSTRY
2. What do you intend your learners to learn about this idea?	Facts about the chemical industry, designing and operating a chemical plant, cost effectiveness, chemical and economic challenges, manufacture of sulfuric acid [Contact Process}, uses of sulfuric acid, [car batteries and as drying agent] sources of hydrogen and nitrogen for the Haber Process, the Haber Process and ammonia production in SA. Differences between by-products, waste products and feedstock, chain of production	The nitrogen cycle, Plants, animals and nutrients, Fertilizing the soil to grow food, Nitrogen fertilizers, Manufacturing of nitric acid and the Ostwald Process, Uses of nitric acid and the decomposition of nitric acid, phosphorous and potassium in fertilizers, Effects of fertilizers on humans and the environment, risks and benefits. Essential nutrients, functions of NPK in plants, four major elements for human nutrition, utilization of chemical elements for particular functions-primary, secondary and micronutrients. Sources of NPK, Rates, yields, neutralization, flow diagrams, sources of potash and eutrophication- causes, consequences, prevention, ways to solve the problem, use of fertilizers on humans and environment.	Chlorine and its relationship to health, purification of drinking water, Electrolysis in manufacturing [diaphragm cell, Castner cell and membrane cell], manufacturing soap and detergents, synthetic detergents [wetting ability] and how surfactants work, science and our world- Chemicals deadly or saviors? Challenges to chemists in the 21st century Identify benefits and risks to human kind from three types of cells; give flow diagrams and answer questions on unknown process connected with these products, impact of use of these products to humans and their environment.	The petro-chemical industry, SASOL, gasification of coal, hydrocarbon synthesis. Production of methanol from synthesis gas, hydro-cracking, other synthesis sites and production options, Electrical energy from batteries, primary and secondary cells, designing batteries, zinc-carbon cell, mercury cell, lead acid batteries, battery ratings, electrolytes and car batteries. Need SA has for chemicals that coal as a resource can meet? Be able to interpret and use data about production, consumption of raw materials, safety, identify social and economic benefits of SASOL production. Identify environmental issues and safety precautions in the plant. W=Vq Cell capacity and use of amp-hour, features of cell structure, internal resistance and distance between the electrodes, current and surface area of electrodes, cell capacity and amount of electrolyte.

Analysis of Colleen's CoRe from pre- to post-CoRe reveals that even at *preparation* stage, Colleen gained a fair amount of understanding of what the CoRe as a cognitive planning tool was all about. It was at this stage that she came up with what she considered to be big ideas and which she stuck to for the rest of her study. Even though one could argue that the big ideas she came up with were too broad and could each be an independent topic with its own CoRe, these were not just ill-conceived topics, but her original conception of themes around which the knowledge area of chemical systems could be built in grade 12. Consideration of Colleen's overall CoRe in terms of the 3C-3S analysis scheme (table 4 in chapter 3), reveals a meta-cognitive planning structure which is sound and adequate in terms of correctness, conceptual depth and connectedness.

The suggested idea of organising *chloralkali industry* topic into three big ideas drawing from Pitjeng and Colleen's inputs could that:

1. the big idea of e*lectrolysis of sodium chloride involves a redox reaction* can deal with the following concepts: electrolytes in solution, ionization and conductivity, oxidation numbers, the difference between oxidation and reduction, strengths of oxidizing and reducing agents, table of electrode potentials, balancing redox reactions.

2. the big idea of *the chloralkali industry plant has impact on the societal, economic and environmental issues* can deal with electrolysis in manufacturing (diaphragm cell, Castner cell and membrane cell), manufacturing soap and detergents, synthetic detergents, chlorine and its relationship to health, purification of drinking water that is impact of use of these products to humans and their environment as well as benefits and risks to human kind from these three types of cells;

3. the third suggested big idea (which could actually come second) *the role of energy in the chloralkali industrial processes* could firstly deal with a) the difference between galvanic and electrolytic cells in terms of electrolytic cell using electrical energy which comes from an external power supply-battery to drive non-spontaneous reactions while galvanic cells generate energy themselves; b) and secondly with electrode potential, electrical energy from batteries; c) and thirdly with their applications as primary and secondary cells, zinc-carbon cell, mercury cell, lead acid batteries, electrolytes and car batteries; electrolysis in manufacturing with focus on the use of the three types of cells: diaphragm cell, Castner cell and membrane cell in chemical industry.

As discussed in the next section, Colleen's move to focus on the whole grade 12 chemical system set the whole research process on an extraordinary and difficult path.

Peer Engagement and Curricular Saliency

Even at the beginning of the programme, we encountered what was initially perceived as a logistical problem, in terms of when the Chemical Systems theme had to be phased in, according to the teaching plans proposed by the department and adopted by all schools. In the case of Colleen, consultation on this issue revealed a lot about how her strategic knowledge related to curricular saliency evolved with the process. As reflected in the exchanges during a planning session below, at the beginning Colleen's conviction and doubt

about bringing chemical systems forward were vague and based on logistical concerns, as well as on imbalances between physics topics and chemistry topics.

> *'Cause it will be actually easier for me personally but I know with all the stuff that we did last week to do chemical change, I mean, chemical systems with my matric 'cause with my matric … different chemicals so to go to chemistry with my matric is easier than with my grade eleven because at least I feel that the balance is better. Okay I'm the only one left in this position 'cause I think we decided … so I would be able first to do them with the matric but I don't want to mess up everybody because that will be like not working … collaboratively.* (hon-proj-plan session)

Besides this issue, Colleen's attitude at the beginning of the process was unsettling and domineering. She kept dominating the discussions, and also jumped from one point to another, raising legitimate yet scattered concerns about how the process would not work.

> *Colleen: I will have to organize with my boss, my boss is actually the way it should end. I think I can probably be able to bring it forward but I'm just saying it's a problem for everyone and you've already planned for the year and whatever and it's right at the end.*
>
> *Noma: Yah, I can bring it forward as well.*
>
> *Colleen: …it forward. In reality also unbalances what you are doing, coz immediately when you can't keep a balance between physics and chemistry; we will start off with matter and materials that we were meant to start off with. And if we go straight from here to chemical systems, we need to be doing chemical change before chemical systems?*
>
> *Sipho: I think it can be done.*
>
> *R: It can be done?*
>
> She then jumped into logistical issues.
>
> *So I am now not at a position, where I thought it was gonna be on this particular day. So it is very difficult to say to you "Come to me in my double period, on the 3rd of May or whatever"; because that's when I am gonna be teaching. I have to make that arrangement much closer to the time. I brought my time table but I don't think it's going to actually help you.*
>
> *R: Ok, that's why I was saying "let's also communicate with sms, if we have made an appointment, if we have problems"...*

It is interesting that Colleen felt that doing chemical systems at grade 11 immediately after they completed matter and materials, would be more problematic than bringing the grade 12 chemical system forward. Grade 11 matter and materials deals with the following topics: ideal gases and thermal properties; atomic combinations; electronic properties of matter and atomic nuclei, while "chemical systems" deals with: exploiting the lithosphere and atmospheric chemistry. Actually, a closer look at the grade 11 syllabus reveals that, in fact, the best way to structure the grade 11 topics is to start doing chemical systems immediately after teaching matter and materials, as it offers foundational knowledge of the concepts which is applied in chemical systems.

C: Ok, I've had a little chat with my supervisor – whether she is happy with me bringing it forward because it's also going to be towards the end of Grade 12. But I think she will be happy doing that then not having any physics for the Grade 11, but I need to discuss that with her, I need to like finalize.

Then all of a sudden, out of the blue, she brought up logistical issues again.

Colleen: You will never get it coz this one can be playing cricket and that one can be playing netball and that one can be playing …

Researcher: Yah, maybe in your case but I'm sure that all of you have different contexts and different dynamics you are working with. So, it cannot be a blanket strategy. We'll have to accommodate everybody according to their unique setting. And in your case you must remember that it doesn't have to be the whole grade 12 chemical system section. It could be that you focus your study only on one of the systems or one of the four themes. You will be drawing from several resources I will be pulling together and hopefully this thing with Heinemann will come through so maybe you could focus on developing lessons and tasks which are addressing LO1, LO2 and LO3 working with just one of the systems and not the whole chemical system section.

From this exchange early in the process during the second session, it is clear that Colleen was advised that she did not have to treat the whole of chemical systems, but could choose just one topic to focus her study on. This was also reiterated several times during the process. It was also made clear that, if there was any big problem with bringing chemical systems forward, the focus of the study could shift from chemical systems as a theme but explore any other theme with a focus on the three learning outcomes. Aware of all these options, Colleen ultimately decided to plunge herself in and focus on the whole of grade 12 chemical systems, a move that points to her initial lack of understanding of the topic and the context she was working in.

The best strategy, which was pointed out, not with such specifics, during the feedback session of the presentation of her CoRe, could have been to focus on only one of the systems e.g. batteries, and couple it with the relevant topic in chemical change. For instance, if the focus is on *batteries* or even *chloro-alkali industry*, first introduce it by dealing with the theme on *electrochemical reactions*, which is put under the *chemical change* section. If the selected focus is on *fertiliser industry*, first deal with the theme of *reactions mechanics* under the *chemical change* section. This was pointed out during feedback on her CoRe presentation during one our collaborative group sessions.

I: But then do you see it, you've seen the framework; for instance I can see that you don't have to focus on the whole chemical system but you can actually combine some parts of chemical systems with some relevant parts of chemical change. For instance for your research project which is about batteries and it's a chemical system theme, you can start with and combine it with the electrochemistry part of chemical change. Actually the research project is an extension of the electrochemistry part of chemical change which is addressing LO3. The way they have structured chemical systems actually was just to group together different themes into case studies but when you look at them they are the extensions of chemical change topics which are addressing LO3.

Colleen: That's true and I think when we get used to the curriculum, … 'cause I think when we get used to the curriculum I am 'gonna' do things now quite differently to the order in which… because you can cover aspects of different topics on this.

Noma's feedback below to Colleen's CoRe presentation is really quite profound and further attests to her understanding of what big ideas are, because here she outlines possible big ideas around which Colleen's vast theme could be built.

Noma: And then on the big ideas, I should think maybe we are not going to put it in the same way, but with the first idea, I should think the first and the second, I should think they are common because, I should think the number one with my I would refer as human and personal impact whereby the we look at what chemicals does the chemical industry use ehh to meet the needs of a growing population … and for number two I would refer, how does the environment as a natural resource meet our human needs so number one and number two we are actually looking at that, you can actually see the relationship between the two so that you can see that… and then … the chemical reactions whereby I am looking at the impact of science on the technological development and that one we actually looking at the types of chemical reactions involved and then I should think number four, I'm thinking now that's where I'm now going to look at the … the idea. (C&N CoRe Pres)

With this very good feedback from a colleague, one would have thought that Colleen would take up the good ideas and revisit her CoRe, to modify it to include some big ideas, even if they did not resemble what was suggested.

Chemical systems is a very broad theme, just like chemical change, matter and materials and other physics related themes, but the trick with it is that it is a unifying theme which deals with the impact of science on society and the environment, and therefore draws on knowledge of all the other themes. At FET, the different topics under chemical systems are actually extensions of chemical change, and matter and materials knowledge areas that place emphasis on the role of chemistry in daily life, with a focus on the effects of technological applications and processes on society and the environment. Broadly speaking at grade 12, the whole knowledge area of chemical systems requires a firm understanding of fundamental concepts in the structure and properties of matter, energy changes and rates of reactions, organic chemistry, chemical equilibrium and electrochemistry.

The topic *chloro-alkali industry* requires a very firm knowledge of electrolysis and, with its focus on the role of technological processes and applications in society and the environment, could serve as a very good extension which addresses LO3 for the electrochemical reactions topic under the knowledge area of chemical change. Actually, almost all the concepts identified as foundational in her fourth 'big idea' are also foundational for this topic, and the big ideas for this industry could be derived from them. These are: *Electrolytes in solution, redox reactions, ionization and conductivity, substitution, elimination and addition reactions, energy and chemical change, electrochemistry, standard electrode potentials.*

The foundational knowledge for the topic of batteries (torch etc. or electrochemical cells) would be the electric circuit topic under Electricity and magnetism in grade 12, as well as the electrochemical reaction section of the chemical change theme in grade 12. Therefore, as in the case of chloro-alkali industry, this topic could also be sequenced as an extension of the topic electrochemical reactions, thereby offering learners an opportunity to engage in LO3 tasks.

One can argue that a teacher with a strong curricular and science content knowledge would readily realize that even though the two knowledge areas, chemical change and chemical systems, are treated separately in the curriculum documents, as well as in most textbooks, in order to maximise learner uptake, the most sensible strategic move would be to synchronise the two themes.

Shifting Knowledge about Learners and Learning

For Colleen, the challenge was clearly not just addressing a new science topic within the framework of a new curriculum; the challenge was also that she was operating in the new context with unfamiliar learners, and thus reveals very interesting dynamics of how the different knowledge domains interface in the development of her PCK.

Colleen's reflections below reveal that she was very optimistic about her learners and obviously had false assumptions and sense of their science content knowledge.

> *Had a double with my grade 12 class and started with economics and the chemical industry. Had a group discussion and the girls participated well.*
>
> *I think the learners are interested in this new section and that their interest was sparked by the research project which they have started.*
>
> *Maybe I could include some kind of role play or debate next time.*

The following day's reflection indicates that Colleen underwent what is referred to as implementation dip, as she was dismayed by the discovery of the poor content knowledge level of her learners:

> *Learners had to write down what they know about sulphuric acid. Most of them were horrified when they were asked to do this. Some could not even write down the formula!!!!*
>
> *Am a bit worried about how much chemistry was taught last year. It is always better when you know what work they have covered.*
>
> *I think teaching this section before the other chemistry sections could be very difficult*

Another thing is that hard work, and very good organization and planning do pay. Colleen's reflections below illustrate how *learner's feedback* leads to increased knowledge of *the learners and the learning* process, which in turn leads to a sense of fulfilment, as well as overall affirmed professional *image and capacities*. It should be noted that, compared to the other three teachers, Colleen fared extremely well for a new teacher in a new school. She worked extremely hard. Never once did she drop the ball as far as the quality of her the classroom inputs were concerned, by focusing on her own studies at the expense of school work. She worked very hard to keep the two worlds going and maybe three worlds, because she seemed to be a very dedicated wife and mother.

The excerpt below reveals a lot about Colleen's epistemology. One can argue that Colleen's thinking about how learners learn best is teacher-centred because it is based on her own subjective conclusions about her learners, as well as the measures she as a teacher gives. There is no indication of how the students themselves interact with their peers or with the teacher about the topic. One can also argue that her concern is on creating a classroom environment that involves the learners, without emphasis on how what they bring to the classroom, will shape the instruction.

I think when they are interested.When you can capture their interest, where you can get something to be real for them or not divorced from reality, not divorced from their lives – so you can put it into perspective, uhmm so I suppose it LO3 – uhmm – where you make that meaningful in the context of their lives – so they can relate what they are learning in class to something that they already know about – it's not always so easy but they are probably going to learn it best when they are interested in what's going on. (Colleen Teach Belief-int)

When it comes to strategies, one could integrate towards learner-centred approaches. The excerpt below shows efforts which were made to try to raise Colleen's consciousness about the importance of starting by identifying learners' misconceptions.

R: Okay that's one thing, and another thing is that with electrochemistry, I mean particularly the task you plan to give them on batteries. Are you intending to do, I mean to make prior inputs? The reason why I'm asking is that I am still on the misconceptions. I gave you an article which highlights the common misconceptions revealed by research on the topic of electrochemistry. It would be good if at the beginning you could try to elicit their existing ideas by either asking them to do a concept map or use the questions used in the article to bring their pre-conceptions to the fore. (Colleen&Noma CoRe-pres)

The excerpt below shows that Colleen was given detailed advice on the strategies she could use and support materials to draw from, to start her teaching by identifying learners' pre-conceived ideas, and letting these direct her teaching, an opportunity which for reasons that were not apparent, she did not take up.

R: ... You can get them to recognize and take ownership of their misconceptions by using strategies such as cognitive conflict with some of the activities at the beginning when you make those inputs on

electrochemistry, and see how they respond to that and see whether those misconceptions are going to go into their research projects or will they have made shifts? You know I am thinking of this format because … those 5Es are good to ensure that your inputs take a constructivist approach to learning. Basically the five stages could be five lessons which begin with eliciting the learners' conceptions about the topic. It could be an engage lesson, then the explore, then the explain, the elaborate and then the evaluate lesson and what I think is that your research task comes at the elaborate stage. The evaluate stage could be a post-test or post-concept mapping to show whether the misconceptions were successfully addressed using the same tools you used at the engage phase.

C: I want to because I've read some articles and I find it very interesting. (Colleen & Noma CoRe-pres)

From the excerpts and the section of the CoRe below, it is interesting how Colleen's ideas and attitude towards learners and their learning shifted. From a position of being content with her own ideas of what she thought was good for the learners during the pre-teaching stage, she realised the importance of seeking their existing ideas and working with them, during the post teaching phase, thus confirming the situated cognition perspective of the power of learning through participation.

In the examination it was obvious that some learners did not understand that the electrolytes need to be soluble as quite a few chose insoluble salts of silver for the electrolyte in a silver half-cell. This could have been due to the lack of discussion about electrolytes on my part. Quite a few of the learners were not able to differentiate between the electrolysis in the chlor-alkali industry and the electrochemical cell. A few were unable to write down the reaction for the production of chlorine gas correctly. Quite a few reversed the reaction which showed a lack of understanding of the concepts of oxidation and reduction. (Colleen PaPeR)

Table 21: Portion of Colleen's CoRe

BIG IDEA/ PROMPTS	ECONOMICS AND THE CHEMICAL INDUSTRY	THE FERTILIZER INDUSTRY	THE CHLOR-ALKALI INDUSTRY	ENERGY FROM THE CHEMICAL INDUSTRY
6. Knowledge about the learners thinking which might influence your teaching of this idea?	**Need to engage the learners in the topic- capture their attention. Need visual material to help!** **Link hydrogen in Haber process to gasification of coal in SASOL process** **Need to assess what they know before starting the teaching process,**	**Need to engage the learners in the topic- capture their attention. Need visual material to help!** **Need to assess what they know before starting the teaching process,**	**Need to engage the learners in the topic- capture their attention. Need visual material to help!** **Need to assess what they know before starting the teaching process,**	**Need to engage the learners in the topic- capture their attention. Need visual material to help!** **Need to assess what they know before starting the teaching process,**

The prompt in the table above shows that Colleen was already out of her depth in constructing this portion of the CoRe, as there is lack of specificity of ideas.

The excerpt below strongly supports the situated learning approach, that learning happens through participation, because it is clear that, for Colleen to start appreciating the strong hold that learners' prior knowledge has on their learning of new concepts, she had to see it practically in her own teaching strategies and in the feedback she got from her learners' assessments.

My planning will definitely be done differently in the future as I realize the importance of checking on my own knowledge as well as the learners' knowledge. I will make use of CoRe and improve on what I have already prepared. (C research report)

I will not teach Chemical Systems before tackling Matter and Materials and Chemical Change in future. This was especially evident in the learners' lack of knowledge about redox reactions, cell potentials, nature of materials and spontaneous and non-spontaneous reactions. It was only done in this order because of the time constraints of the Research Project. (C research report)

From the excerpt below, it is quite evident that Colleen's PCK developed in terms of its various knowledge bases. She gained a lot of insight into her learners' learning, as well as getting to know them better. By using the CoRe, she also developed a more systematic approach to planning and reflecting on her teaching efforts.

My planning was done with a different motive as I planned for my own and my learner's benefit and not to fulfil some administrative need. I will definitely be planning differently in the future as I realize the importance of checking on my own knowledge as well as the learners' knowledge. I will make use of CoRe and improve on what I have already prepared. Engaging the learners in different ways was also a very positive strategy as the learners' responses to different strategies was enthusiastic and the standard of the work that they produced was excellent. (C-SAARMSTE, 2009 pres)

The excerpts below from Colleen's report confirm that she experienced a sense of growth which she felt was worthwhile, and was prepared and committed to adopt and extend it in her future practices.

This has been an amazing and worthwhile journey in which I have grown both as an individual and as a teacher. I realize that it is a journey without end as there is always room for improvement. I have overcome my fear of being videoed and am able to accept the positive criticism from my colleagues and have a more honest idea of my own teaching abilities. I will in future adopt and use a CoRe to help with my planning. I will also continue to use a reflective journal and both learner and educator concept maps. (C research report)

From Colleen's data and considering the *challenge, synthesis and enculturation domain* of the analytic model of this study, her framing and re-framing of practice came primarily because of learner feedback rather than peer engagement. Even though inputs were made during peer engagement to try to help her integrate possible learner misconceptions on electrochemistry into her approach, so that it became a more learner-centred approach, she did not react to these inputs. She only started reacting and appreciating the role of learner misconceptions from her learners' assessment feedback. These findings strongly support a situated approach to learning, that real learning happens when one engages with the context oneself.

6.4 Conclusions

As put forward by the critics of the new curriculum, the vagueness of concepts presented in the curriculum makes it inaccessible to most teachers and this point is supported by data from this study as it was apparent that the teachers were not able to abstract the big ideas directly from the curriculum documents on their own. As in the case of Noma, the curriculum did not

provide sufficient access to big ideas to allow them to plan coherently and this process needed mediation which this study was able to provide.

Even though the process was intensive, high pressured and even frustrating at times, the results show that engaging in self-studies helped the four teachers to develop their content knowledge for teaching chemical systems at FET level and enhanced their meta-cognitive skills in planning and reflecting on their teaching. The process offered teachers support to explore the conceptual structure of the new topics in ways that are not accessible directly from the curriculum. Noma, Sipho and Bongani worked quite well together and it is evident that their learning and shifts in knowledge base were stimulated and deepened during peer engagements. They worked very hard and most of the time were very well motivated and enjoyed the process. Both Noma and Sipho's uptake from peer engagements were quite substantial. Bongani struggled, but also learned a lot, even though he seemed to have problems of comprehension, and could not learn much from reading articles in other materials independently.

Colleen's three staged CoRe was her own individual work, and it reflects progressive deepening of her content knowledge of grade 12 chemical systems from one stage to the next. From the different excerpts included in the discussions, it is quite evident that both Colleen and Noma experienced a deep sense of fulfilment, as a result of a newly awakened commitment, and the confidence to systematize their teaching efforts, as well as taking an experiential outlook on their practices.

It is also evident that the CoRe, as a conceptual tool in research, is not just a data representation tool, but is in itself an intellectual design and product, which demonstrates and portrays the development of the teacher's PCK. These CoRes are, in themselves, evidence of the depth of the teachers' complex knowledge base for planning to teach chemical systems. As illustrated in this chapter, they provide a lot of information on thought processes, content and reflections prior to the teaching phase, and on how these capabilities grow, as the process progresses.

For me as a researcher, teacher educator and supervisor of the projects, the study shed light on effective strategies of linking academic programmes with school and classroom practices, to ensure that the theory promoted in academic programmes is translated into practice. I also gained a great deal of insight into the teachers' personal practical knowledge, as well as on how to use self-study as a strategy for supporting development of science teachers' PCK. To

be specific, I gained insight into the realities and constraints impacting on the teachers' classroom operations, curriculum change issues and their own personal issues, and how self-study can offer a sustainable and on-going strategy of response to change in the face of those realities.

CHAPTER 7
CONSISTENCIES, INCONSISTENCIES AND SHIFTS IN THE PROFESSED AND THE PRACTICE

7.1 Introduction

Literature has revealed the critical role played by teachers' beliefs in the process of reform because of their resistance to change. In this chapter, I report on the relationship of the participating teachers' beliefs about the nature of science, about the teaching and learning of science with their classroom practices, as well as how aligned their practices are with the aspirations of the new curriculum. All the aspects of focus and discussions are highlighted in the model (Figure 13 below) that serves as a framework for this study. For easy reference, all the different aspects of the model are allocated numbers and those aspects of focus and discussions in this chapter are highlighted.

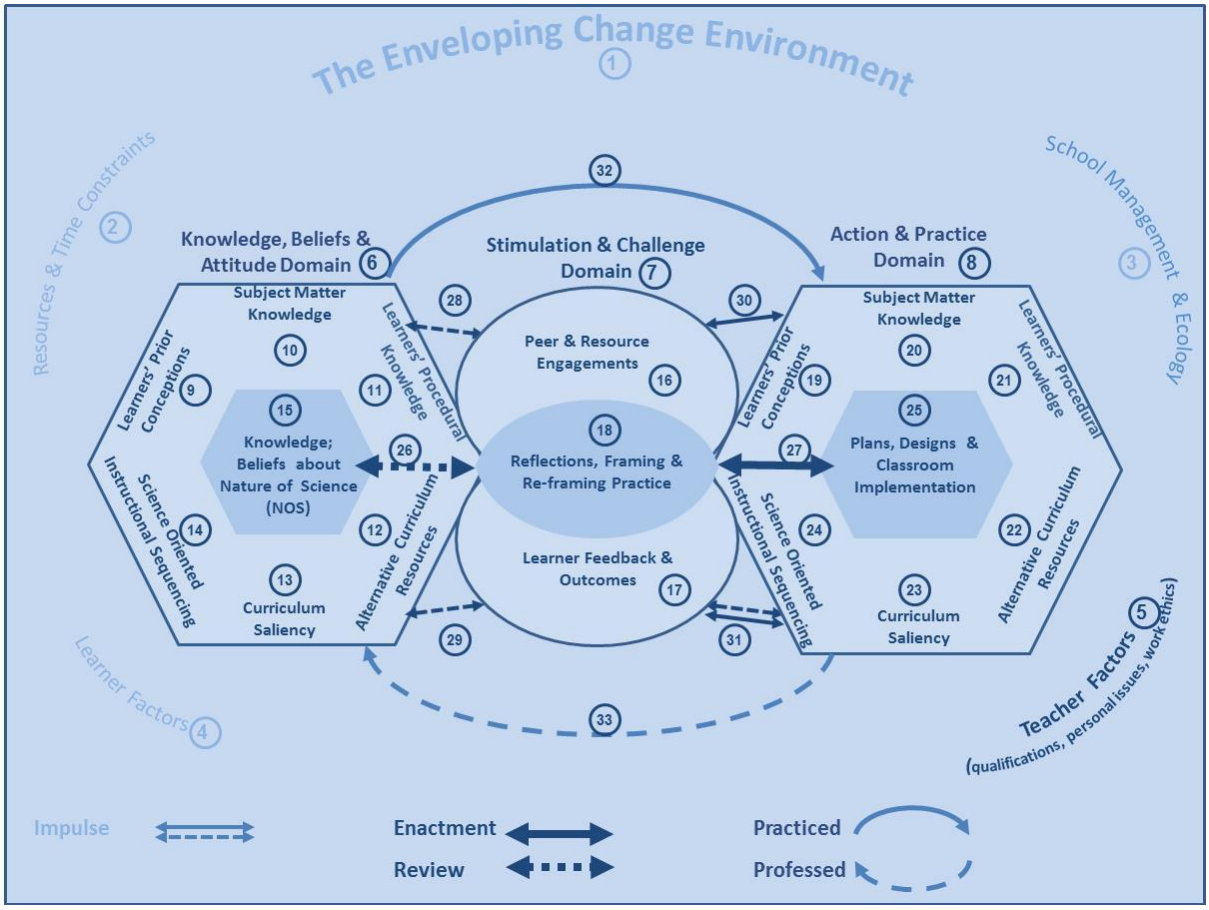


Figure 13: LTtP Chapter 7 Analytic Framework

Many studies (Aldridge, Taylor, & Chen, 1997; Pajares, 1992; Nespor, 1987; Munby, 1982) have revealed the critical role played by teachers' beliefs in the process of reform to explain their resistance to change. Some studies indicate that mismatches between belief and practice, in the face of reform, arise as a result of either the stability of the initial epistemological system, or lack of support for the enacted constructivist epistemology (Tobin, Kahle, & Fraser, 1990; Bryan & Abell, 1999). Teachers require shifts in knowledge and beliefs to be able to sustain suggested changes in practice (Haney, Czerniak, & Lumpe, 1996).

What the teachers say they do, and what they actually do in practice, is traced by considering the teachers' beliefs and views (6) on all of the six aspects of their PCK: their knowledge and views on learners' prior conceptions (9), their own science SMK (10), their learners' procedural knowledge (11), alternative curriculum resources (12) their curriculum saliency (13) the science oriented instructional strategies employed (14) and how these six aspects manifest themselves in the plans and designs they produce, as well as in their actual classroom actions (19, 20, 21, 22, 23, 24) within the domain of action and practice (8).

The study seeks to identify consistencies and inconsistencies in knowledge, views and instructional practices traced across a variety of data, to depict each teacher's changing profile towards reform-aligned approaches. The focus is on issues of alignment between what the participating teachers profess and what they practise in their classrooms within the framework of the new curriculum. The chapter addresses the sub-questions of the first key research question, which are:

1. How do the teachers' knowledge bases for teaching science shift, as they plan, design, teach and reflect on their practice?
2. Are there any relationships between their beliefs about the nature of science, the learning and teaching of science and their actual classroom practices?

I start by explaining the aspects of the model (fig 13) relevant to this chapter, and how it was used in the analysis of data that informs this chapter. I then move on to consider each teacher's profile on what they say they do, which portrays their *knowledge, beliefs and attitudes* (6) and what they actually do in their practice, which is captured in the *action and practice domain* (8). In the previous chapter, the focus was on extracting the knowledge underpinning the plans and the designs the teachers produced, and how engagement in these processes affected the teachers' meta-cognitive capacities. In this chapter, however, the focus is on the knowledge and the philosophy that underpin the teachers' plans, designs and their

classroom actions, and the consistencies, inconsistencies and shifts made, as they engage with the process. The other aspect of focus in this chapter is to see how the teachers are coping with the demands of the new curriculum, and the alignment of the teachers' philosophies and approaches, and the shifts they have made from teacher-centred to learner-centred orientations.

For the knowledge and views domain (6), data were mainly from the Teacher Belief Interview (TBI) responses (discussed fully in chapter 3), as well as from unstructured interviews on teachers' general practical strategies, on how they plan for their inputs, how they assess and how they manage the three learning outcomes in their classrooms.

7.2 Descriptions of the Analytic Frame

The Learning for Teaching through Participation (LTtP) model (fig 13) is used to synthesise a profile of each teacher on each of the two domains (6 and 8), which are the focus of this chapter using the relevant data collected. This framework identifies three interrelated domains (6, 7, 8), which encompass the teachers' professional world and present multiple professional growth pathways (26, 27, 28, 29, 30, 31). The domain of *knowledge and views* (6) pertains to all the capacities, thought processes and dispositions inherent in each teacher, which prompts certain professional actions and responses to different situations in their work, and thereby gains expression within the domain of *action and practice* (8).

Those actions, in turn, lead to certain consequences latent within the realm of *feedback and outcomes* (17), and present certain professional growth opportunities. The latter can be harnessed and used within the *stimulation and challenge domain* (7), to support teachers to engage and collaborate with each other, to systematise and reflect on their own practice. The domain of *stimulation and challenge* (7) draws not only from classroom *learner feedback and outcomes* (17), but also from external expertise from wider *peer engagements* (16), which should serve to reinvigorate and stimulate deeper learning.

This study engaged teachers in self-studies, with a special focus on the development of PCK while approaching a new topic in the new curriculum. In this chapter, the focus is on the interrelationships of the two domains (6 and 8), to see how each teacher's dispositions and beliefs about science learning and teaching relate to their classroom practices.

7.2.1 Knowledge, Beliefs and Attitudes Domain (6)

This domain is about the inherent knowledge, the beliefs and the attitudes which underpin teachers' practices in science teaching. One can argue that personal views are generated from knowledge, beliefs and attitudes of an individual about that specific aspect. Even though many educational researchers have different descriptions of what beliefs are, there is common recognition about the importance of understanding and describing teachers' beliefs because of their influence on the implementation of innovations in the classroom.

At the beginning of the study**,** teachers expressed their current ideas (perspectives and practices) about teaching and learning, both generally and in the context of a particular subject area, through interviews, as well as through completion of closed and open-ended questionnaires. The teachers' ideas about teaching, learning and nature of science were captured using a structured interview about beliefs (IAB). Nature of science refers to values and beliefs which are inherent in science, as a way of knowing and in the processes of generating its own knowledge (Abd-El-Kalick, 2001) with the aim of trying to further elicit insights into the ways those views affect their teaching practices (Aldridge, Taylor, & Chen, 1997). Within this domain, the teachers' utterances and responses are subjected to the six aspects which serve as lenses to discern the teachers' PCK.

7.2.2 Action and Practice Domain (8)

This is the domain where the teachers' inherent capacities gain expression during the planning phase, and where the teacher researches, learns new subject matter and plans for implementation. It also includes actual classroom implementation, as well as engagement and sharing with colleagues. The teachers planned, developed and implemented lesson tasks which aimed at addressing two or all three learning outcomes, while teaching chemical systems for the first time in FET classrooms.

Each teacher was encouraged to have a research, as well as a learning and teaching agenda prior to each lesson. Reflection sessions involving the whole team were used to view videos of lessons of individual teachers and offer critical feedback. This fostered reflective practice and developed more effective and meaningful approaches to judging ideas about teaching and learning, based on shared experiences. Within the action and practice domain, the teachers' plans, designed/selected tasks and classroom actions are subjected to the six images of PCK used in this study to discern the teachers' PCK.

7.2.3 The Aspects of Teachers' PCK

Two of these 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. These are *learners' prior conceptions* (9) and *learners' procedural skills* (11). The other four have to do with the teachers' science *subject matter knowledge* (10) the range of *alternative curriculum resources* (12) of the SMK the teacher employs, the teacher's *curriculum saliency* (13) knowledge and the types of *science oriented instructional sequencing* (14) the teacher employs.

Learners' Prior conceptions (9)

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 (11)

These constitute 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 minimised 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 other's ideas?

Subject Matter Knowledge (10)

This 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.

Alternative Curriculum Resources (12)

Each curriculum will have a full range of programmes designed to teach a particular topic at any grade or level and these will normally be accompanied by a range of materials used to teach those topics. This aspect is about the teachers' knowledge of a whole range of alternative teaching resources available 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 its 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.

Curriculum Saliency (13)

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, the 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.

Science Oriented Instructional Sequencing (14)

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.

In the next section I discuss each teacher's journey traced through their utterances, responses to research tools, their teaching plans and artefacts, as well as their actual teaching. For this chapter, data from interviews and classroom videos were analysed using this observation-analysis scheme. The following sources provided data for the professed teacher beliefs about teaching and learning interviews, structured interviews of teachers' practice, while sources of data for the practised were the PaPeRs (from the research report), the classroom video recordings and the produced lesson plans and assessment tasks.

7.3 Tracing the Teachers' Practice through the Artefacts and Classroom Episodes

The findings of this chapter are presented in the form of episodes which are compiled using each teacher's classroom video records, the tasks they set, their reflective journals and the accounts they gave in their interviews and reports to profile the consistencies, the inconsistencies and shifts portrayed in what they profess and what they practise. The episodes are then further subjected to the TBI categories, to discern how each teacher's views, plans and actual practices align with the ideas of the NCS. Since this section involves a lot of comparison between different stages of the process, the quotations used in this section are numbered for easy cross-referencing.

Even though a similar variety of sources of data was used in this chapter, each teacher's setting and how they approached the tasks were unique, and hence the data generated from the teachers' experiences varies a lot from teacher to teacher. These profiles draw across the set of each teacher's data, with the aim of revealing their unique journeys for evidence of profound learning, challenges experienced, points of stagnation and exciting and interesting moments, pointing to shifts in mind-set behind their practices. The *Beliefs-Practice cross case analysis matrix* (table 8) discussed fully in chapter 3, served to provide a map which gives coherence to the different pieces of teachers' data which allows construction of a profile for each teacher.

The *Belief-practice cross case analysis* matrix was used to profile the teachers' against the five categories based on variety of data which speaks to their convictions/utterances (beliefs) about teaching and learning as well as their actual acts in the classroom (practice).
The analysis begins with the case of Noma.

7.4.1 Noma's Case

Learners Prior Conceptions (9) and Learners' Procedural Knowledge (11)

From what she professed at the beginning of the process

In the excerpt below, which happened at the beginning of the process, Noma explains the strategies she employed to maximise her learners' learning. Her statement reveals that her focus was on creating a classroom environment where she could involve her learners by using a variety of activities that could help to facilitate their understanding of concepts. This placed

her as a *transitional* teacher (trans), who believes that learning happens when learners are involved, and are encouraged to do their own thinking.

> *Noma: umm I think I am giving them more work. (R: mmhhm) Emm I'm giving them more activities to be done – and try different ways of presenting the subject matter knowledge to ensure that they learn and understand that particular concept. (R: Okay) Ja for example ehh instead of coming up with definitions I'd rather introduce – ehh representations that can come from learners themselves.* (Noma practice-int) **(i)**

Other responses she gave about how she knows when learning is happening in her lesson, are still generic but interesting:

> *R … or how do you identify that they are learning?*
>
> *Noma: When answering questions and when they feel free to bring their books to you comparing their work with others and then you will be able to say here this is what you were supposed to do – but when they become quiet that becomes a problem yeah – you need to allow them to, if you put the question I allow them to state the question differently, the way you put the question if they don't understand and they can share ideas with one another, they actually learn more.* (Noma TBI) **(ii)**
>
> *R: Ok, how do you know when learning is occurring in your class?*
>
> *Noma: Participation from learners I would say participation, when there is no participation I will be running the talk show.*

Her response to the question of how she adapts her teaching to best represent the discipline of science is interesting, because it reveals that, even at those early stages, she was aware of the complexity and the intellectual nature of teaching. Good teaching is about the teacher being able to transform and package the science subject matter, in such a way as to make it accessible to the learners. What seems to drive Noma's teaching efforts, is that they should help learners to make connections, and realise that science is about making sense of what they experience in their everyday lives, rather than think of it as something foreign, or something they only meet in their science lessons:

> *Noma: You know when you tell somebody about science, we talk as if it is something that is not within reach — so what I normally do is I want to umm I normally change it in such a way – transform the knowledge in such a way that a person realises 'kuthi'[that] we are discussing our environment - you make it to be real you make it to be relevant, you want to make it to be sort of it, I don't know if I am understanding you very well but that is what – I don't want to say this is physical science as if we are talking about something in another world – so I am presenting it in such a way that you realise that umm I am solving problems within my environment; science is for as long you can explain why am I seated like this and my walking can be explained in terms of science – so I am bring it more to reality and everyday experience* . (Noma practice-int) **(iii)**

However, a closer consideration of the comment above, on how she positions the learners in the learning, reveals that it is about the teacher's transmission strategies, rather than the learners' construction of their own knowledge for themselves. This again places Noma as a *transitional teacher*, who is conscious that, to make subject matter accessible to learners, one

needs to link new concepts with their everyday environment, but still sees learning as being transmitted by the teacher, rather than learners being constructors of their own knowledge.

When questioned on how this translates to her classroom practices, her response below uses concrete physics examples to reveal that she knows what she is talking about, and that it is firmly entrenched in her thinking, as well as in her practical processes. It also reveals that her subject matter knowledge of the concepts she was illustrating is reasonably good:

R: Can you give me an example?

N:Like I've given you an example that when you walk you can explain using Newton's law, what makes you to be able to move forward – as you are seated you can explain in terms of Newton's law – the process between the chair and yourself or maybe – looking at – when you are applying Newton's law of motion. (Noma practice-int) **(iv)**

From what she professed at the planning stage

As expressed below during her CoRe presentation, within peer engagements (15) her learning and appreciation of possible learners' misconceptions did not only alert her to the role of misconception in teaching and learning, but also addressed her own misconceptions about the topic. It is quite evident that there is a lot of self-realisation in Noma's prior conceptions about learners and learning, and the role of learners' conceptions in the process:

Noma:Yyah and then we came on to the difficulties or the limitations connected with these ideas, so also on this one they gave some examples on the misconceptions that learners have and not only learners' misconceptions it's also misconceptions by the teachers or at least my own misconceptions. So whilst developing this we had to sit down through our discussion and I was able to understand myself my previous failures when I approached this idea that maybe this concept was supposed to be explained in this format only to find out, I also had some misconceptions on that, using the general knowledge that I had, since this is still a new topic, so besides developing the core, learning also truthfully, I sort of learned a lot ,especially the water cycle because there is a lot that I didn't know about it. (N&C CoRe pres) **(v)**

As reflected in the discussions and the excerpts in this section, one can discern a shift in Noma's utterances about learners and learning (9) at the planning stage (19) from the utterances she made at the beginning of the process. To begin with, Noma's views on how learning happens do not reflect any appreciation of the critical role played by learners' prior conceptions (9) and how these are addressed in the teaching process. This recognition clearly surfaces and dominates all other aspects in her utterances at the planning stage and this is an indication of a clear shift.

From the actions and the practice domain (8) during classroom Implementation (25)

In this section, I consider three aspects of Noma's lesson development to discuss the consistencies and the inconsistencies in the strategies she employs in her practice and what

she actually does in her classroom teaching. I also look at how the strategies she evolved during the planning stage are sustained in the actual implementation stage. I also seek to place Noma's strategies along the curriculum alignment continuum.

In the plans and the designs

The teachers were expected to use the available resources to develop their own, to address the science learning outcomes. Noma and Sipho decided to settle for existing tasks developed by the researchers and augment them with a few other worksheets they developed themselves, as well as those drawn from elsewhere. Noma's strategic curriculum knowledge (13) is reflected in the strategy she adopted, and how she managed to carry it through in the classroom materials (12) she adopted or modified, and in the actual lesson presentation in her classroom (samples included in Appendix P). The teachers were encouraged to explore the use of the 5-E curriculum design learning cycle because of its close alignment with the aspirations of the NCS, and Noma adopted this for her project (samples included in Appendix P). The 5-E strategy employs the constructivist approach to lesson sequencing by promoting the use of learners' prior knowledge. The five-phased lesson sequencing strategy begins with what is referred to as the *engage lesson*, which is meant to arouse learners' interest, as well as elicit their prior knowledge. The latter would be used to guide the follow-up instructional inputs. The next lesson in the sequence, referred to as the *explore lesson*, is aimed at giving the learners an opportunity to experience the phenomenon of focus, and allow them to explore questions and test their ideas through inquiry-based investigation and problem-solving activities.

The section that follows shows the plans which were put together through the framing and re-framing (18) process during peer engagement (16).

Actual classroom implementation

Noma implemented her project lessons during the school holidays, and, even though the invitation to participate was extended to all learners, she ultimately worked with the group of 25 learners who turned up. Her project was based on the water cycle section of chemical systems at grade 10. The weekend before her first lesson, she briefed the learners about the topic for the project they were going to work on, and gave them three pre-tasks to work on before the first lesson. Vignette 1 below, describes nature of the tasks which Noma gave to her learners to complete prior to her teaching, with the aim of eliciting and accessing their prior conceptions about the topic she was about to teach.

Purpose: *To introduce the topic by setting the context, raise questions and elicit the learners' existing beliefs*

Nature of the task: *The weekend before Noma implemented her project lessons, she briefed her learners about the project and the topic they were going to engage with. She then gave them three pre-tasks which she put together, for them to complete before her first lesson. The first pre-task was to draw a concept map of the water cycle, the second was to design a colourful, labelled A3 poster, depicting the main components of the planet Earth and to prepare a presentation on the importance of the sun for the planet Earth. The second task was accompanied by what she referred to as a marking rubric as follows:*

Levels	*Components*	*Importance of the sun*
4	*All mentioned*	*4 and above*
3	*Only 3*	*Only 3*
2	*Only 2*	*Only 2*
1	*Only 1*	*Only 1*
0	*None*	*None*

The third and last pre-task required them to read and study a two-paged extract, taken from the grade 10 Heinemann-RADMSATE Physical Science textbook which is on Solar Radiation. The concepts covered were quite substantial and included: the three types of radiation (visible, IR and UV radiation) constituting solar radiations, their nature, what happens to incoming solar radiation, their role in nature (driving the weather) in terms of the physical (warming) and chemical (photosynthesis) processes that happen when they are absorbed, both in terms of what is observed macroscopically and how it is explained microscopically (changes in

Vignette 1: Noma pre-lesson tasks

As reflected in the pre-tasks (vignette 1) that Noma gave her learners at the beginning, one can argue that Noma was aware of the importance of addressing the learners' prior conceptions (9). There is evidence of a conscious effort to build that into her initial strategies during the engage lesson. Also, a concept map is a powerful tool to reveal what learners know about any topic. (12)

This was quite a substantial amount of work to expect from the learners, especially during their school holidays. So, at the planning stage, one sees consistency in what Noma professed as a strategy she employs to maximise her learners' learning in quote (a) above: *umm I think I am giving them more work. (R: mmhhm) Emm I'm giving them more activities to be done – and try different ways of presenting the subject matter knowledge to ensure that they learn and understand that particular concept.* (Noma TBI)

Even though she is conscious that to make subject matter accessible to learners, one needs to link the new concepts with what they know in their everyday environment but still she sees learning as being transmitted by the teacher rather than as being constructed by the learners themselves.

Vignette 2 below represents stage 1 of Noma's *engage* lesson. This was a two staged lesson which took place over 2 hours and there were 22 learners in the classroom seated in two groups of five and three groups of four. In the first stage of the lesson which took place in the first hour, the teacher explored the learners' prior conceptions (9) based on two of the pre-tasks the learners were given a week before classroom implementation.

Episode 1

The teacher started the lesson by describing the three tasks she gave to the learners and finding out whether they completed the tasks. They confirmed that they completed their concept maps all the other tasks and she decided to focus on the second task which required them to design posters of the component of the Earth. All the groups confirmed that they were done with that particular task except for one group who had already started but were not yet done. This was a reasonable indication that the learners were used to being given a variety of tasks and activities by their teacher to do on their own as a strategy to enhance their learning.

The next thing Noma did was that instead of allowing learners an open floor to come to the front and present their work and justify their responses, she reduced the whole process to a question and answer session where she just demanded to know what each group regarded to be the components of the earth. The groups gave responses as follows and Noma failed to ask them to justify why they regarded these as the components:

Group1: solid, liquid, and gas.

Group2: biosphere, lithosphere, hydrosphere, and atmosphere

Group3: the sun, rain, wind and the clouds

Group4: the sun, land, water and air

Group5: the crust, mantle, outer core and inner core

In the next section of the lesson, instead of inviting learners to present their ideas on the importance of the sun, Noma turned the session into a question and answer session where she invited learners as individuals to say what they thought the importance of the sun is. She introduced each learner with the phrase: *without the sun …* and the learners gave very interesting responses which she just repeated as confirmation and moved further to invite further contributions. The learners gave the following responses (*without the sun: there is no weather, we have no temperature changes, we have no light, we are not going to have a water cycle*) which were not explored further excerpt for the one about not having *not the water cycle*. At that point she paused and asked the learner: *what do you mean about that*? *Can you elaborate?* And the learner responded with: *the sun is the one which heats the water so that the water vapour could rise into the atmosphere, so if there was no sun there would not be water cycle* and Noma responded with: *ohh that's beautiful* and she moved on to continue the process of inviting other contributions and the list followed as (*without the sun we won't be able to differentiate between night and day; we can't differentiate between winter and summer*; and at that point she made the comment in the form of a question: *so in other words it is also contributing to that factor of the weather patterns? Yes. Another contribution? Musa?* The learner: *We also feel the energy from the sun which warms our bodies; the sun helps the plants to photosynthesise, we use the sun for solar power to generate electricity...*

Vignette 2: Noma Engage Stage 1 Lesson

Learners' Prior Conceptions (9, 19)

The actual events of this lesson show that Noma was not able to sustain the ambitious plans she made. All in all, the tasks (12, 22) were rich enough to support Noma in exploring her learners' prior conceptions (9), as well as use those identified conceptions to further the learning and teaching process. Potentially, the teacher had at her disposal avenues to structure her lesson so that it used learners' prior conceptions (9) to engage the learners in a way that promoted development of their procedural skills (11) through presenting and justifying their responses. The instructional strategy (24) Noma decided to employ to get feedback on their pre-tasks, and the decision to exclude feedback on the concept maps (12, 22), really reduced the session to a cognitive question and answer session at the lowest level. It was clear from the learners' responses that they did their tasks and knew a lot, but the teacher failed to manage this knowledge to stimulate further learning. A potentially vibrant lesson, where learners could present their prior ideas (19) and all types of misconceptions, was totally undermined.

Noma's reflections at the end of the first engage lesson illustrate that learner feedback (17) served as a stimulus and challenged (7) her to frame and reframe (18) her practice on the aspect of her subject matter knowledge (9) and knowledge of her learners' conceptions (14).

The excerpt below reveals that the potential of the lesson was not only stifled by the strategies (24) the teacher employed, but also that the role of secure subject matter knowledge (20) played quite a significant part:

> *I had mixed feelings. I was excited by the implementation process in my self-study, at the same time felt very much intimidated by one group of learners that used geographical terms such as hydrosphere, lithosphere, atmosphere and hydrosphere. This really caused my level of confidence to drop.* (Noma post lesson-reflect)

Clearly Noma was thrown off balance and this might have led to the reductionist approach (24) she adopted for the rest of the lesson, in her effort to maintain power and not lose face with her learners. This adopted coping strategy on the part of the teacher reveals a lot about how she perceived her role as a teacher: as the sole information source who does not expect to learn from her learners. It is consistent with what she professed at the beginning of the process, to be her role as a teacher:

> *Noma: Ok as a teacher I know I want to say I can take myself to be a – to my learners and I can take myself as a person who can guide them through the process of learning – whereby in whatever they do I can help them to become more eligible.* (Noma TBI)

On the positive side, the excerpt below from Noma's reflections shows that she reflected deeply (18) about ensuring that, in future, she should prepare thoroughly and make sure that she was on top of her subject matter (20). It also reveals that teaching is a balancing act and Noma needed to fall back on secure subject matter knowledge (10, 20), as well as knowledge of her learners' conceptions (9, 19), to ensure quality inputs.

> *I realised that I had to revisit the components of the earth and address learners' misconceptions.*
>
> *The fact that I felt that learners had some background knowledge of this topic motivated me to go and make a thorough preparation for my next lesson.* (Noma post lesson reflect**)**.

Another positive aspect revealed by the excerpt above is the role and the power learners have, in holding their teachers accountable and in shaping the quality of their teachers' inputs, when they take ownership of their own learning.

Looking at the lists of responses the learners gave, one can see that the variety of responses the learners brought to the fore presented an opportunity for Noma to explore what is meant by components, as opposed to structure, as well as exploring components as connecting systems. The fact that Noma did not ask her learners to justify their responses also closed down what potentially could have turned out as a great learner conceptions engagement lesson.

The nature of task 2 and the way it was used during the lesson reveals a lot about Noma's instructional and assessment orientation (24). At first glance, when one reads the fact that learners are requested to *design* and then to *present,* one gets the sense that the task is open-ended and complex enough to elicit a variety of responses (22). These can be channelled to quality interactions and inputs, where learners' prior concepts (19) on a variety of aspects are explored. The rubric generated also brings into question Noma's understanding of what rubrics are used for in assessment. They are normally used on open-ended tasks, to ensure accurate and fair assessment, by communicating expectations of quality, as well as delineating consistent criteria for grading. A closer look at the rubric reveals that what the teacher expects from learners are closed task responses.

Even though Noma could not expand extensively on her learners' ideas, at the end of this part of the session, she managed to use the terminology she had just learned from her learners to link her planned components of the Earth (air, water, ground and living organisms) and bring everything to a dignified conclusion.

Noma's journal shows clearly how her reflections on the process after the session, allowed her to think of the learners' contributions further and identify what she regarded as the misconceptions they had.

I learnt about my learners' knowledge of the topic. In this lesson, reflecting on what learners said and marking the learners' books, I gathered ideas of what my learners know and do not know. The following misconceptions emerged in the lesson:

- *Some learners perceive the components of the earth as the structure of the earth.*
- *Some learners confuse phases of matter with the components of the earth*
- *Some learners associate components of the earth with climate*
- *Two of the groups regarded the sun as a component of the earth and yet it is another planet*
- *One group of learners had the correct geographic terminology of the components.*

While Noma was busy dealing with her learners' misconceptions, her own misconception of regarding the sun as a planet surfaced. What is very interesting is that she realised that her strategies remained teacher-centred and that she also reflected on what she should do to change the situation.

My practice still reflected a traditional approach other than the learner centred approach.

In my presentation I should allow learner participation as much as I can. (Noma post lesson reflect)

Below is Vignette 3 which is a continuation and captures stage 2 of Noma's engage lesson. Here Noma employed a fill in missing word concept map task (included in appendix O) which she designed on her own.

The concept map reflects Noma's good grasp of concepts constituting nature of solar radiation which she clearly learned during peer engagements as it was one of the identified big ideas during the construction of the team generated CoRe (Appendix M).

The vignette reveals that Noma's content knowledge about solar radiation improved remarkably as she is clear about the three types of radiations that constitute solar radiation, their nature and the types of changes they effect. Not only her content knowledge has improved, but also her strategic curriculum knowledge (13, 23) which is reflected by how she sequenced and addressed the concepts as well as her assessment and instructional knowledge (14, 24) were reflected in the quality of the task she developed and set (12, 24).

The concept map task itself was a good and comprehensive tool (12, 24) because it captured almost all the concepts entailed in the extract and those which surfaced during the brain storming session. The distinctions between the three types of radiation constituting solar radiation were captured in depth in terms of their distinct nature and energy and the types of

changes they responsible for in nature. It also covered how the radiation is transferred and distributed as it passes through the atmosphere with its absorption by the lithosphere and the hydrosphere resulting in weather changes. The critical aspect missed and is captured in the book extract and also did surface during the brain storming are the changes that happens when it is absorbed in the biosphere.

Purpose: the lesson was continuation of engage lesson still with the purpose of *introducing the topic by setting the context, raising the questions and eliciting the learners' existing beliefs*

Nature of tasks:

In the second stage Noma employed two activities to engage learners. The first activity which forms the fourth task of the engage lesson was designed by Noma herself and involved concept map completion task on solar radiation. It was a good task and really served its purpose of engaging the learners effectively with some of the main concepts contained in the pre-task extract.

Episode 2

Noma started the session by using a presentation strategy to briefly recap the main components of the earth as well as to use the chalkboard to capture the importance of the sun and its effect on these on the components.

She then moved on to introduce the fourth task which involves filling in missing words in *the Sun as the main source of for the planet Earth* concept map. She used this activity for summative as well as formative assessment purposes. She reminded the learners about the extract they were tasked to go and study on solar radiation and gave the learners 10 minutes to work individually in completing the concept map task. As she dished out the task she said: *I want you to complete this individually which will be an indication that you did complete the work that I gave you last week.*

After 10 minutes she asked the learners to exchange their work across groups and do peer marking. Before they could commence with peer marking she started a discussion on *what happens to the incoming solar radiation* using the diagram in the book extract which shows how solar radiation is distributed into different percentages as it passes through the atmosphere and 80% reaches the ground on a clear day and only 45 to 10% manage to reach the ground on cloudy days. During this section of the task even though she posed some questions while explaining the diagram, she did most of the talk because she did not give the learners a chance to respond but went on to provide answers herself.

She then moved on to marking of the task and instructed learners to either use a pencil or a pen to mark (implies that there are right and wrong answers) each other's work. She engaged learners to some extent by reading the questions out and inviting responses from the learners themselves. She however did a lot of expatiations in which she did not engage her learners in constructing. What was good about her strategy was that during her expatiations she kept on referring to and acknowledging the points which were raised by the learners during the brainstorming session.

Vignette 3: Noma Engage stage 2 lesson

On the general pedagogic front, this episode highlights consistency in what Noma claimed she did in the excerpt below, to manage individual and group work in her classroom, in order

to ensure that each learner had an independent uptake in the teaching process. It indicates consistency between the professed and the practised.

> *I tell you I am very strict when it comes to making sure that people work individually because you find that when in a group work, what I want them to learn is that umm, even if we are sharing but as an individual you must write your own work – even if we mean we are writing the same things. I don't have a problem with that. umm They come from a situation which whereby they were allowed to do a lot of work in groups – so in my first sessions what I normally do is instruct learners that they must write on their own, so sharing I am doing it as they discuss but I don't normally allow it maybe later when they submit their work ... What I normally tell them is I don't want them to introduce themselves, I always remind them don't introduce yourself, I will always remember you tomorrow but the only way – is through your work, every time you submit your book I will remember you.* (Noma practice-int)

Vignette 4 below forms part 3 of the engage lesson (22)

Nature of task:

The second activity was a nine-itemed multiple-choice diagnostic test (Nakedi, 2004 MSc report) to explore the learners' conceptions of the particulate nature of matter and its role in explaining the behaviour of water molecules in the water cycle.

Episode 3

In this part of the lesson, Noma employed a consensus strategy where learners had to complete a multiple-choice question task individually, then discuss in their groups to come up with collective group responses which were then presented to the teacher to capture on the chalkboard for whole group discussions. The task was designed to elicit learners' prior concepts in relation to the particulate nature of matter. The items are designed in such a way, that they expose the learners' understanding of the relationship between what is being observed at macroscopic level and the microscopic explanatory model given in terms of particle representations.

Vignette 4: Part 3 Engage Lesson

The session was very lively, with vibrant discussions, and it was clear that the learners enjoyed themselves. As noted in Noma's reflections below, she was happy with this part of her lesson and felt that she managed to engage her learners more effectively.

> *It was an exciting lesson; there was a slight improvement in my practice. I managed to engage my learners in the discussion and allowed them to answer before interrupting. It was also frustrating in a way because I could not handle some misconceptions.* (Noma post lesson –reflect)

As reflected in the comment above, Noma was also thrown out of balance during this part of the lesson when she could not justify the option she chose on the items below to the learners' satisfaction.

The explore lesson on the next page showcases Noma's efforts to carry through the learning of engaging learners' prior conceptions (19) which she acquired at the planning phase of peer engagement (fig 1), as seen in the excerpt below:

> *... another challenge was that one of knowledge of learners' thinking which influences your teaching of this idea, ...It's showing the abstractness of what we actually have to present, because with this water cycle, you have to also indicate the relationship between the microscopic and the macroscopic. So it's a bit abstract,*

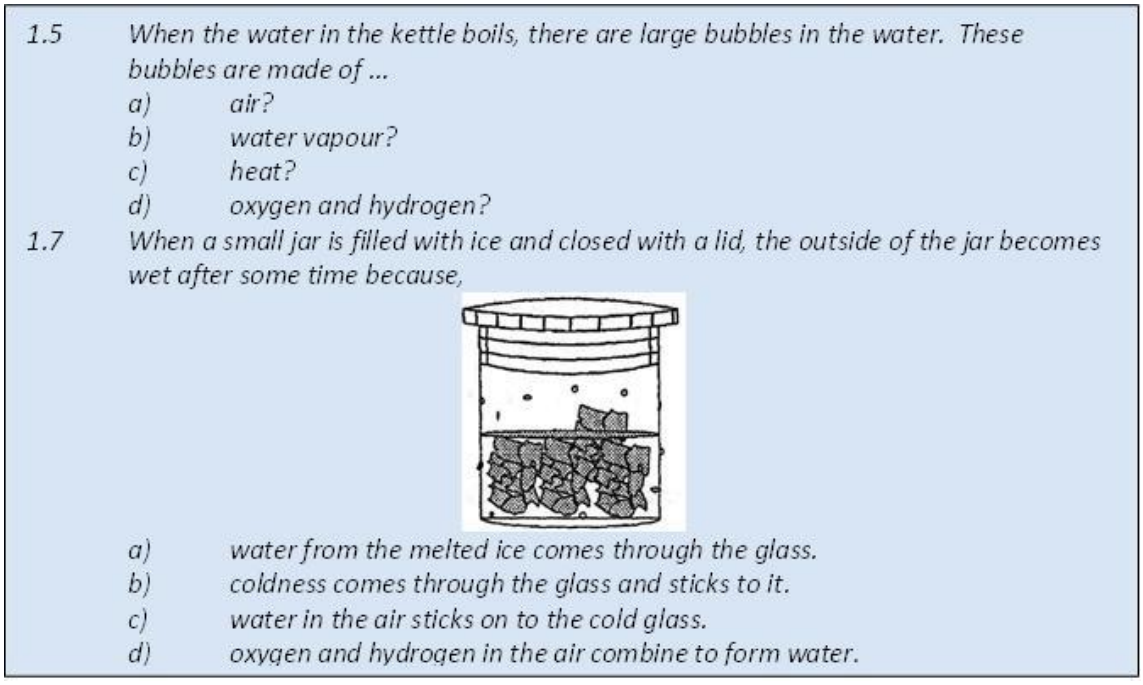
there are lot of things a person has to think about when it comes to number six. I had a serious challenge with that one. (Noma & Colleen CoRe pres)

In this lesson, Noma revisited the issues but even though it is apparent that she discovered that the option she chose previously was wrong, she just focused on explaining that the sign of a bubble indicates that a gas has been evolved and going on to give examples of instances where bubbles are formed and there is no heat involved. She did not commit to whether the gas is air or water vapour.

Water cycle as a topic involves phase changes where liquid water evaporates, water vapour condenses as well as precipitation and therefore this was a tool to support the teacher to elicit learners' misconceptions around these concepts. One thing that is also clear is that the success of these lessons could be attributable to the role of well-designed tasks and curriculum materials, in supporting teacher inputs and stability during their teaching efforts.

Noma's Explore Lesson

They argued that the correct option for 1.5 below was *heat* and not water vapour, as Noma was suggesting, and Noma also got confused and could not substantiate her choice.



1.5 When the water in the kettle boils, there are large bubbles in the water. These bubbles are made of ...

a) air?
b) water vapour?
c) heat?
d) oxygen and hydrogen?

1.7 When a small jar is filled with ice and closed with a lid, the outside of the jar becomes wet after some time because,

a) water from the melted ice comes through the glass.
b) coldness comes through the glass and sticks to it.
c) water in the air sticks on to the cold glass.
d) oxygen and hydrogen in the air combine to form water.

Vignette 5: Sample items of Noma Engage task

Unfortunately Noma was still not clear how to justify that the bubbles are made out of water vapour rather than air as suggested by some students. This is one of the most prevalent of all the misconceptions about this phenomenon because when boiling water one actually observes two types of bubbles.

The teacher needed to clarify that the dissolved air in water, forms bubbles along the walls of a container just as the water starts to get hot. But since the solubility of gases decreases when temperature increases, by the time water reaches boiling point all these air bubbles have already bubbled out of the water and what actually happens at boiling is that water and its vapour are at equilibrium and therefore the bubbles are made out of water vapour. Other learners chose heat as an option and here also an opportunity to clarify that heat was a form of energy transfer was missed.

Purpose: *Aimed at introducing the topic by setting the context, test, learners' ideas investigate and solve problems.*

Nature of the task:
The activity is referred to as – *where does the water come from?* - explores all three phase changes of water but with particular focus on condensation. The worksheet was design to force learners to shift and make links between the macroscopic observations and microscopic explanations. The questions are structured in such a way to ensure that as learners make their observations they think of the explanation of what they are observing in terms of the microscopic changes.

Lesson Description
There were 26 learners with two groups seated in groups of 5 and four in groups of 4. The lesson happened in three parts because Noma started by addressing issues which surfaced in the previous engage lesson on particulate theory of matter, where learners challenged the options she chose in a diagnostic multiple test and she could not substantiate her choices.

Part 1

She started by reminding the learners about the debate they had regarding what constituted the bubbles formed during boiling. She started by writing on the chalkboard and got the learners to complete the statement: *Bubbles are caused by ...* Some learners chorused *heat* and others *air*. She ignored those who proposed air and completed her sentence with *heat*. She then focused her explanation on why she says bubbles were not formed by heat as some were suggesting. She gave several examples of instances in which bubbles are formed but there is no heat like in the case of ENO, citro soda, and coke.. She explained that bubbles are just indication that a gas is evolved and it's a reaction. She also wrote the equation on the board as she reminded them that when zinc reacts with hydrochloric acid gas is evolved and there is no heating that takes place. After these explanations she found out from the learners whether they were convinced and they accepted.

Part 2

Noma then moved on to introduce the lesson of the day by pointing out that the lesson was based on a practical investigation. She started by revisiting another issue that surfaced and led to animated debates in the previous lesson which involved the question of the origin of water on the outside of a beaker containing icy cold water . She had actually put ice in a beaker and put it outside of it to melt so at that time she went to take the beaker and bring it inside for the learners to observe and discuss further. She came back with the beaker and called for the learners' attention...

Noma: Right. What I have actually done – I put ice inside the beaker – it was dry. But if you can check now there is water (wiping the outside with her hand and showing holding it up and open for the learners with the expectation that they would see that it is we). Are we together neh?

Learners: chorus Yes

Noma: Let us go to that one, I should think that the last time I did not explain it clearly to you. Right. When I say, this water is due to the air, I'm referring to the water vapour which is in the atmosphere. Which comes in contact with this cold surface and then it starts to condense. Are we together? When I listened to myself saying it comes from air – maybe in your mind you had this thing that air is the mixture of gases. Yes, but remember, we also have water vapour which is here. Because if it is dry we will not have a situation which is like that. Are we together neh?

Learners: yes

Noma: so, it is the air which is in the atmosphere, it is the water vapour which is in the atmosphere. So when it come into contact with the cold surface it is going to change back into water phase. That is why ***mange enza (I do)*** *so (wiping the outside of the beaker with her hand and holding it up as if she expects the learners to see that it is wet) can you see that it is wet?*

Learners: Yes

Noma: and the same apply let's say you take a bottle of coke or milk anything into the refrigerator. You take it out, you wipe it, but after sometime, what is it that you are going to see? You are going to see water outside. So please good people, its' the water vapour from the surrounding. Are we together... (the lesson continued with the same pattern for about 5 minutes)

Part 3

Noma: Ok fine. So now what we are going to do - we are going to start with our activity. We are together neh. So what I am going to do I am going to give you some glass beakers and those glass beakers I am going put some ice and you will also have a thermometer. Now I want you to begin with that activity. You can use your pencils to answer the questions.

For the next 30 minutes, the learners worked within their groups to carry out the investigation and discussed the answers to the questions accompanying the activity. Noma allowed her learners to work with the materials and carry the investigation on their own while she walked around from group to group, listening to their discussions and attending to their questions...

During discussions...

Noma: where does the water outside the beakers come from?

L1:

3 Where does the water come from?

Q4 Is the water you see outside the vial a solid, a liquid or a gas?

Vignette 6: Noma Explore Lesson

This explore lesson showcases Noma's ability to carry through the learning of engaging learners' prior conceptions which she acquired during the planning phase, as seen in the excerpt below:

> *... And then another challenge was that one knowledge of learners' thinking which influence your teaching of this idea, again with this one. I think it's linking again to number one, what you expect learners to know already … Yes it's also linking to number one, and it's showing the abstractness of what we actually have to present, because there is for example with this water cycle, you have to sort of make them, you have to also indicate the relationship between the microscopic and the macroscopic. So it's a bit abstract, there are a lot of things that maybe a person has to think about when it comes to number six, I had a serious challenge with that one.* (N & C CoRe pres) **(v)**

What is also clear is that the success of this part of the lesson could be attributable to the role of well-designed tasks in supporting teacher inputs and stability during the session, as the well thought through learner-centred strategy – *1–3-whole group consensus learning strategy* – chosen to be employed in that section of the lesson.

On general pedagogic aspects of the lesson one can note a missed opportunity from Noma's lesson to engage her learners in procedural skills underpinning scientific investigation. Instead of involving her learners (or calling on volunteers) in setting up so that they can appreciate the role of evidence in experimentation, she opted to do it herself and expected her learners to believe what she was telling them without witnessing what she did. Another thing which undermined the investigation process was that she took the set up outside in the sun out of the learners' sight where they could monitor what was happening by themselves and thus introducing issues of validity or controlling variables and thereby negating the very principles that underpin experimentation.

On cognitive aspects of the lesson, even though Noma revisited these two issues 1.5 and 1.7 (fig 3) one after the other, her explanation did not show learners that during phase change the molecules of a substance do not change and that in these two items they were dealing with two different forms of phase change in which water vapour was involved. There is also no mention of the idea of phase change that links the two examples that she deals with. Instead, they remain two separate examples. The examples she used to explain what constituted the bubble also were all from chemical reactions, could potentially lead learners to confuse phase changes which are physical changes with chemical changes. Also the fact that she kept on mentioning that gas evolves during a reaction could lead to these misconceptions. This is a common misconception and some of Noma's learners had chosen option D for item 1.7 which gave her the opportunity to explain that condensation does not involve chemical change and that the water molecules remain intact during phase change.

This illustrates how experienced teachers act like novice teachers when confronted with a new topic, a persistent theme in the literature (Gess-Newsome, 1999). Thus despite having the teaching resources which could support her to deal with her learners' misconceptions effectively, her lack of sufficient content knowledge undermined her intentions. Pedagogically, what Noma did in this section of her lesson, and the nature of the exchanges she had with her learners, confirm the consistency between what she professed in the excerpt below and what she actually practises in her classroom. The way she normally approaches science concepts is by using the learners' environment to explain phenomena, so that they understand that most scientific understanding involves abstraction from natural phenomena.

> *So what I normally do is I want to umm I normally change it in such a way – transform the knowledge in such a way that a person realises 'kuthi' [that] we are discussing our environment – you make it to be real you make it to be relevant, you want to make it to be sort of it. I don't know if I am understanding you very well but that is what … I don't want to say this is physical science as if we are talking about something in another world – so I am presenting it in such a way that you realise that umm I am solving problems within my environment. Science is for as long you can explain why am I seated like this and my walking can be explained in terms of science – so I am bringing it more to reality and everyday experience* . (Noma practice-int)

The pattern of exchanges in the episode above shows consistencies between what she professed her views were about learners and learning, and the way she positions her learners in her actual teaching. It is still clear that it is about her transmission strategies, rather than the learners' construction of their own knowledge for themselves. This is a clear consistency between the professed and the practised, and again places Noma as a *transitional teacher* in both what she professes and what she practises in her class. Even though she is conscious that to make subject matter accessible to learners, one needs to link the new concepts with what they know in their everyday environment, she still sees learning as being transmitted by the teacher rather than as being constructed by the learners themselves.

> *Noma: Ok fine. So now what we are going to do – we are going to start with our activity. We are together neh? So what I am going to do I am going to give you some glass beakers and [in] those glass beakers I am going put some ice and you will also have a thermometer. Now I want you to begin with that activity. You can use your pencils to answer the questions.*

For the next 30 minutes, the learners worked within their groups to carry out the investigation and discussed the answers to the questions accompanying the activity. Noma walked around from group to group, listening to their discussions and attending to their questions. As reflected in Noma's post lesson reflections below, she felt very good about the process and fulfilled that she managed to realise the goals she set for herself. She felt that she was able to engage her learners optimally.

It was a good experience because learners were excited; all of them were engaging in the process.

The comment below also captures her joy and that she felt confident and in control:

It was an exciting lesson. I did not care much about being videotaped. The learners were able to use the thermometer and they also have correct reading and recording skills. I could deliver content as planned. I needed to exercise authority in managing the class. (Noma_PaP-eR)

The last two statements say a lot about her belief in maintaining a good learning environment and could be attributed to how her next two lessons, which were her explain phase lessons, unfolded (discussed below).

She was also quite proactive about capturing what she saw as barriers to her learners' learning:

A number of misconceptions emerged in the lesson

- *Some learners believe that taking the reading of the temperature of ice outside the classroom will differ than when it is taken inside the classroom. They think the sun will have an effect.*
- *The water outside the beaker is due to the ice melting inside the beaker.*
- *Learners argue that in the activity they could see three phases of water.*
- *They think the dry carbon dioxide is iced water.*
- *Irrespective of our previous discussion some still want to maintain that the glass beaker is wet because of the melting ice inside the beaker.* (Noma post lesson-reflect)

From the variety of activities which Noma carried with her learners, the different teaching strategies she used to engage them in the learning process during the *engage* and *explore* lessons and the reflections she made at the end of each lesson, it is quite apparent that she was able to sustain the learning she gained during the planning phase as captured in the excerpt below:

... And then with number seven, the teaching model and procedures, okay that's again here we shared a lot in saying how can you approach this section of work; there we had to go back to the actual content that we had to teach, we had to teach and then see how it can be delivered in a way that learners can understand it, so we came up with a teaching procedures whereby could be discussions, practical work, engage learners. (N & C CoRe pres)

Vignette 7 below reveals interesting dynamics in the teacher's learning path. It illustrates elements of abstraction in the teacher's practice, where Noma is using theory and symbolic representation to explain phenomena, by linking what the learners observe at macroscopic level with the explanatory theory of how the particles behave at a microscopic level. This is a common challenge in teaching science (de Vos & Verdonk, 1996; Taber, 2002) and can therefore be used to highlight her developing PCK. It is a reflection of the teacher's use of forms of representations with the aim of promoting a strongly coherent learner conceptual

understanding (9, 19) of the topic. It can only stem from strong science subject matter knowledge (10, 20) on the part of the teacher. This constructive engagement with learners' conceptions reflects a sophisticated knowledge base on Noma's part, and places her as a *reformed-based teacher* in that aspect of her PCK. This is also indicative that Noma was able to sustain the learning she claimed to have made during her planning phase, as captured in excerpts (iii) and (iv) in the earlier section. This strong aspect in her PCK is, however, totally undermined by the instructional strategy (24) she chose to adopt, as well as how she positions her learners in the learning process in this session. This places her as a *didactic teacher* whose sole focus is to transmit knowledge in a structured environment, where learners are expected to pay attention and receive that knowledge.

What is also clear in Noma's experiences through the three lessons (engage, explore and explain) is the shift and growth in her CK which equipped her to deal with her learners' prior knowledge more effectively. The quality of her explanations at the explain lesson clarified the confusion that learners had during the engage lesson over the nature of bubbles during boiling. Her explanation clarify that **heat** in the form of infrared radiation from the sun was responsible for the **phase changes** and that during phase change, **the structure of water molecules remains intact**.

Episode 5

Explain Lesson: to compare ideas, introduce definitions and concept names as well as to construct explanations and justify them in terms of observations and data.

We will be discussing in detail our water cycle. But before that I want us to look at what we have actually gone through and things that I going to help us in following up what water cycle entails. Right when we started we focused on the sun as the source of energy and our focus was on the infrared radiation.

She used a concept mapping to teach and write on the chalkboard.

(solid liquid gas)

Sun → Radiation → IR → absorbed by water molecule **macroscopic**

↓ ↑

physical changes

↓

microscopic

(atoms, molecules, shape of water molecule)

The infrared radiation is absorbed by water molecules. These water molecules have the ability to absorb IR and what is important is that physical changes occur (pause) and we talk about the microscopic and macroscopic changes. When it comes to macroscopic we will be looking at what we can see with our naked eye in looking at the solid, the gas and the liquid. When is comes to microscopic we have to look at the particle arrangements and the shape of this water molecule. And what you will realise is that irrespective of the fact of the phase changes, the structure of the water molecule remains the same the only difference that you see is the spacing between the particles.

Noma: can you give me those properties of water? Can you remind me about them?

L1: melting point

Noma: melting point (repeated the phrase as she wrote it on the chalk board). Yes (pointing to another learner)

L2: freezing point (repeated as above)

L3: water expands (teacher repeated as above and many learners had their hands up with anticipation to be given the opportunity to respond)

L4: water absorb lot of heat while the temperature don't.

T: Ahh? The potential to absorb... and asked L5 who had his hand up – do you have a better way of putting it?

L5: ice is less dense than the liquid

T: Ok. (face L4 and said - we will come back to your point) and to L5 you mean the floating one as she wrote the word floating on the chalkboard. She then put an open bracket and started writing 'ice less' and then rubbed off (she then move in a position to conceal what she was writing and she turned to the learners she had written in brackets – solid ice less dense than liquid water. Without reading or engaging the statement she had just written she moved on to invite L4 – can we get to what you said?

T: did we leave out anything?

During the lesson, some of the learners did not even seem to be listening to what the teacher was on about and were busy carrying on with completing some task which was not directly related to what the teacher was explaining. This to me came across as some kind of passive resistance which I could not say with any certainty where it emanated from. When the teacher asked a question, one could see from the learners' faces and the manner in which the hands were raised, their burning quest to share their own ideas.

Vignette 7: Noma Explain Lesson

Pedagogically, it was evident from the quality of responses that Noma's learners gave and from the few comments that Noma made during the session about their progress, that Noma's learners had already learned a lot about the topic. Given the purpose of the explain lesson – *to compare ideas, introduce definitions and concept names, as well as to construct explanations and justify them in terms of observations and data* – one can argue that what had already transpired in the way of learning between Noma and her learners, gave them the ability to draw from these experiences and engage in interactions where their ideas are compared. In these processes, she introduced definitions and concept names while they constructed explanations and justified them in terms of what they observed and the data they produced during the "engage" and "explore" sessions. This move not only promoted their conceptual understanding (9, 19), but also their procedural knowledge (11, 21) as they interacted with each other's ideas, as well as those of the teacher. For this session, however, Noma settled for a chalk and talk mode of instruction (24), and in a 30 minute session, the only interactions she had with her learners' ideas was through two sets of closed questions where the teacher expected specific answers. This went against the prevailing spirit underpinning the purpose of the "explain" lesson, and squarely placed Noma as a didactic teacher. It also confirmed the assertion by Magnusson, Krajcik, & Borko, (1999) that:

> *... the chosen activities may not be conceptually coherent if the teacher does not understand the purpose of particular activities and as a result omit or inappropriately modify critical aspects of them.*

This actually reversed the momentum of change already built up from the prior activities, as well as their awakened aspirations to learn through a dialogue and expression of their own ideas. Noma interviewed a learner after her "explain" lesson and this is what the learner had to say:

> *The lessons are going well except that you don't allow us to figure out the answers ourselves. You tend to give us answers all the time*. (Learner interviewed for feedback)

Noma's response to this learner's feedback comments was also interesting, because she immediately switched to asking this learner what he thinks about the debate they held in class during the explore session, on what bubbles represent during a reaction.

Haberman (1991) argues that students play a very powerful role in maintaining defective teaching strategies which disempower them, and are adopted by their teachers in schools. He explains that students ensure this maintenance by rewarding the teachers who take away the responsibility of their own learning from them, through compliance, while punishing those teachers who expect them to take charge of their learning, through resistance.

Again, Noma's adopted strategies during the session reflect that she was not able to sustain the resolution she came across during her reflections after the first engage lesson: *In my presentation I should allow learner participation as much as I can.* This move also went against what she professed to be her belief in terms of how she knows that learning is occurring in her lesson, in excerpt (ii) of the earlier section: *When they start asking more questions like definitely they are understanding it will be like they are actually understanding when there is communication. ... Participation from learners I would say participation, when there is no participation I will be running the talk show.* (Noma TBI)

At the end of the explore lesson, Noma was very excited about the outcome of the lesson and the excitement it evoked in her learners, but then she felt that she was losing control: *I needed to exercise authority in managing the class.*

Possibly, this statement in her reflections set the tone for her future lessons, and the reductionist approach she adopted in her teaching strategy was a result of her feeling the need to take more control of her learners. This is similar to how experienced teachers act like novice teachers when confronted with a new topic, a persistent theme in the literature.

Even though there were elements of *transition* orientations in Noma's practice overall, data point to Noma gravitating towards *didactic* practices. It is interesting that irrespective of having adopted 5Es, a constructivist lesson sequencing strategy, as well as using tasks which were targeting learners' prior knowledge, she still shifted to a more teacher-centred approach in engaging her learners.

7.4.2 Colleen's Case

Knowledge and Views (6) in the Action and the Practice (8)

Colleen's account is captured through *artefacts* which give the descriptions of the nature of the task she designed, and *episodes* which describe how she used these tasks with her learners (12, 22). As already alluded to in the previous chapter, Colleen decided to base her research on the entire section of chemical systems, which was too vast. This had a negative effect on how innovative she could be in experimenting with new ideas in her inputs.

For the purpose of this analysis, I decided to confine the study of Colleen's PCK to three tasks she produced to try to address the three science learning outcomes in her classroom, and the way she managed the tasks to engage her learners in the classroom. The other source of data is the analysis of the only lesson she video recorded.

The reason for confining the focus to these activities is because they reveal a lot about what Colleen produced for the project, to try to address the three learning outcomes, and her underlying assumptions of how learners learn. The rest of the inputs, to other parts of chemical systems, were content driven and rushed because of time constraints, and were therefore just presented using power point. The three tasks covered good ground by first exposing learners broadly to the world of chemical industry (research project), and the other two tasks, the practical investigation, and a poster on batteries and how they are disposed of, had a focus on electrochemistry, its applications and environmental impact (12, 22).

The fact that a lot about Colleen's PCK can be discerned through the assessment tasks she set for her learners, seems to confirm what she professed in the excerpt below, at the beginning of the process, that she uses assessment for formative purposes, to capture her learners' interest and as a window to discern whether learning is happening or not.

> *How do I know? Well, same sort of way if they are interested; uhmm obviously the assessment is going to let you know whether they're learning uhmm and I try to do as much – as little as possible of assessing learning. Uhmm even if it is just assessing in a very informal way by – checking on what they doing uhmm but obviously you have – you know, fair number of formal assessments even if they're not ... you know practical work, or some of the assignments or whatever.* (Colleen Teach Beliefint)

Colleen worked with 26 learners in her Grade 12 class. Besides Grade 12 being a high stakes grade for Colleen, the challenge was clearly not just addressing a new science topic within the framework of a new curriculum, but also that she was operating in a new context with unfamiliar learners. Her case study thus reveals very interesting dynamics of how the different knowledge domains interface in the development of her PCK.

Curriculum Saliency (13, 23)

That Colleen's project was done in grade 12 set a special kind of pressure. As reflected in the excerpt below, she was quite aware of the assessment demands placed by the GDE, as well as those specific to her research project. This was the driving force behind her inputs.

> *In preparing this research assignment I was very aware of the time constraints as well as the requirements of the GDE. I tried to engage the learners by providing some research material and introducing the learners to some controversial aspects of the chemical industry. The requirements for the grade 12 portfolio involve a research task which involves collecting information to understand a particular set of circumstances. [LO3]. The research work should not take more than three weeks.* (Colleen PaPeR)

The types of decisions she made, the nature of the tasks (12, 22) she developed and the manner in which she used these to engage her learners in the classroom, reveals a lot about her strong strategic curriculum knowledge (13, 23), her strong chemistry subject matter

knowledge (10, 20), her undying passion for the subject, her great work ethic and her great time management skills.

At face value, Colleen's response to the question: 'in a school setting, how do you decide what to teach and what not to teach in your science class?' It suggests that her decisions are based on teacher focus or direction, because she declares that they are based on her preparation. A deeper look into the subject matter of her preparation reveals that they are based on trying to raise her own understanding far above that of her learners. This is expected to be through consultation of a variety of textbooks, as well as curriculum documents (12, 22) as the following interview excerpt reveals:

> *C: Ohh, I think it's based on my preparation so I usually prepare especially the sections I haven't taught. I prepare by going to textbooks, my own textbooks, so at a higher level than the learners would go to, umm doing some research and then checking out what's in the curriculum and what is in the range of text books for the learners, and then deciding from that what's important what's not important and what has to be in the lesson—*
> *I: Ok*
> *C: So it's a bit of a process especially with the new curriculum; in the old curriculum where I knew what was important then I didn't go to so much trouble but at the moment you have to, because it's difficult to know exactly at what level to fit it.*
> *I: Umm, so it's sort of a learning process, interacting to the curriculum itself so that …*
> *C Yah.*
> *I So maybe how, how is it, when it's a familiar topic, maybe say how do you –*
> *C When it's a very familiar topic, then it's easy, because I know what is important. I've been there before. I know what the learners are going to struggle with – what they not going to struggle with – ehm – so I suppose if you like it's a piece of cake. I know what's expected, and what type of questions they will ask and what pitfalls there are, where the learners misconceptions are going to be.*
> *I Aha.*
> *C So then it's a lot easier, so if it's a lot easier, I just sort of look over the – topics, decide what I want to do, decide what questions we going to go over etc…. Tthe old stuff was easy.* (Colleen TeachBelief-int)

From the above statements, it is clear that Colleen's guideline in what is important and what is not, is based on ensuring that her inputs should be cognitively appropriate for the students, and also aligned with the aspects of the standard, as pronounced in curriculum policy. It is also clear that she does consider learner prior knowledge (9) in her preparations and how she would strategise to deal with them in her inputs. This places Colleen as a *reform-based* teacher which is the most progressive and the most curriculum-aligned practitioner.

The response she gave in the excerpt below about how she sees her role in maximising her learners' learning, points to a highly evolved notion of how learning happens, that knowledge is constructed and the critical role of the teacher is to create environments which can capture learners' interest, because learners are the only ones who can choose to learn or not to learn.

I don't know. I don't think I do – I think I try to but I don't think I do. I don't think any teacher at the moment has got the time to do or use as many strategies as you can – Give them the opportunity to come to extra lessons and whatever but I don't know that you ever maximise it. The child can, only the child can do that. – Not many can do it, not the teacher. You can give them all the opportunity but if they don't take them ... (Colleen TeachBelief-int)

Colleen used a discovery approach to introduce the theme of Chemical systems to her learners using the research task she had designed. As illustrated in the nature of the task above, Colleen set a complex but a very clearly articulated task for her learners. She engaged the learners in a brief session to introduce and explain the task, giving a few examples and inviting them to choose their topics. She provided them with a sheet with a list of topics and each learner had to fill in their name next to the topic of their choice on the sheet, ensuring that only a maximum of four learners could choose one topic from the list. Colleen had also put together information materials on the different topics in the laboratory for learners to go and consult and take an informed decision when choosing and settling for a specific topic. The learners were not allowed to remove the material from the laboratory.

Vignette 8: Colleen's research project task mediation

But we need to examine the nature of the tasks she produces and how she uses them to engage learners in the learning process, to see whether Colleen is able to use this highly evolved thinking about the learning and teaching of science, in her actions and practices.

From the excerpts below it is clearly evident that the task Colleen set and her introduction session were very successful in ensuring that the learners took ownership (11, 21) of the task enthusiastically.

They were very enthusiastic and even asked to research topics not on my original list. An example of this was a learner who wanted to research about diet pills and their effects ...

I was pleasantly surprised by the quality of the work the learners produced and they seemed to have gained insights into their topics. Some of the learners brought newspaper articles and pictures to enhance their oral presentation and asked me questions about many aspects. An example of this was a learner who brought an article on natural antibiotics which made claims about the lack of side effects. It turned out to be an advertisement and not an article. Another example was the learner who found that banned drugs are freely available by ordering on the Internet. I actually learned a lot from these learners' work. (Colleen research report)

The Research Project

Purpose: From Colleen's utterances at various stages of her PaP-eR, the following emerge as the overall purposes of the research project:

- To introduce the theme of chemical systems
- to address LO3 by exposing learners to some controversial topic in the form of a research project
- to fulfil the assessment requirements of GDE

Nature of the task:

The first research assignment was a kind of a pre-task which required learners to research their topic of choice from the provided list and preparing an 8 page written report worth 40 marks, as well as a 4 minute oral presentation worth 10 marks. The task exposed learners to a specific chemical product produced in the chemical industry by challenging them to go and research the history of how the product was first discovered and what it is used for; the chemistry of how the product works; its commercial importance, as well as the impact it has on the environment. The list provided to the learners was wide and varied in scope as follows: *PLASTICS (polymers) – e.g. polyethylene, polypropylene, PVC, Teflon, polystyrene; SOAPS, detergents and surfactants; INSECTICIDES – e.g. DDT; herbicides; antibiotics; FOOD ADDITIVES (anti-oxidants, emulsifying and stabilising agents, anti-caking agents, colourants – (tartrazine, sunset yellow); preservatives (sodium dioxide, propyl and methyl paraben, pimaricin, sodium benzoate); flavour enhancer (MSG-monsodium glutamate); sweeteners (saccharin); FERTILIZERS – phosphates, nitrates and sulphates* etc.

- The task was very clearly set with certain cautions which promoted scholarly attitudes and ensured that learners produce quality work included (e.g. *MUST be written in your own words as plagiarism is not permitted; at least five different sources of information should be used and these should be cited in your text and included in a bibliography at the end*; for the presentation part of the task a statement: *NB. YOU MAY NOT READ YOUR ASSIGNMENT TO THE CLASS*).

Vignette 9: Colleen Research Task Description

Learners' Procedural Knowledge (11)

This is what the physical science LO3 states:

> ***The Nature of Science and its Relationships to Technology, Society and the Environment***
> *The learner is able to identify and critically evaluate scientific knowledge claims and the impact of this knowledge on the quality of socio-economic, environmental and human development.*
> And assessment standard 1: Evaluating the Impact of Science on Human Development
> Research case studies and present ethical and moral arguments from different perspectives to indicate the impact (pros and cons) of different scientific and technological applications.

Inherent in the nature of the task (25) produced and how Colleen used it to engage her learners in learning (9, 11, 19, 21) was a strong strategic curricular knowledge (13, 23). There is clearly also a solid grasp of subject matter knowledge (10, 20) on her part, inherent in the nature of this task (12, 22) and how she used it to promote her learners' procedural knowledge (11, 21). The design of the task (22) and the way Colleen used it (24) to engage her learners (21), qualifies it as an open inquiry task (22, 24). It is designed and used in such a way that it requires learners to deal with complex information derived from a scientific

context, where they are expected to work as autonomous decision makers, using their own initiative and judgement, as well as engaging in creative and critical thinking (11, 21). On the aspect of *alternative curriculum resources* (12, 22), Colleen demonstrated versatility in terms of how she engaged leaners in drawing from their immediate environment to address and engage with the topic. She also drew from variety of resources to make content accessible to her learners. However there is still a lot of room for improvement in the design of the task and its use to engage learners further in these procedural skills (11, 21).

Teachers' Instructional and Assessment Strategies (23)

The nature of the task (21), how Colleen used it in her instructional strategies (23) and the feedback (17) she gave about how the process went, suggests consistency between what she professed as her thinking about how learners learn best at the beginning of the process and her actual classroom practice (24). In the excerpt below from her interview earlier on in the process, it is clear that she is driven by the idea of an environment which can help to capture learners' interest, through linking what they have to learn with what interests them in their everyday context.

> *I think when they are interested, when you can capture their interest, where you can get something to be real for them or not divorced from reality, not divorced from their lives – so you can put it into perspective, uhmm so I suppose it LO3 – uhmm – where you make that meaningful in the context of their lives, so they can relate what they are learning in class to something that they already know about. It's not always so easy but they are probably going to learn it best when they are interested in what's going on.* (Colleen TBI)

From what she professed and what she actually practised, one can argue that even though she is conscious about linking the subject matter with the learners' context to capture their interest, her thinking about how learners learn best is still teacher-centred, because it is based on her subjective conclusions about her learners, as well as the measures she, as a teacher, gives. There is no indication of how the students themselves interact with their peers or with the teacher about the topic. This response places Colleen as a *transitional teacher* because she creates a classroom environment that involves the learners.

This is further supported in the strategies (24) she used to manage the task in her classroom. For a task like this one, which involved learners researching different topics, one would expect that the environment created should not only allow learners to present their ideas, but also to learn a lot from each other's ideas (22). The excerpt below by Colleen reveals that the process was not without constraints, but one is left with the feeling that it was managed

very well under the circumstances. The learners were also engaged relatively well but there was still room for improvement.

> *The learners had to hand in an eight page project and present their work in class orally. This was meant to allow a general discussion on each topic. Unfortunately there was not enough time to do this in class so groups of four or five learners presented their work to each other. I used a question and answer method after every presentation to interview each learner. Almost all were enthusiastic and positive about what they learned during the process. They also showed interest in each other's work.* (Colleen PaPeR)

Besides these logistical constraints, one can say that the potential of the presentation session (24) was not exploited to the fullest. During each presentation, other learners (22) were not expected or encouraged to engage with the group's ideas, even in just the form of questions or comments. This interaction style (24) neither enabled nor required that Colleen's learners build upon each another's contributions (22), nor considered whether they understood and agreed with them.

Colleen explained that this missed opportunity was due to time constraints (2). However, this reveals a lot about Colleen's assumptions of how learning happens and what the third LO really means (9, 11). Science is the process in which scientific knowledge is socially constructed and therefore, argument (11) is at the core of communication in the formation of scientific knowledge (10). I can assert that this is a typical instance where the instructional strategies (24) adopted by the teacher often inhibit participation of learners in social discourse (22) where they critically attend to, defend and evaluate understandings by engaging with each other's ideas (19).

There is little modification which needed to be done to the task to ensure peer engagement, and still in its present form, there is a lot which could have been done in the way of its management to ensure peer engagement. At the classroom implementation stage, Colleen was somehow subject matter driven (20) and not concerned with promoting procedural skills (21), expected in LO3, which should help her learners appreciate the processes involved in the generation of scientific knowledge (11, 21). The task has aspects of a written account and an oral account, which opened possibilities for Colleen to help her learners appreciate the nature of science as a human endeavour, socially constructed through logic, reasoning and evidence based on argumentation within a community of practice. The presentation part of the task presented an opportunity for Colleen to create an environment where learners could engage each other in a scientific discourse of proposing or arguing about ideas in their research projects (10, 11, 20, 21).

Assessing the Learning:

The task was also accompanied by marking rubrics for the written report as well as for the oral presentation clearly spelling out to students how their work was going to be assessed. The rubric for the written report consisted of ten assessment criteria, mapped across four levels of performance. The assessment criteria were as follows: *acquiring scientific knowledge* which had to do with subject matter knowledge; *researching* which had to do with ability to find information from a variety of sources and using it with insight and understanding, *relevance of information, summarising information, writing a scientific report, neatness, identifying social problems, identifying positive impacts on technology, identifying negative impacts on technology, identifying issues.*

The five oral presentation criteria were ranked at two levels and had nothing to do with science subject matter or procedural skills. They were as follows: *oral presentation* which had to do with audibility, clarity and time management, *maintaining audience attention, use of language, eye contact* and *pacing.*

Vignette 10: Description of Colleen's Research Task

A closer look at the assessment aspects and the types of learner expectations inherent in the task reveals that most of the process skills the teacher targeted during oral presentations had nothing to do with the learning and teaching of science. This reveals a lot about the teacher's knowledge of the nature of science, and the types of procedural skills one needs to target and promote in science lessons to cultivate the attitudes and values inherent in science.

Learners' Prior Conceptions (9, 19) and Learner Feedback and Classroom Outcomes (18)

All elements point to the fact that this was not only a very well thought through exercise, but captured the teacher's passion about teaching and learning. It also pointed to the fact that hard work, very good organization and planning on the part of the teacher, does pay off. Colleen's reflections below illustrate how *learner's feedback* (17) leads to increased knowledge of the *learners and learning* (19, 21) process, which, in turn, leads to a sense of fulfilment, as well as an overall affirmed professional *image and capacities*.

> *I felt very good about how the learners responded to the research project as well as their responses to the lesson. Quite a few of the learners said that the info presented was easy to understand and they found the lesson interesting.* (Colleen post lesson reflect)
>
> *Had a double with my grade 12 class and started with economics and the chemical industry. Had a group discussion and the girls participated well.*
>
> *I think the learners are interested in this new section and that their interest was sparked by the research project which they have started.*
> *Maybe I could include some kind of role play or debate next time.* (Colleen post lesson reflect)

However, what transpired next, points to the fact that learning and teaching is a very complex dynamic. Colleen's reflections (21/04) below which were captured after the project presentations she had with her learners, reveal that she was very optimistic about her learners and obviously had false assumptions about their science subject matter

knowledge. The following session's reflections indicate that Colleen underwent what is referred to as an implementation dip (Fullan, 2001), as she was dismayed by the discovery of the subject matter knowledge level of her learners:

Learners had to write down what they know about sulphuric acid. Most of them were horrified when they were asked to do this. Some could not even write down the formula!!!! (Colleen post lesson reflect)

Am a bit worried about how much chemistry was taught last year. It is always better when you know what work they have covered.

The Practical Investigation Task

Purpose:

This task had three parts and was aimed at addressing all the three learning outcomes.

Spelled out 10 learning objectives which can be summarised as

Design and construct a working battery from a set of given materials

First draw a plan by

writing out a hypothesis about your cell before construction and calculation of the cell potential

Drawing a diagram identifying and labelling anode and cathode, electron flow, ion flow, oxidation and reduction reactions, chemical used as well as location of each hand

to fulfil the practical investigation assessment requirements of GDE

Nature of the task: The task consisted of three parts with an overall mark of 75 and was introduced in a form of a letter addressed to each learner, inviting them to enter a competition hosted by the so called *South African Institute of Electrochemical Research*. The main part of the task is an open ended practical investigation where learners are expected to design an electrochemical cell as well as investigating the effect of an electrolyte concentration on the potential difference. This main task is assessed in two parts which are: the design and construction part where they are expected to get approval of the plans of their designs by the teacher before launching into the designing phase and this is worth 9 marks and the second part is a laboratory report worth 48 marks. Prior to the designing phase learners were engaged in a pre-task where they had to watch a video called the busy electron and answer theoretical questions about concepts which underpin electrochemical cell and how it operates to give a theoretical base for the main task. The third part of the task was allocated 15 marks and required learners to design a poster about battery disposal.

Prior to this main task Colleen gave learners a pre-practical task which was meant to address the requisite subject matter to engage in this task and this included how electrical energy could be produced by using a copper/zinc cell as an example as well as the concepts such as electrode, electrolyte, anode, cathode, electrolytes, salt bridge, electron flow, ion flow, oxidation and reduction reactions and cell potential. The learners worked in groups of five members.

Vignette 11: Colleen Practical Investigation task

I think teaching this section before the other chemistry sections could be very difficult. (Colleen post lesson reflect)

The nature of the tasks Colleen designed to engage her learners resonates with what she professed at the beginning in the excerpt below on how she adapts her teaching to best represent the discipline of science.

C: Well I like try to do as much practical work as I can, and I've been trying very hard now with the, you know, the grade12 but I've done it with grade 11s. Now I've to do a more open ended practical investigation. I've done it. We did it with the grade 12 with calculation and acceleration and I have just done that this week

with the grade 11on Boyle's law where we gave them an open ended problem that they had to solve with the apparatus instead of the more rigid – you will do this this this this – and then that will be your conclusion.

I: Ok

C: So they were to come up with their own hypothesis, their own plan uhmm, so we are trying very hard with practical work but also with other types of activities that we do with the kids.

On the issue of use of misconceptions in facilitating learning, the analysis made by Colleen below, as she was evaluating her learners' work during the process of their projects, and at the end while marking, reflects a deeper appreciation of the complexities inherent in the learning of electrochemistry as a topic, and areas that research has already revealed as possible conceptual learning barriers for learners.

Some of the learners thought that electrons flowed through the salt bridge to complete the circuit. According to the literature this is a common misconception resulting from statements used in textbooks or by instructors (Schmidt H.-J. M., 2007). I could not find anything in my data to verify whether this misconception was due to my instruction. Only a few of the learners were confused about the idea. (Colleen PaPeR)

S*ome of the groups were successful in interpreting their data but in other groups some of the learners showed that they had little understanding of what the group had done. This was in spite of allowing the learners to choose their own groups. Possibly the cause of this was the lack of one of the brighter more able learners in some groups. I did note in my reflective journal that some of the weaker learners had achieved a level of understanding that surprised me. This however was not so evident in the question on electrochemistry in the May examination.* (Colleen PaPeR)

Some of the learners were unsure of how to choose the metals that they were going to use as their electrodes and some were unsure of which electrolyte should be in the salt bridge. Quite a few chose sodium sulphate for the salt bridge because it was in the example that I had given them. Only a few learners had their own ideas about the ions in the salt bridge. It was evident from the practical reports that many of the learners had not thought about the direction of ion movement from the salt bridge. Some also forgot or did not realize that the design of their cells had to include an external circuit. (Colleen PaPeR)

When Colleen presented her plans and her designs during the planning phase, the feedback she received was to try to persuade her to look at the article she was provided with, which deals with the barriers learners normally have when learning this topic. When it comes to strategies, one could integrate towards learner-centred approaches. The excerpt below shows efforts which were made to try to raise Colleen's conscience about the importance of starting by identifying learners' misconceptions.

Me: Okay that's one thing, and another thing is that with electrochemistry, I mean particularly the task you plan to give them on batteries. Are you intending to do, I mean to make prior inputs? The reason why I'm asking is that I am still on the misconceptions. I gave you an article which highlights the common misconceptions revealed by research on the topic of electrochemistry. It would be good if at the beginning you could try to elicit their existing ideas by either asking them to do a concept map or use the questions used in the article to bring their pre-conceptions to the fore. (Colleen & Noma CoRe pres)

The excerpt below shows that Colleen was given detailed advice on the strategies she could use and what support materials to draw from, to start her teaching by identifying learners'

pre-conceived ideas and letting these direct her teaching, an opportunity which for some reasons which were not apparent, she did not take up.

Me: ... You can get them to recognize and take ownership of their misconceptions by using strategies such as cognitive conflict with some of the activities at the beginning when you make those inputs on electrochemistry, and see how they respond to that and see whether those misconceptions are going to go into their research projects or will they have made shifts? You know I am thinking of this format because ... those 5Es are good to ensure that your inputs take a constructivist approach to learning. Basically the five stages could be five lessons which begin with eliciting the learners' conceptions about the topic. It could be an engage lesson, then the explore, then the explain, the elaborate and then the evaluate lesson and what I think is that your research task comes at the elaborate stage. The evaluate stage could be a post-test or post-concept mapping to show whether the misconceptions were successfully addressed using the same tools you used at the engage phase.

C: I want to because I've read some articles and I find it very interesting. (Colleen & Noma CoRe-pres)

From the excerpts and the section of Colleen's CoRe (see table 20 on page 227), it is interesting how Colleen's ideas and attitude towards learners and their learning shifted from a position of being subject matter with her own ideas of what she thought was good for the learners during the pre-teaching stage, to seeing the importance of seeking their existing ideas and working with them, during the post teaching phase, thus confirming the situated cognition perspective of the power of learning through participation.

In the examination it was obvious that some learners did not understand that the electrolytes need to be soluble as quite a few chose insoluble salts of silver for the electrolyte in a silver half cell. This could have been due to the lack of discussion about electrolytes on my part. Quite a few of the learners were not able to differentiate between the electrolysis in the chlor-alkali industry and the electrochemical cell. A few were unable to write down the reaction for the production of chlorine gas correctly. Quite a few reversed the reaction which showed a lack of understanding of the concepts of oxidation and reduction. (Colleen-PaPeR)

The excerpt below strongly supports a situated learning approach that learning happens through participation, because it is clear that, for Colleen to start appreciating the strong hold learner's prior knowledge has on their learning of new concepts, she had to see it practically in her own teaching strategies and the feedback she got from her learners' assessments.

My planning will definitely be done differently in the future as I realize the importance of checking on my own knowledge as well as the learners' knowledge. I will make use of CoRe and improve on what I have already prepared. (C-research report)

I will not teach Chemical Systems before tackling Matter and Material and Chemical Change in future. This was especially evident in the learners' lack of knowledge about redox reactions, cell potentials, nature of materials and spontaneous and non-spontaneous reactions. It was only done in this order because of the time constraints of the Research Project. (C-research report)

The theme which runs through Colleen's story is that, while she appreciates that learning involves construction of knowledge and only the learner can make it happen, and that the role of the teacher is to create an environment that captures the learner's interest, her knowledge of how to create this environment, especially in terms of the social and cognitive aspects, is

still not evolved. She still does not appreciate the central role played by learners' prior conceptions (9, 19) in the construction of knowledge. She also still does not appreciate the critical role that social interactions play in mediating and promoting the requisite procedural skills (11, 21) inherent in the nature of science and its learning. This blind spot resulted in her gravitating to instructional strategies (24) that assume that knowledge is transmitted and not constructed. The overall inclinations and instructional orientations she adopts in practice position her as a *transitional teacher* whose main drive is in facilitating learners' understanding by creating an environment where learners interact with the teacher and the phenomena.

7.4.3 Bongani's Case

Bongani's Professed Practice

Generally Bongani's responses are quite generic and do not go into specifics of the learning processes, let alone the science learning.

Bongani's response below to the question: *How do you decide what to teach and what not to teach in your science class, classroom – what is your deciding principle?* – places him as a didactic teacher.

> *Ehh, the documents, the RNCS documents, in fact, we usually, at the end of the year-you should prepare for- for next year, so we- prepare work schedule-so work schedule indicate-in which week, are you going to treat a topic-then a daily focus-will specifically indicate-which subtopic are you going to deal with-so in other words- it may-maybe overlap sometimes because, of circumstances here at school sometimes maybe- there are no class for- you are disturbed, and you, you'll indicate ukuthi (Zulu word for 'that') you haven't finished, ehh the past.*

The response clearly indicates that his decision is guided by the adopted curriculum or on other school factors.

To the question, *how do you decide when to move on in your classroom?* Bongani's response places him as a responsive practitioner.

> *Ehh, because of- ehh,-time constraints-in other words we- we, in fact I must make sure that each and every individual is-comfortable about the topic-if learners they don't understand-a topic I must make time-for those who don't understand the topic- like for an example- presently I'm doing a morning class in a certain day –I will be doing an afternoon class-for those who are, ehh- for those who don't understand the topic.*

He is driven by his learners' feedback and as he is expressing in the quote above, he is even going beyond the call of duty by organising extra time so that he can respond to his

learners' needs and ensure that they are comfortable with the topic. In the excerpt that follows, he explains that the practice arises as part of the school culture.

And also- at school we are requested to- to produce like-eeh –a remedial eeh eeh strategy-what are you going to do with learners who don't understand-how do you get those learners-maybe you give them a task, they don't understand a task-then you will group them, after knowing-try to explain-to them or let one learner who do understand assist them-that is usually what I do at school-

He went on to explain the practical strategies he would employ to ensure quality intervention using group work and peer engagement strategies.

L: Err, my learners usually-it depends-it depends, because others, they learn while you are teaching them in class, others they need time, and eeh it is-sometimes- it is impossible, to even err, know individually how-how they, cope with the work because of the numbers in class-but most- of the time, you see, learners they usually err if you give them err like homework-eeh, you give them ho-you-you teach them something, then ask them questions-they will say, they understand-and then after you when you give them, a task to do, that is where you discover that some of them-they don't understand the subject matter, and in turn they will-borrow books from-from others, so, err my strategy ,I usually-ehh when I, enter the class I will, make sure that I check each and every individual that he has done the homework, before I can even, write on the board- the corrections or what-

The quote is also revealing a lot about his knowledge about his learners and how he manages them to ensure order and progress under the constraints afforded by the context he is operating with.

I: Ummh, ok, so- you referred to morning lessons, what do you do, with them during morning lessons.

L Morning lesson, ehh, ehh- more especially topics that are difficult -that I know –eeh they are not easy –for them to understand-I give them enough time; maybe early in the morning we do something then ehh-during our ehh, period – it then that I'm giving them maybe, a task-to find whether they do understand –if – they don't understand- even them they will say ukuthi, we don't understand this- give us time, we usually stay at, afternoon classes. Usually, they need to-sometimes –it become a problematic -because am studying- eeh, usually, I attend morning classes, usually I attend morning classes--afternoon classes it is a difficult process because- I need to attend even myself

I umm, ok so morning classes, what time?

L Eeh, I arrive at school at, quarter to seven, learners arrive at-seven o'clock-then we have got that-forty five-minutes.

To the question, *tell me how do you describe your role as a teacher* – the answer below focuses on generic or moral aspects of teacher's role and does not touch on perceptions of the teacher role in terms of learners and learning. He raises very interesting points about role modelling which are centred around teacher-learner relationships and this places him as a transitional teacher. The response is heart-warming, in that it reveals a lot about his morally grounded perspective to life, as well as his pastoral attitude towards his profession.

L Eeer, a role of a teacher is like a father- or a role model, because as an educator–learners they, they, imitate some of the things that you are doing, and I don't think as a teacher-you need to do wrong things because-you will be misleading the very people –the – very learners that are-are imitating you as a teacher, or parents are-are entrust- entrusting you with their kids, and then you as a person, you-you

behave in a wrong way. I think you need to behave properly err dress-properly, eeh manage your things-at school, like for an example-late coming –as a teacher it's a bad thing if you arrive late once learners arrive late, obviously they may say Mr so and so, will arrive late–usually arrive-early and late at school, so it is a bad thing even-to yourself

I Umm

L -and to your colleagues, err language, insulting, learners, you know-so those are the things that you need to avoid as a role model, you are part of that community-you need to- show them-how to present themselves in a good manner, as learners.

In other environments, certain things would be a norm and therefore not worth raising, so, in a way, his response is also revealing a lot about what takes precedence in the enveloping change environment, that is, the school ecology and the types of contextual dilemmas he, as a teacher working in that environment, is faced with. It is also saying something about the background of the learners because the teacher in such an environment has a critical role to play, possibly because certain principles are not reinforced anywhere else in the learners' life. It is also interesting that aspects which are directly related to learning, such as hard work, conscientiousness, purposefulness etc. are not included in the response, which might be an indication of what takes focus and precedence, and explains the level of achievement of the school.

This next question is forcing him to consider his role in terms of learners and the learning of science: *And how do think your students learn science best?*

Err, usually, we- with my colleague, in fact I was inspired by her - eeh most of the time, she will eeh eeh engage learners- in terms of practicals. In each topic-in each topic he will engage learners in a practical–situation, when-he handles a-a topic, she will give them a theoretical background-then thereafter, they will do the practical, and he'll she would always assist them, and most of the time he usually do that-that is where I was-I was inspired by her, because I become, eeh acquainted with his style- her style because of –practical part of it because learners they will, they love a practical, although-the theory part of it, they don't apply.

Bongani's response above pronounces him as a transitional practitioner, because it reveals that his perception of how his learners learn science best, is through use of particular procedures, and, in this case, practical work. The response below also reveals that his decision for selecting practical work as a good strategy through which learners can learn science, is based on the fact that the learners enjoy doing practical work, but that it does not necessarily lead to the scientific conceptual development of his learners.

L They usually, they want to do the practical, I don't know why, but the reason behind that it is, to reinforce the information, but, if you ask them questions based on the practical, then, it is- some of the learners, they don't even understand the-the concepts that they need to-in fact the theory behind that

I Umm

L Some of them they don't understand –the majority, but, some years back we usually do those practicals-like for an example the-H- H2S –with that smell-a rotten egg, you know, we'll do that practical with them, and they will do those class practicals- but, only to find that, the remainders of that they are going to put that in classes-so that they, will be disturbing other learners, and when you revise with them, the very same thing-maybe in a test you ask them- the properties of H2S -they won't say it smell like a rotten egg-but they have done that

I Umm, ok

L Most of the time, they will dwell on the fun part of it, but with no understanding

I Ey, yah, ok. You talked about your colleague, ah, so- basically-do you- you work together- you share things, aha,-

From the excerpt below, it is clearly emerging as a troubled school, with very low culture of learning. No wonder it falls under the worst performing schools in the country. The level of teaching is disturbingly low.

I So, you talked about Saturdays-are you able to-to keep on getting your, your

L This year it's difficult,

I Aha, aha

L this year it's difficult, that is why, I am saying last year, it was.....-but after-after June, after-after that strike-it was not ok because-that year it was not okay, because even the very learners, that were attending classes-when I ask them-come and attend-they were not willing to-to come.

I Umm, and you talked about, eeh giving them task, but there, I mean for revision, is it different from-test, the task?

L -the task that I'm giving the-giving them, they are almost similar-to-to tests-and class work

I Ok

L so- like for an example if-if I know that- I've done similar problems, and when I analyse –the test-only to find that there are-there are few –problems, most of them they-they didn't get those eeh problems-those are the problems that I highlight

The excerpt below indicates that the learners have a say in their own learning, which is a very good thing, but unfortunately, it also indicates that the learners set very low learning goals for themselves, and have very low expectations of their own capacities. The discussions are not focused on the understanding of concepts but are more playing politics. What is even more worrying and unique about this situation is that they are not even shy to expose themselves and their disturbingly low attitude towards learning, to their teacher. Clearly, they are not at all interested in learning, but only after marks. There is absolutely no culture of learning or hard work.

-and then I will-will always assist them first, then give them a similar problem, but what I have realised-about Mathematics-is that, err learners they will- in fact not Mathematics, learners, they will tend to-in fact I will talk about two things, first that is in Maths-when you give them a sum they will do that sum maybe-in a test- you give them a similar-eeh, eeh problem, some of them they didn't –understand they'll say, why can't you give us the one that you we-we've done in the class

I Mmmh,

L Then- one-one learner-in my class err we wrote a test, then we were –doing some corrections- in fact I give them scripts-then in turn he raised up his hand, he said, menier, eeh,eeh you know, I'm surprised that- you-you have, given us-this problem whilst we didn't do it in class-in this manner- I said, this is part of the language-a language, it a language barrier

It is quite interesting that the teacher's analysis of the situation does not point to the problem of rote learning or indolence and sloth, but to the problem of language. What is also very interesting is how fast the teacher is able to transfer the problem to the language teacher. The excerpt also reveals a lot about issues of collegiality amongst teachers in this school. Another way to look at it is that consistent with the prevailing SADTU climax in learning and schooling affairs, there seems to be no room for learning from critical friendship amongst the teachers. The teachers cannot deliberate honestly on issues of learning which cross learning areas.

L -in fact because - It was-something that was straight forward-most of them, they've understood the problem, but, this one didn't understand the problem,
I Umm
L because, when we-we dealt with that problem, I've just indicated with a line, it was oxidation numbers-I said calculate –one—element, in that compound, so I said Mn- in- so it was a problem, now it is not my problem, it is a problem of language
I Umm
L So, shut things-if you- give them, that opportunity to raise those things –you are able to discover with those....-even the language part of it-whilst, then I wouldn't understand-and I wouldn't, eeh eeh go and say to- their English teachers –some-some people they-they will be offended-if you tell them that-eeh, learners are not coping with English, you know –so, it is a difficult, eeh problem.

The next question is forcing him to consider his role in terms of learners and learning: how do think your students learn best?

L Err, my learners usually-it depends-it depends, because others, they learn while you are teaching them in class, others they need time, and eeh it is-sometimes- it is impossible, to even err, know individually how-how they, cope with the work because of the numbers in class-but most- of the time, you see, learners they usually err if you give them err like homework-eeh, you give them ho-you-you teach them something, then ask them questions-they will say, they understand-and then after you when you give them, a task to do, that is where you discover that some of them-they don't understand the subject matter, and in turn they will-borrow books from-from others, so, err my strategy ,I usually-ehh when I, enter the class I will, make sure that I check each and every individual that he has done the homework, before I can even, write on the board- the corrections or what-

I ummh, ummh

L but, some-some learners, they do understand the subject matter –when you present, some, it is difficult- more especially Maths and Science, and there-there is this, eeh problem that we have that, Maths and Science those are difficult subjects -so most of the time –learners- they won't- they wouldn't say, eeh eeh, they don't understand in class- I don't know, if it's because of peer pressure, but some of them they do ask, if they don't understand-then they will say, I don't understand, I further explain-give them examples, or maybe- eeh give them that opportunity, for one learner that does understand the-the subject matter to explain to them, and eeh, I find it easy, because some of these learners, if they work with their peers –they, they are free-

Even with this direct question Bongani's response remained generic. This concurs with Gess Newsome's (2000) assertion that teachers who lack confidence in their SMK, tend to use

more pedagogically generic strategies than those which are content-specific in orientation. The lessons reveal very interesting dynamics which mainly emanate from insecure SMK.

Bongani's Practised SMK (10, 20), Learner Engagements (19, 21) and Instructional Strategies (24)

He divided his lessons into the three big ideas of the Atmospheric Chemistry CoRe which are: *the structure and composition of the atmosphere, the chemistry of the atmosphere and its role in nature* and *the human impact on the atmosphere*. He used three teaching strategies: lecture mode, question and answer mode and role play. In the first two sections of his lesson, he used lecture mode and question and answer mode, and, in the third section, he gave the learners a task of coming up with a role play that addresses the big idea.

In the first session, he worked with 28 students, ten girls and 18 boys seated at desks which were organised in ordered rows but randomly across the classroom. Given the nature of the lesson, which was a 1 hour lecture and a 10 minutes question and answer session towards the end, the students were just abnormally too well behaved and very attentive also. As shown in Bongani's reflections below, this clearly was not normal:

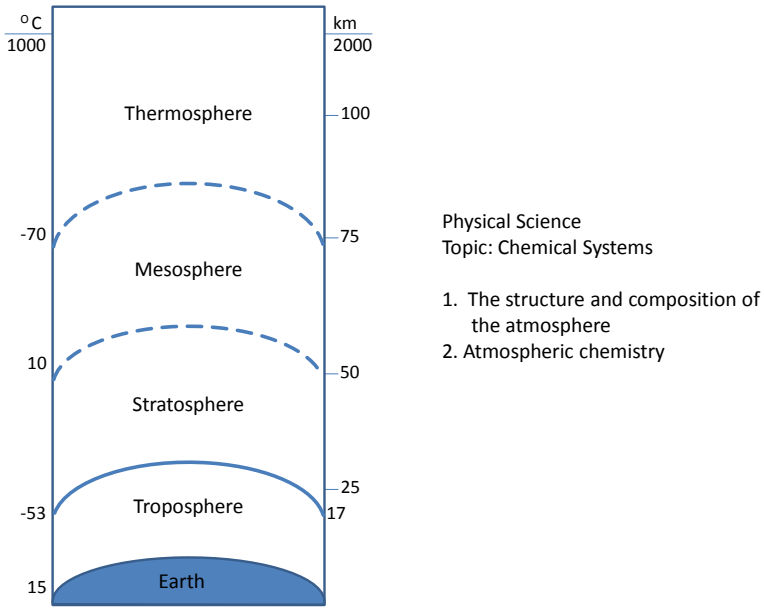
> *The other learners did not want to raise their hands so that they can appear on the video while they taking. Maybe my learners did not talk so much because they were videotaped. My concern was that the learners did not misbehave in class like lesson that was presented by me. My learners focus on the lesson through the period, which was a surprise on my side.* (B- post_lessn_reflctns)

What we witnessed in the video is clearly an artificial setting and this is confirmed by Bongani's pre-lesson reflections as shown below:

> *When I told them about my research project, they became excited began asking questions about the project. What I have realise is that maybe it is because I am going to use a video camera for my lesson. Maybe my teaching is not interesting enough or my methods of presenting are not accommodating all the learners. I have discovered that my subject matter knowledge is lacking, even my teaching style is not accommodative to my learners.* (B- pre_lessn_reflctns)

Bongani's reflections reveal very uncomfortable and painful realities about the dilemmas of insecurity and lack of confidence he faces in his profession. After these painful reflections, what is amazing is that with all the inputs and resources providing opportunities to experiment with some of the more innovative methods we discussed during peer engagements, he decided to settle for a lecture and question and answer mode of teaching.

He started the lesson by introducing the topic as chemical systems. He already had a diagram of the atmosphere showing its different layers and temperature and atmospheric pressure trends drawn on the chalkboard. I thought that was a very helpful survival strategy because he used and referred to the diagram in his whole presentation.



He introduced the lesson as follows first referring to what he had written on the chalkboard next to the drawing:

In the learning area physical science the topic is chemical system, that is the theme. Under chemical system we are going to look at - the structure and composition of the atmosphere. And also we are going to look at the atmospheric chemistry. Which is the chemistry of the atmosphere. Now, ehh the structure of the atmosphere. The atmosphere it is the mixture of gases – it is the mixture of gases. Now we are going to look at the structure of the atmosphere. The first structure – ehh the first layer. It means the atmosphere consists of four distinct layers, which is – the first which is the troposphere, the second one is the stratosphere

Vignette 12: Bongani's Lesson Introduction

Suffice to note that, even though generally, a lot of issues surfaced during Bongani's lesson execution, there is also a lot of evidence that his teaching was systematic, and that he also grasped a lot of concepts concerning this topic which he articulated fairly well during his presentation. Therefore, there was a lot of uptake on his part which happened when he was preparing to present his lessons.

From the excerpt in Vignette 12 above, it is clear that Bongani's lesson pace is very slow, mainly because he repeats every statement he makes and is also not proficient with the language. That could be why he normally loses his learners, as he admitted in the earlier section. The excerpt below reveals further issues arising in Bongani's lesson execution. Throughout the lesson, Bongani involved his learners at certain points by asking questions and the learners' responses were reasonably good, reflecting that they were very attentive. Participation was widespread and did not only revolve around a few learners, but nonetheless, two learners whom I shall call L1 and L2 stood out throughout the lesson. They were not only proficient with the language and pace of articulating their thoughts, but their articulation of concepts reflected a better grasp of concepts than even their teacher. The excerpt below captures some of these dynamics.

Now we are also going to look at the composition – the composition of the atmosphere. An atmosphere is composed of various gases. Who can name the gases?

L1: Nitrogen, carbon dioxide, argon and oxygen.

T: (repeats Oxygen) there are also other gases that played a role also. Hydrogen, helium, methane etc, etc. So those are composition – those are composition. Now, can you give me the chemical formula of carbon dioxide.

L2: CO_2

T: [repeats CO_2 as he writes it on the board.]

Also we got four major gases. The first one that is CO_2. Also we've got oxygen (writing on the board), and also we got nitrogen. The last one is (learner respond: argon), argon. Now these, they are in majority – they are in majority. What percentage is nitrogen?

L1: 78%

T: ehh 78%. Oxygen?

L1: 20.9 %

T: 20.9%. Now these are important – these are important.

Bongani's inputs carried a lot of misconceptions and misunderstandings he had about the topic. The excerpt below reveals some of the content issues that permeated his inputs. He clearly did not have a full grasp of the greenhouse effect as a phenomenon and missed the whole point of absorption of terrestrial infrared radiation by the greenhouse gases. Another issue was that, throughout the lesson, he kept referring to absorption of ultraviolet radiation

instead of infrared radiation, which is a sign that his confusion concerning the concepts of global warming and greenhouse effect were still present.

What happens in these layers? Now first of all because we have this layer we call the tropopause which is the layer that is closer to the... to the Earth. Now the temperature in that layer - the temperature in that layer, it decreases. Because of ehh, carbon dioxide - because of molecules carbon dioxide and molecules of water which absorbs the radiant energy from the sun. Obviously everything is from the sun. So we've got two important gases which are carbon dioxide and water which play a major role of absorbing ultraviolet radiation - which is the radiation.

Furthermore, the atmosphere is a very complex system and the concepts of density, pressure and temperature variations of the atmosphere are very critical to understanding its structure and composition. Because of gravity, 90% of the mass of the atmosphere is found within 15 km above the earth and 99.9% within 60 km. Bongani talked a lot about temperature variations throughout his lesson and the excerpt below reveals (in bold) all he articulated about atmospheric density and pressure variations. This will obviously create a serious gap in his learners' conceptualisation of the topic and it might be all he ever grasped concerning these critical concepts.

Now, going further we've got what we call, the tropopause – the tropopause also it plays a major role also. We are going to look at the trends in that ehh tropopause, also the temperature, the temperature also decreases with altitude, it means when you go up. When you go up, the temperature changes. That is why we say that the temperature- the temperature at that tropopause changes. Ok? (Learners chorus yes). It changes. Now ehhh, a question. We said in the troposphere - we said in the troposphere the temperature does what? (Learners chorus – it decreases) T: it decreases and also at the tropopause. Remember the tropopause is just above the what? (Chorus together with learner – the troposphere). Is above the troposphere. So in other words the temperature decreases with altitude. You need to understand other things again. ***You need to understand that the temperature (writing on the board) temperature versus pressure. So it means temperature is directly proportional to – directly proportional to pressure. If you say the temperature decreases it means also the pressure decreases because it is directly proportional. OK? (Learners chorus yes)***.

In several instances during the development of his lesson, there was evidence that Bongani conflated microscopic and macroscopic attributes:

The structure of ozone layer consists of three atoms of oxygen (and he writes O_3 on the board).

So by chain it means an ozone layer will split, it will split into a molecule and an atom.

In the above excerpt, he was trying to explain the structure of ozone layer, while below, he was explaining that radio waves are only reflected in the ionosphere.

There is no way that here you can see radio waves, they move up there.

Earlier on, I alluded to the quality of the responses of two of his learners revealing that they had a better grasp of the topic than he did. The excerpt immediately below captures how Bongani explained the process of ozone depletion during his lesson.

Obviously in developing countries, undeveloped countries they use these chemicals. They are unstable, but when they go up, at this region, at the stratosphere, that is where they are going to react with what - with the

ozone layer. Obviously one chlorine of this will react with the ozone layer. It will be a chain – a chain. So by chain it means an ozone layer will split, it will split into a molecule and an atom. ***They will react with CFC and immediately they react they will cause harm to the ozone layer. So that is why they call the depletion of the ozone layer or a hole. Now if there is a hole it means everything will pass through.***

Throughout the whole lesson, Bongani never referred to ozone as a gas but always conflated particulate explanations (atoms and molecules) with macroscopic descriptions (ozone layer) which was very confusing. Irrespective of this, Learner 2 gave the response that follows later on during the question and answer session.

T: Now, what causes the depletion of ozone layer? What causes the depletion of ozone layer?

L2: CFC produced by human activities that rise to the ozone layer and react with the ozone gases and thereby causing ozone depletion.

Another confirming instance is that throughout the lesson, he never referred to greenhouse gases but referred to them as greenhouse effect.

T: What is the effect, what effect do they cause? They are all what?

Learners: [some learners responded:] they are harmful[and when the teacher was just about to repeat that L1 responded:] Greenhouse gases.

The other evidence came during the question and answer session after the role play with the quality of one learner's question quoted below. That was a very good insightful question, to which none of the learners could give a satisfactory response, and Bongani did not intervene anyway.

Why is there more emphasis put in the role of carbon dioxide in greenhouse effect than in the role of water?

Another issue which surfaced is that he failed to take the opportunity to address learners' misconceptions which recurred several time during the lessons. Irrespective of his clarity with most concepts, it was very apparent that Learner 1 (L1) had a common misconception we explicitly addressed during our project sessions but Bongani failed to address it. As revealed in the excerpt below, during his lecture session, he posed the following question and L1 responded as follows:

Remember the combination of this molecule with this atom, they form that ozone. When one molecule reacts with CFCs then the whole ozone is disturbed. That is where it is disturbed. So in order for us to prevent that reaction what are we supposed to do?

L1: Conserve vegetation

T: Conserve vegetation? (with a rejection tone)

L2: I think we should try to reduce CFC production.

L1's response above clearly shows that he is confusing global warming, which is due to an exceeding concentration of carbon dioxide in the atmosphere and ozone depletion. During

the role play, he assumed the role of the world renowned scientist. The same misconception surfaced in the comments he made and Bongani did not do anything about it.

7.5 Conclusions

Generally, in both Noma and Colleen's cases, what they professed at the beginning of the process to be doing in their classrooms can be discerned in the plans and designs they produced, as well as in their actual classroom practices.

There is evidence of a huge shift in Noma's own conceptual knowledge of the topic which happened through the activities she engaged in at the planning stage, and was apparent in her utterances during her presentation of the water cycle CoRe, as well as inherent in the sophisticated features of the subject matter she presented to her learners. Her lessons were built around the big ideas identified through a team effort during the development of the CoRe and covered fundamental concepts underpinning the topic of water cycle.

The big lesson for Noma which happened at the planning stage was the critical role played by prior knowledge in the learning process. Unfortunately with the exception of the second engage and explore lesson, this learning was not sustained in her actual classroom implementation and was undermined by the teaching strategies she adopted. Related to this aspect, what became apparent was the role of well-developed and conceptually coherent tasks in grounding the teacher's instructional efforts in her classroom.

As noted in her reflections at the end of her sessions, Noma tried to respond to her learners' feedback, but could not sustain this in her classroom strategies. She struggled between engaging learners and opening the floor for their participation and perceived loss of control of the class, noted in the apparent suppression of the learners' will to learn by expressing their ideas and Noma's struggles to maintain power.

The philosophy of constructivist approach to learning inherent in the 5E lesson sequencing strategy was lost. Even though the tasks and the teaching strategy adopted for her research had inherent features which could assist Noma to operate as a reformed-based teacher, the way she modified them during her actual lessons declared her as a *didactic teacher,* revealing that the epistemology underpinning her practice as objective and therefore not consistent with post-modern views about the nature of science.

Unlike in the case of Noma, at the beginning and at the planning stage, Colleen's utterances at the beginning of the process seemed like she appreciated the central role played by learners

prior to the learning process. At the planning stage, inputs were made during peer engagement to try to help her integrate possible learner misconceptions on electrochemistry, as well as to adjust her approach to a more learner-centred approach, but she did not react to these inputs. She only started reacting and appreciating the role of learner misconceptions from her learners' assessment feedback. These findings strongly support a situated approach to learning that real learning happens when one engages with the context oneself.

Inherent in the assessment tasks she designed to address the three science learning outcomes is a reflection of very strong science subject matter and strategic curriculum knowledge on the part of Colleen. However, due to the strategies she adopted in the classroom to engage her learners, there is some level of compromise of these great innovations to promote the learners' procedural knowledge inherent in the social dimension of the doing of science.

Colleen's inclination was to create a learning environment which was aimed at capturing learners' interest in learning and facilitating understanding through learners' interaction with the teachers and the phenomena, rather than a focus on using learners' prior conceptions and developing them further by promoting interactions not only confined to the teacher but also between the learners themselves. This places Colleen as a *transitional* teacher.

Bongani's struggles throughout his lessons were clearly issues of poor SMK. Most of his conceptual issues are consistent with what was revealed by the conceptual test discussed in chapter 4. As already expressed, irrespective of all the misconceptions he carried into his classroom, it was only at this point that his uptake became evident. What was also revealed in chapter 4 and would have some link with his poor SMK is his trajectory and qualifications as a science teacher.

CHAPTER 8
BRINGING IT ALL TOGETHER

8.1 Introduction

There are many signs that the phasing in of the NCS in South Africa was a great shock to the educational system. The main challenge was the high expectation of the curriculum on teachers' professional knowledge and procedural competencies. The philosophy underpinning this new curriculum necessitates a total paradigm shift for most teachers, in relation to their training and present outlook on practice. Amongst the realities the teachers' classroom data revealed was how unfair it is to have such high expectations of teachers without proper support. It was also disheartening to witness the coping strategies a teacher used when expectations were high and how opportunities for learning were compromised.

Indeed, the ideals of NCS curriculum placed complex intellectual demands on teachers. With physical science, the problem was further exacerbated by the introduction of new advanced topics to the school curriculum. Therefore, this study sought to investigate how some physical science teachers handle change in the face of challenges imposed by these curriculum reforms in South Africa. In this final chapter, I firstly draw on the learning across findings from chapters 4, 5, 6 and 7 by highlighting cross cutting issues which suggest questions for further learning. I then move on to reflect on the whole study to bring together key ideas, formulate insights and lessons learnt, as well as highlight questions raised.

Reflections across Chapters 2, 4, 5 and 6 yield emergence of 9 big themes which are expressed as assertions that can be regarded as the key findings, and are used to organise the discussions in the first part of this chapter. These themes can be put into three categories. The first category which consists of the first three assertions, has to do with factors which are external to the teacher's internal world. The second has to do with the teachers' internal resources and how they either enable or constrain efforts to change. The last set, which involve the last assertion, form part of methodological findings and has to do with critical engagement of processes, strategies and resources, which are effective in supporting the teacher change processes. In the second part of the chapter I will consider the methodological findings of this study, as well as critically engage with the LTtP model of teacher learning which emerged from this study and was used to organise the three findings chapters as a

potential framework for organising teacher learning. In the last part of this chapter, I consider each research question of the study, and show how the questions were answered in the first and second sections of the chapter.

8.2 Constructive and destructive dynamics within teacher learning environments

The choice of site of teacher learning in the minor case study (Chapter 4) was influenced by arguments put forth by researchers such as Kass & McDonald (1999), that learning is both a constructive and an enactive process in which a person and a setting co-emerge. According to this line of thought, the context in which learning is situated is an important part of the picture. Another strong confirming argument put forth by Cochran, DeRuiter, & King (1993), is that, understanding is situated as well as context-bound because social interactions are foundational and intricate to the development of the thinking tools and in understanding of how they should be operated. Therefore, this study began with what I refer to as the minor case, and was initially conceptualised as a school-based small-scale collaborative action research project, that sought to promote an experiential learning outlook on practice, and thereby engendered practices and habits of mind which mobilise teachers for change.

This cherished ideal came with its challenges and in this section, I discuss my findings on how prevailing contextual issues in the teachers' enveloping environment can affect the learning and teaching processes by undermining efforts of highly committed teachers.

8.2.1 Assertion 1:

School dysfunctionality serves as a threat to subject-focused teacher professional development because school collegiality is a critical criterion in the school's capacity to support innovation.

Rogan & Grayson's (2003) notion of capacity to innovate seeks to elaborate on factors that are able to support or constrain implementation of innovative ideas and practices in an institution or school set-up. They argue that not all schools have the capacity to support innovation and that it is impossible to implement innovation in schools that are in disarray and are dysfunctional. The four factors they have identified as indicators of the capacity of schools to support innovation have been adopted and slightly adapted, as indicators in describing the teachers' enveloping change environment. The four have been adopted as follows: school management and ecology, learner factors, teacher factors and physical

resources which, in the present study, are referred to as resources and time constraints, and, in the minor study, competed with external factors which were partly incorporated within the school management and ecology.

In the minor case study, what appeared in the beginning as a functioning well cultured school, emerged during the research process as a school in turmoil. As discussed fully in chapter 4, the focus school was fairly new and within a period of two years had already been under several different administrators who acted as principals and deputies since the principal's dismissal. Rogan & Aldous (2005) revealed that school ethos and the way in which a school is managed, have a high impact on implementation. Consistent with some of the issues that emerged in this study, they argue that the level and style of accountability are also important. What emerged was that the school was a highly politicised and contested terrain with sweeping contextual issues, ranging from a principal dismissed on a charge of embezzlement; an acting deputy principal resigning under a cloud of controversy over learner molestation, student and teacher political activities that corrupted the school and grave teacher incompetence and irresponsibility. What further destabilised the school set-up was that leadership was rotated and each time one of the staff members acted as the principal, others did not cooperate but sabotaged the leadership.

What Rogan & Aldous (2005) further assert is that whole school development is more important than professional development in particular learning areas, since varying approaches to curriculum change in a school can be counter-productive. Related to this assertion, a factor that emerged strongly in the findings from chapter 4 in support of prioritisation of whole school development over subject focused professional development initiatives is the importance of *school collegiality.* From the types of collegial issues that emerged from the minor case study, establishment of whole school collegiality is an imperative in ensuring the support base for the subject-focused professional activities and any learning which can spring from professional development initiatives.

Powell & Anderson (2002) argue that, for schools to be able to sustain any form of curriculum innovation and ensure its success in translating the reform agenda into real practice, they should be set as communities of practice which are partly characterised by sustained collegial support from the whole school community, which is itself oriented towards the reform vision. In this study, the issues which were raised by the acting deputy principal and those which arose with efforts of trying to integrate the new science teachers

who joined the school later on, as discussed in the next section, were actually such powerful forces that undermined the whole process and led to a breakdown.

8.2.2 Assertion 2:

Key participants' prevailing commitment, collegial and learning spirit are the driving forces for change and are easily achievable in formalised, as opposed to non-formalised, professional programme settings.

The findings in this study bear witness to Rogan & Grayson's (2003) argument, that professional development needs should be institutionalized and approached in a systematic way or otherwise it becomes a futile exercise. Even though there was great potential for professional engagement in the minor case study, the challenges were too deep, in my estimation, and beyond the scope of this PhD study. The types of challenges that emerged in the minor case study affirm the two requirements raised by Cohen, Manion, & Morrison (2007), at the planning stage of a school-based action learning teacher professional programme. These are: firstly, a clear and explicit expression of the project's objectives, in a way that all participants understand and are very clear about their implications; secondly, a careful analysis of the context in which the programme will be launched, with the aim of determining precise, but adaptable, relationship between the research and development aspects of the programme. They argue that this stage is critical for the venture, in that it is at this point, that the seeds of success or failure are planted. If the objectives, purposes and assumptions are not made perfectly clear to all concerned, and unless the role of key concepts is stressed (e.g. feedback), the enterprise can easily miscarry.

Related to this assertion is that it can take one passionate, visionary and committed individual to mobilise change within a school system. This came clearly in the roles that Lerato and the acting deputy principal of her school assumed. They showed that it is possible for one individual, who is not necessarily at the helm of power, to become a catalyst in bringing about the change needed, even in the most hopeless situations. In chapter 4, I explained that when I first went into the school, I was impressed by the professional image the school portrayed. The flowers and the gardens around the administration block, which gave such a great image of the school as a place of learning, were due to Lerato's efforts and participation in the environmental course she did through Rhodes University. Lerato was a mover and a shaker, and the spirit of commitment and enthusiasm she engendered, as she got her

colleagues to rally around the programme, and the intensity she displayed while participating in the activities, was remarkable.

In the case of the acting deputy principal, this spirit could be discerned in the account she gave during an interview on how she stood by the truth, irrespective of the risk of isolation she faced, because of the love and respect she has for her learners and her profession. As discussed fully in chapter 4, she was remarkable because she stood her ground in the face of intense political and social pressure. She was not passive about the issues which cut so deeply in undermining the culture of learning in the school. Analysis of her moves is very interesting, because it reveals proactive and constructive action on her part. She single-handedly uprooted deep-seated corruption and incompetence prevalent in her school context. She was the HOD and shared teaching of English with another colleague at grade 12. Even though she was sharing a grade with a very problematic colleague, she stuck to her professional ethos and upheld her standards; she ensured that she did her work thoroughly in class so that her learners were very well prepared for the matric exam. To show that her concern was about learners' progress, and not about competing and exposing her colleague, she went out of her way to try to do extra lessons for the learners in the other teacher's class in her own free time. Not only did she do her own work in the classroom, but she was vocal about challenging and confronting those who were not committed, in staff meetings, as well as in reports at district level. When the MEC visited the school, her allegations were supported by data; even though the matric results were very bad, deeper analysis of the results revealed that her class obtained a 100% pass rate, while the other teacher's class was below 18%.

In the major case study, reflections and exchanges during the first planning meeting discussed in the seventh chapter indicate that initially Colleen displayed a domineering attitude, which was just noted but not explored further. Sipho, on the other hand was a passionate and highly committed participant who played a constructive role in the process, and this was evident in his input throughout the process, especially during planning at the beginning of the process. His role during the planning session indicates that he was constructive and played a catalytic role when Colleen was dominating the discussion, and jumping from one point to another, trying to torpedo all suggestions. He responded calmly to most of Colleen's queries, showing how it was possible to implement the ideas in their schools. In the sessions that Sipho attended and the activities he participated in, he was an enthusiastic player who shared his ideas generously, and was open about expressing his

learning points. The only external peer engagement activity he participated in, where the team presented their work, was a local teacher workshop, part of the ongoing thrust activities the university unit hosted. During this workshop, Sipho was very vocal and spoke highly about the benefits of participating in the programme, and how it was impacting on his practice.

It is quite evident from the work produced and the level of participation reflected, that this team of teachers worked extremely hard, and the learning and insights were enormous. The process started with a lot of scepticism and lack of enthusiasm, especially in Colleen's attitude, but ended up with feelings of deep appreciation, as well as personal fulfilment, with the researcher receiving very special presents from Colleen on the day of the last comments for her final draft; Noma and Bongani made special visits to present their gifts later on. Unfortunately at the end of the 6 months, only Noma, Colleen and Bongani managed to submit their projects. Sipho did not meet the deadline and had to do a different project from scratch the following year. As reflected in Bongani's profile, he was a low performing student with serious SMK challenges and, even though he managed to submit his project within the six months, he only completed outstanding courses for his degree in 2011. We had not been in touch for two years but after learning that he passed all his courses, he gave me a call and said: '*I called to say that I am ultimately qualifying for my degree and would like to send my deepest appreciation for the support and exposure you provided during the time when we did our honours projects.'*

Comparing the two case studies, it is clear that stability and commitment in the major case study was guaranteed mainly because the participating teachers were enrolled in a formal programme working towards a qualification. As discussed in chapter 4, with the exception of Colleen, the three teachers were working in school contexts which were as dysfunctional as the high school in the minor case study. Irrespective of their working contexts, the teachers' uptake and productivity were quite substantial, compared to the teachers in the minor case study. They struggled, but managed to keep a balance between their work and the demands of their studies.

8.2.3 Assertion 3:

Great potential for mutual learning from primary school and high school collaborative efforts

This assertion is based on quite a few indicators which were short-circuited by the premature ending of the minor case study. In chapter 4, it is clear that both the high and the primary school teachers have two distinct areas of strength which, if combined in a common programme, would guarantee an environment where each group could learn from the other's strengths. The contrast in the way the two schools (high school and primary school) in the minor case study went about their planning for learning, revealed that the primary school was more organised and had a working understanding of the policies of the new curriculum. This is confirmed by the following observation made by the acting deputy principal:

> *...and I think that's done because I was saying if things are not done properly like monitoring of educators. I have colleagues who are senior managers ' ko di' (Tswana for 'at') primary schools and I feel small every time they say this week is submissions. All educators will be submitting their personal files. We don't do that in my school. I don't know whose fault is it but we all know that it suppose to be happening but it is not done I want to tell you the honest truth, it is not done.* (acting DP_int)

On the other hand, the concept challenge revealed that teachers at high school had stronger SMK, compared to teachers at primary schools.

Reflection sessions, which would allow the two groups of teachers to enter each other's classrooms through viewing of videotaped classroom lessons, would ensure cross-pollination of good practice across the two phases. A pattern which emerged from the pre-lessons was that the primary school teachers were strong in modelling learner-centred approaches in their classrooms, but shallow in addressing content knowledge. The reflection sessions would allow the FET teachers to witness and appreciate demonstrable instances of what it means to manage a learner-centred classroom. On the other hand, the FET phase teachers were relatively strong in content knowledge and review of the videos of their lessons would serve to expose primary school teachers to a relatively fair and constructive address of science concepts in their classrooms.

8.3 Factors related to the Teacher's Internal Resources

In this section, I discuss patterns and the types of learning that emerge from consideration of each teacher's profile and their unique experiences while participating in the programme. This section is mainly based on the findings of the major case study (chapters 6, 7 and the last part of chapter 4). I carefully consider the factors at play, and how their personal capacities, knowledge, beliefs and attitudes enabled or constrained their efforts to access resources, tools and strategies aimed at supporting their endeavours of enacting change in their classrooms. Findings in this section revolve more around Colleen and Noma's experiences because Sipho did not take the process beyond the planning phase, and Bongani's uptake was minimal.

8.3.1. Assertion 4:

Strong teacher content knowledge and comprehension skills are central to the teacher's strategic decision-making during planning and implementation of innovations.

The elements of curriculum saliency and content knowledge came through strongly in Colleen's case. As already alluded to in the previous chapters, curriculum saliency is a concept put forward by Geddis to describe the type of strategic curriculum knowledge which enables teachers to sequence the science topics and their inputs in strategic, logical ways to ensure coherent learner conceptual knowledge.

Noma

Most misconceptions in chemistry are borne out of failure to make shifts between descriptions of what can be observed at macroscopic level and how these are explained at microscopic level. In chapter 4, even though Noma scored high in the concept challenge, the results revealed that she scored very low on these types of problems as well as on problems that involve energy change during physical and chemical changes. These together with her pre-CoRe discussed in chapter 5 are indicative that she started off with poor content knowledge of the "chemical systems" theme in both grades 10 and 11. Irrespective of this, her comprehension skills facilitated good uptake, both during the group sessions, as well as in her independent studying towards a group task. There were signs of a huge shift in Noma's own conceptual knowledge of the topic, which happened through the activities she engaged in at the planning stage. This was apparent in her utterances during her presentation of the water cycle CoRe, and was also inherent in sophisticated features of the content she presented to her learners during the classroom implementation phase.

As discussed in chapter 7, her lessons were built around the big ideas identified through a team effort during the development of the CoRe, and covered fundamental concepts underpinning the topic of the water cycle. It was apparent in the comments she made during group sessions, that she held several misconceptions around the concepts of greenhouse effect, global warming and ozone depletion, which she cleared mainly through the group discussions. She also appreciated the role of integrating common learner misconceptions in the lesson, as well as strategies of abstractions and theory building, in ensuring understanding through clear distinctions of the macroscopic, microscopic and symbolic, in descriptions facilitating learner understanding.

Irrespective of the learning that accrued during the planning phase, Noma still struggled to translate this to practice during the classroom implementation phase and learning happened over several sessions mainly through the mediating processes of action and reflection. Managing and developing skills underpinning open inquiry tasks is very complex, as this entails a combination of high ordered procedural skills, as well as an understanding of the inquiry process. As discussed in chapter 5, Noma's strength in curriculum saliency became evident in her utterances during the *beliefs about learning and teaching* interview. After gaining knowledge on how to manage LO1 (scientific inquiry), Noma reviewed and adjusted her teaching and assessment strategies (13) on her own, to home in on the procedural skills (10) underpinning open inquiry in her classroom. She deliberately slowed down her pace, revisited the practical work they had already done and modified it, to engage and develop the learner's skills for planning scientific investigation, data collection, handling and interpretation.

It also became evident that she was conscious of the limitations imposed by textbooks in addressing the science learning outcomes, and was actively working to overcome that in her strategies. She was able to use her knowledge and understanding of scientific inquiry, and align her teaching strategies to assist learners in gaining knowledge of the procedural skills (10) involved in planning a scientific investigation. This, in itself, is very commendable and a clear evidence of Noma's working understanding of LO1.

Irrespective of these clear self-professed utterances which were quite convincing that Noma had a working understanding of developing learners' open inquiry procedural skills the strategies Noma adopted during her explore lesson. As discussed fully in chapter 7, she took the set-up outside in the sun out of the learners' sight where they could monitor what was happening by themselves and expected them to take what she told them as a fact instead of allowing them to observe on their own and draw their own conclusions. This move on her part was a missed opportunity for her to introduce issues of validity or controlling variables as it negated the very principles that underpin experimentation. Another move she made which resulted in a missed opportunity to engage her learners in procedural skills underpinning scientific investigation was when she opted to carry out the procedure herself instead of involving her learners (or calling on volunteers) in setting up so that they could appreciate the role of evidence in experimentation.

Colleen

Even though Colleen had the least classroom teaching experience of the four teachers and did not hold a professional teaching qualification, her strong science content knowledge gave her the edge to claim autonomy and deeper engagement in the process. Colleen had a very strong content knowledge and, of all four teachers, she was the one who was able to design high quality tasks independently, which addressed the three learning outcomes, as well as integrate the project within the set on-going school-based plans. Unlike the others, she managed to stay within schedule, in terms of her research progress and school work without having to make informal arrangements outside school hours to accommodate her research. She managed to address a huge scope of grade 12 content within her research, as well as use it to respond to the GDE assessment requirements. She was the only teacher who was able to share her work with a colleague, who happened to be her head of the department, and use her research resources parallel with her classroom implementation in another class. She was also in a highly functional environment, and its reduced flexibility increased the demands on her.

Colleen was teaching both grades 11 and 12 and the other three teachers were teaching at grades 10 and 11. For the sake of forging collaboration amongst the four of them and also because grade 12 is a high stakes grade, Colleen was encouraged to focus her study on grade 11. She was also encouraged to narrow her study to one of the topics making up the chemical system theme and not on all of the themes. As discussed in the previous chapter, Colleen ignored this advice and decided to focus on the whole grade 12 Chemical Systems. This made her whole research project difficult, as became very apparent in the construction of a CoRe as a topic specific cognitive framework.

As a consequence, she had to deal with a large range of topics, resulting in her not being able to come up with appropriate *big ideas*. What she identified as big ideas were too broad and would each be an independent topic with its own CoRe and *big ideas*. These, however, were also not just ill conceived topics, but her original conception themes around which the knowledge area of chemical systems could be built in grade 12.

As discussed in more detail in chapter 5, a closer analysis of how the discussions during the first planning meeting unfolded, and how Colleen negotiated the focus of her study, revealed a lot about her strategic curriculum knowledge, as well as her content knowledge of the topics constituting chemical systems in grades 11 and 12.

One can argue that a teacher with a strong curricular and science content knowledge would readily realize that, even though the two knowledge areas, chemical change and chemical systems, are treated separately in the curriculum documents as well as in most textbooks, in order to maximise learner uptake, the most sensible strategic move would be to synchronise the two themes.

Sipho

Even though Sipho did not stay with the process very long, it was clear that his relatively strong content knowledge, and very good comprehension skills and language proficiency facilitated good uptake and quality contributions during group sessions. During the construction of the water cycle CoRe and the reflections on the *Inconvenient Truth* DVD, he was able to take discussions to a deeper and more profound level. He also attempted to create a worksheet to add to the curriculum programme he had put together with Noma for classroom implementation. He was fascinated with the use of models and particle diagrams to address learner conceptual difficulties and he started putting together a worksheet using magnets and circular papers of different colours to represent molecules of different substances. This worksheet showed potential to assist learners in making shifts between microscopic descriptions and macroscopic observations, but unfortunately he did not see it to completion.

Bongani

Bongani's content knowledge was extremely weak and he struggled to keep pace with the intellectual demands of the tasks, while working independently, as well as within the collaborative group. His writing and comprehension skills were also poor, but he tried and stayed with the process, even though his inputs and uptake during discussions were superficial. In the classroom, it was most disheartening to observe Bongani's struggles with science content, especially how this lack constrained his ability to facilitate fruitful learning for his learners. During his lesson delivery, his own misconceptions e.g. *that carbon dioxide and water absorb ultraviolet radiation*, as well as his conceptual difficulties of conflating microscopic and macroscopic attributes, surfaced in the descriptions he put forward, e.g. statements like: *ozone layer is splitting into a molecule and an atom*.

8.3.2. Assertion 5:

Ignoring learners' prior knowledge set limits on the teachers' efforts in pushing the boundaries of innovation.

Another dynamic, which emerged clearly as impeding the teachers' change efforts, was their level of awareness to the role of learners' prior knowledge in the teaching and learning process. In all three cases, the level of their awareness about the critical role played by the learners' prior knowledge was a factor in constraining their efforts of implementing change in their classrooms.

What came through in Noma's story, is the profound learning which happened during the planning stage about the role of learners' prior conceptions in learning. She also addressed her own misconceptions about the topic of the water cycle, which led to clarity and increased her own content knowledge. Unfortunately, with the exception of the second "engage and explore" lesson, this learning was not sustained in her actual classroom implementation and was undermined by the teaching strategies she adopted. What became apparent in Noma's experiences (discussed fully in the next section), is that this lack of awareness takes one's practice on a teacher-centred route, irrespective of how curriculum-aligned the materials or teaching strategies are. Another related aspect, which became apparent and is discussed fully in the next section, is the role played by well-developed and conceptually coherent tasks in grounding the teachers' instructional efforts in her classroom.

As discussed above, Colleen's strong science content knowledge and knowledge of industry supported her efforts and gave her an advantage over the other three teachers. What really undermined her efforts (as discussed fully in section 8.2.4 below,) was the lack of appreciation of the critical role played by learners' prior knowledge.

The theme which runs through Colleen's story, is that, while she appreciated that learning involves construction of knowledge and that only the learner can make it happen, and that the role of the teacher is to create an environment that captures the learners' interest, her knowledge of how to create this environment is still not evolved. She still does not appreciate the central role played by learners' prior conceptions (14, 24) in the construction of knowledge. She also did not appreciate the critical role that social interactions played in mediating and promoting the requisite procedural skills (10, 20) inherent in the nature of science and its learning. This blind spot resulted in her gravitating to instructional strategies (23) that assumed that knowledge is transmitted and not constructed. The overall instructional orientations she adopted in practice positions her as a *transitional teacher* whose main drive is in facilitating learners' understanding, by creating an environment where learners interact with the teacher and the phenomena.

Colleen's inclination was to draw on her strong content knowledge and knowledge of the world of industry to create a learning environment which was confined to capturing learners' interest in learning, and facilitating understanding through their interaction with the teachers and the phenomena. This approach was limited, in terms of focus on, and use of learners' prior conceptions to, promoting interactions not only confined to the teacher, but also between the learners themselves, in order to develop their conceptions further and promote a dialogical learning environment.

This placed Colleen as a *transitional* teacher, who was still struggling with thinking of her teaching in terms of what is good for her learners, rather than what she knows personally and is comfortable with during teaching. In Colleen's case, one can argue that what seemed to be a lack in her repertoire of knowledge and skills, and which was also at the core of undermining her efforts at curriculum-aligned teaching was the knowledge of research on learning theories of how learners learn, as well as appreciation of the nature of social aspects in the generation of scientific knowledge which relate to (10, 11, 14 and 15) in the TLtP model.

With Bongani there were several learner misconceptions arose, which indicated that learners were confusing global warming and ozone depletion, but Bongani did nothing to address them. The questions he incorporated in his lesson delivery were also low-ordered questions and did not facilitate fruitful classroom discourses for deeper learning. During a question and answer session at the end of the role play, one learner asked a very good and challenging question which could spark a good debate about *why there was more emphasis put on the role of carbon dioxide in greenhouse effect than the role of water.* This question was not answered well by the learner (role player) and Bongani did nothing to address this situation.

8.3.3. Assertion 6:

There is interplay between teacher beliefs and the inert character of curriculum aligned materials in supporting teacher orientation in reform-based approaches.

Some studies (e.g. Powell & Anderson, 2002; Pajares, 1992) highlight the centrality of the behaviour and belief of teachers, in relation to how the curriculum is put into action. The argument raised is that ideas teachers hold about learning and teaching are at the core of their practice. These studies also highlight how previous reform efforts fell short of success because they largely ignored the influential nature of teacher beliefs about changes in

teaching practice. The findings of this present study indicate that there are both consistencies and inconsistencies in the conceptions the teachers hold about the learning and teaching of science, how learners learn and their actual classroom practices.

Coupled with the role of beliefs is the potential role of curriculum-aligned materials in supporting reform initiatives. Generally, in all three teachers who stayed with the course, there was alignment between their planning and implementation. Experiences of all four teachers attest to the critical role played by curriculum-based materials in assisting to initiate reform-aligned strategies. What unfolded in all four cases is that even though these materials are tangible tools, they are inert in character and are totally dependent on the teacher's philosophy about the nature of knowledge and therefore learning. This is in conformity with Powell & Anderson's (2002) assertions, that curriculum materials are inert and do not generate change by themselves but are rather just tools that teachers can use to enact change.

The findings also reveal that the potential of these curriculum-aligned materials to support and sustain reform in the classroom can be undermined by the epistemologies underpinning the teacher's practice. Therefore this study supports studies (e.g. Loucks-Horsley, Hewson, Love, & Stiles, 1998; Powell & Anderson, 2002) which argue for use of reform-based curriculum materials, coupled with comprehensive transformative professional development as an effective mechanism to support reform in science education.

As discussed in the section above, the learning which Noma picked up during the planning phase, concerning the role played by learners' prior knowledge in the learning and teaching processes, was not evident in the her lessons during the classroom implementation process. Even the philosophy of the constructivist approach to learning inherent in the 5E lesson sequencing strategy was lost. The tasks and the teaching strategy adopted for her research had inherent features which could assist Noma to operate as a reform-based teacher, but the way she modified them during her actual lessons declared her as a *didactic teacher*, revealing that the epistemology underpinning her practice as objective was therefore not consistent with post-modern views about the nature of science.

Unlike Noma, at the planning stage, Colleen did seem to appreciate the central role played by learners' prior knowledge to the learning process. Inputs were made during peer engagement, to help her integrate possible learner misconceptions on electrochemistry, as well adjust her approach to a more learner-centred approach, but she did not react to these inputs. She only started reacting and appreciating the role of learner misconceptions when

faced with her learners' assessment feedback. These findings strongly support a situated approach to learning that real learning happens when one engages with the context oneself.

Inherent in the assessment tasks she designed to address the three science learning outcomes is a reflection of her very strong science content knowledge. Colleen's research task (see appendix S) shows that she did not totally ignore the advice to consider learner's prior conceptions but it is in the way she chose to use that knowledge to facilitate learning that was problematic. She did identify the research based list of possible learner misconceptions in electrochemistry but instead of engaging her learners with these she incorporated them in the task and expected her learners to engage with them independently. This was a move on her part that revealed her lack of knowledge of theories of learning; of the critical role as well as the resistance of learner misconceptions in the construction of new knowledge, at the time of the project. Unfortunately she also chose not to use the recommended 5Es lesson sequencing strategy to frame her lessons and the opportunity was lost there also. As illustrated by Noma's classroom implementation struggles, if Colleen used the 5E strategy, she would also have been forced to consider and integrate learners' prior conceptions from the beginning (engage lesson) and right through the stages of her teaching. Unfortunately she also chose to ignore the use of this strategy to plan and sequence her lessons. However, due to the transmission strategies she adopted in the classroom to engage her learners, there is some level of compromise of these great innovations to promote the learners' procedural knowledge inherent in the social dimension of science.

Powell & Anderson (2002) make a convincing argument that successful use of curriculum-aligned materials in the classroom needs to be accompanied by a teacher's revised conceptual understanding of science content, knowledge of the research on how students learn and well developed PCK. In Colleen's case, one can argue that what seems to be a lack in her repertoire of knowledge and skills and which is at the core of undermining her efforts at effective curriculum-aligned teaching is the knowledge of research on learning theories of how learners learn, as well as appreciation of the nature of social aspects in the generation of scientific knowledge.

8.3.4. Assertion 7:

Opportunities for asserting learners' will to learn and promoting their procedural skills during the lesson can be undermined by the teachers' struggles for a sense of self-efficacy.

Besides teachers' beliefs about learners and learning, it can be argued that there are many dynamics to explain the tendencies of teachers who perceive knowledge to be transmitted rather than constructed. Bandura (1977) argues that teachers with a strong sense of efficacy would be more inclined to seek and be led by their learners' prior knowledge in organising for instruction, because they are able to think about what is best for their learners during learning, rather than what they know or feel comfortable with themselves.

This came through strongly in Noma's case with clear patterns of teacher insecurities. As a survival mode, Noma adopted teaching strategies which totally undermined her learners' aspirations to contribute in class, squashed learning aspirations and created a compromised learning culture in the classroom. As noted in her reflections at the end of her first two sessions, Noma started very well by trying to respond and be guided by her learners' feedback, but ultimately she could not sustain this in her actual teaching. The strategies which Noma adopted in her first lessons as part of the "engage" strategy, viz. to seek her learners' prior knowledge, generated a lot of excitement amongst learners to share their ideas and participate fully in the lesson. Instead of seeing this as an achievement on her part, it was perceived as loss of power and control of the class. She then reverted to teacher-centred transmission mode where she displayed a show and tell attitude, and rarely involved learners or asked for their ideas.

Gess-Newsome (1999a) highlights the distinction in orientation of strategies used frequently by the majority of teachers, and those which are used less frequently. She points out that the less frequently used strategies have content-specific orientations while those used more frequently are pedagogically more generic – a finding which she argues might be linked to teachers' lack of confidence in their content knowledge. This might also serve to explain the gap between beliefs and practice that this study addresses.

In the few instances where she did open the floor and ask for learners' ideas, one could almost perceive an upsurge from suppression which was apparent in the aggression and competition learners displayed, to try to be the ones answering the questions. It was clear that the learners were keen to be involved and desperately wanted to share their ideas. There was a clear power dynamic at play, with the teacher trying to keep the class under control and the zest and will to use self-expression as a mode of learning from the learners. It was a very interesting power dynamic, where one could clearly see passive reactions as the teacher's strategy suppressed the learners' will to learn through participation. In the one instance

where Noma interviewed one learner about how he perceived her teaching, he passionately expressed to Noma that during the lessons, she was answering for them and not allowing them to contribute. Even with this open response from the learner, Noma did not seem to get the message but simply shifted, asking the learner a tricky content-related question which was almost as if it was meant to expose his lack of knowledge.

In Colleen's case, this dynamic was more complex and not as apparent, as in the case of Noma. Her utterances during informal discussions, as well as during interviews, revealed that she was vacillating between a sense of insecurity and confidence in some instances. There were instances when she expressed a sense of insecurity about her professional teaching knowledge because of her lack of professional teaching qualification, and in other instances a sense of confidence because of her strong science content and industrial knowledge. One can argue that these varying positions in the sense of self-efficacy could also account for the varied strategies she employed. In some instances, she was able to give her learners the platform and autonomy to carry out their investigations and present their work, and in others, displayed very self-absorbed tendencies, as in her 45 minute lesson presentation where she just did a *chalk and talk* lesson, and hardly involved her learners in discussions or questions. This was very strange because it was a recap lesson, after the learners' open investigation tasks which had generated so many ideas and learning. Colleen put this down to lack of time.

In Bongani's case it was quite disconcerting to witness the struggles he endured to implement the ideas he planned for. First of all, the way he expressed his dismay in his reflection at the manner in which his learners were attentive during his lessons, indicated that he has accepted his learners have little respect for him. He expressed that, that type of respect and attention did not happen in his normal science lesson, and attributed it to the fact that the learners were excited about being video recorded. In his lesson delivery, he used a lecture mode and did not attempt any curriculum-aligned strategies, except when he gave his learners a task which involved role playing. He left the role play totally in the learners' hands and did not bring in any scaffolding measures, or correct the misconceptions that surfaced from the learners' presentations. The one positive thing about his lessons was that he built his lessons on the big ideas which were identified as a collaborative effort during the planning phase. Even then, one could see signs that he was struggling and not confident about the matter he was delivering. Opportunities which arose were many, but Bongani's lack of sufficient content knowledge totally undermined his ability to engage his learners in fruitful learning experiences. What was even more disheartening was that some of his proactive learners were

even more proficient in the language of instruction and in articulating their scientific ideas than he was.

What also became evident is the importance of openness as the starting point in the learning journey and that the position of being a teacher and expected to know it all, can actually prevent one from engaging in reflective practices, or opening up during in-service training. This also reveals how unfair it is to have such high expectations of teachers, without proper and ongoing support, as well as the types of coping strategies a teacher calls on when put in the difficult position of being the all-knowing.

8.3.5. Assertion 8:

Teacher growth patterns are idiosyncratic, topic-specific and shifting because teacher change is bound to time, place and person, and teachers are knowledge producers rather than knowledge receivers.

Consistent with Powell & Anderson's (2002) assertions, the findings of this study attest that there is uniqueness and individuality about any change process and that teacher change is situated in time, place and person. This theme is connected to the notion of the enveloping teacher change environment, that the identified factors create a unique dynamic in the way they play out in each teacher's life, and hence affect and determine each teacher's learning prospects. According to the LTtP model, as these factors are external to the teacher's intrinsic world, they can either constrain or mobilise each teacher's unique internal resources to support the teacher in accessing the necessary tools and skills to enact change in their professional world. In this section, I focus on the unique and multiple ways each teacher's internal resources are mobilised, to access available tools, resources and processes aimed at opening a variety of possible paths to their own professional growth.

In this section, each teacher's unique growth path is mapped, using the LTtP model. This would be what Banks, Leach, & Moon (2005) refer to as a *personal subject construct*, which they argue is a missing link to show how the interaction between SMK, pedagogy and contextual factors result in PCK. In this section, each teacher's unique growth path is mapped using the LTtP model. Numbers are used to indicate progression and colour variations to indicate the intensity or dominance of the marked change and advancement of capability. Only three of the teachers (Colleen, Noma and Sipho) in the major study are profiled, because Bongani did not make any notable shifts. Even in the case of the three

teachers, the shifts are not very substantial because of time limitations, as well as complexities involved in teacher change. Powell & Anderson (2002) argue that, from experience, the success of transformative professional development programmes is both time and resource intensive, to a point where, in some cases, the level of required support to ensure meaningful change in a school setting could mean a one-to-one ratio of researcher to teacher. This, they further argue, is not an indication of the teachers' inability to change, but rather a reflection on the complexity and the level of difficulty in initiating and sustaining cultural change of routine classroom practice.

Colleen

Colleen's background is unique and brings rich and interesting dynamics to the study, because, on one hand, she had less teaching experience and no professional teaching qualification, and, on the other, she was qualified in pure sciences and had industrial working experience. Using this model to analyse Colleen's growth pattern reveals that her pure science background qualification, work experience in industry and strong work ethic (1) served as a strong knowledge, beliefs and attitude base (2) for some components to support her change efforts, while her lack of professional teaching qualifications and limited teaching experience undermined her efforts in some aspects.

From this mix of strong and weak base springs strong initial knowledge of science content, of learners' procedural skills, learners' positioning in learning and instructional and assessment strategies (3) which she was able to use to effectively (4) engage with peers and resources (5) within the stimulus and challenge domain during the planning phase. What is also evident within the knowledge and views domain is that it supported her to independently engage with the resources (5) made available within the stimulation and challenge domain, as well as from her own sources, to come up (7) with the plans and the designs (8) for her classroom implementation.

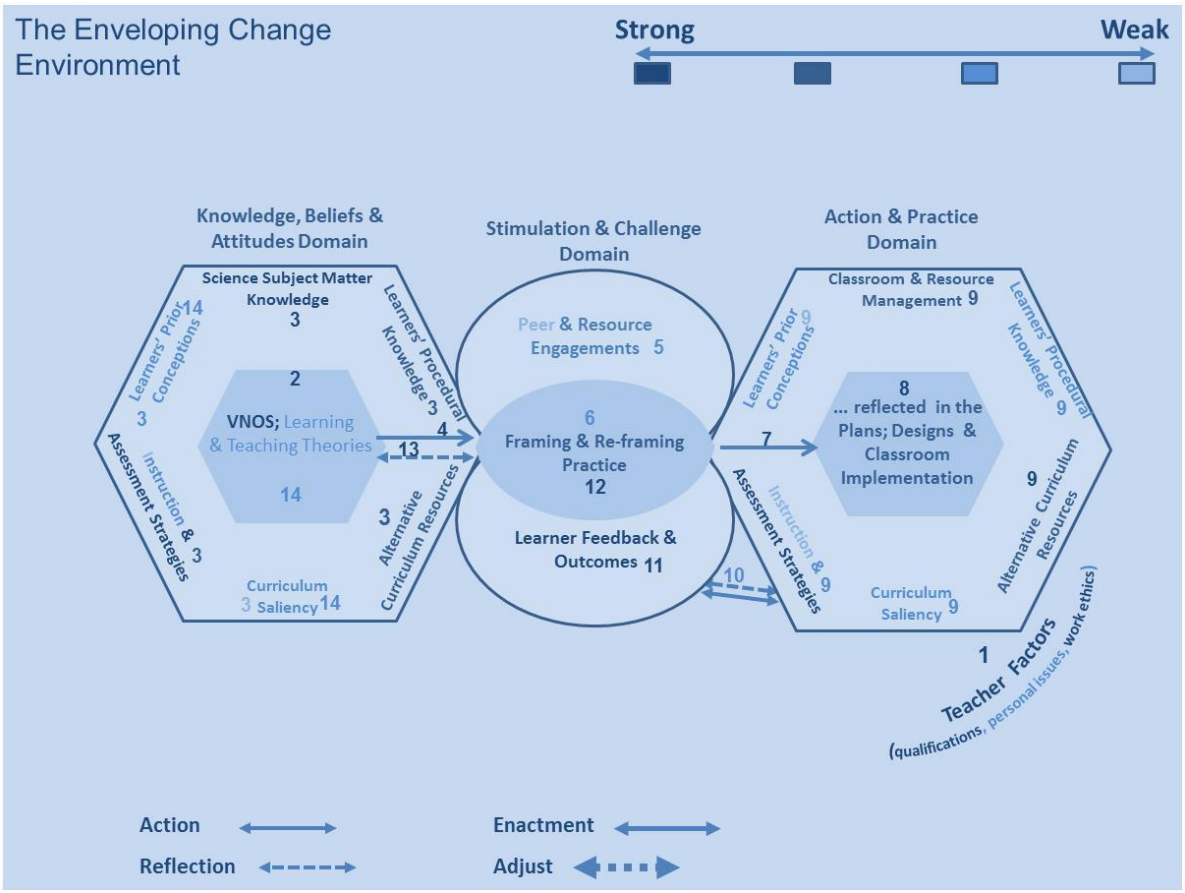


Figure 14: Colleen's Growth Pattern

Data further reveal that, even though inputs were made during peer engagements (5), to help her enhance her strategies by integrating possible learner misconceptions (9) on electrochemistry, as well as adjust her approach to be more learner-centred, she did not accept the suggestions. What is evident is that the framing and re-framing (12) of her practice, on issues which were raised with her (14) during peer engagements (5), only came about after she received feedback from her learners (11). Besides the evident pattern that Colleen actively ignored peer engagement inputs, these findings strongly support the situated approach to learning, that real learning happens when one engages with the context oneself. This finding is in line with Park and Oliver's (2007) assertion that, even though teachers' knowledge can be influenced and improved by receptive learning, the most powerful changes result from experiences in practice because teachers are knowledge producers and not knowledge receivers. They argue that teachers do not simply receive the knowledge that others create to teach, but that they themselves produce knowledge for teaching through their own experiences.

Noma

Of all four teachers, Noma seemed to take full advantage of the collaborative aspects during peer engagements (1). Noma started off with a very shaky content knowledge (4) of the topic of water cycle. Her greatest learning came through the process of collaborative planning and designing, which drew from the resources made available during peer engagements (1). Unlike Colleen, who worked independently and only started reacting from her learners' feedback, Noma did not know much about the topic of water cycle at the beginning, and the framing and re-framing (2) of her practice happened through peer engagement (1) activities.

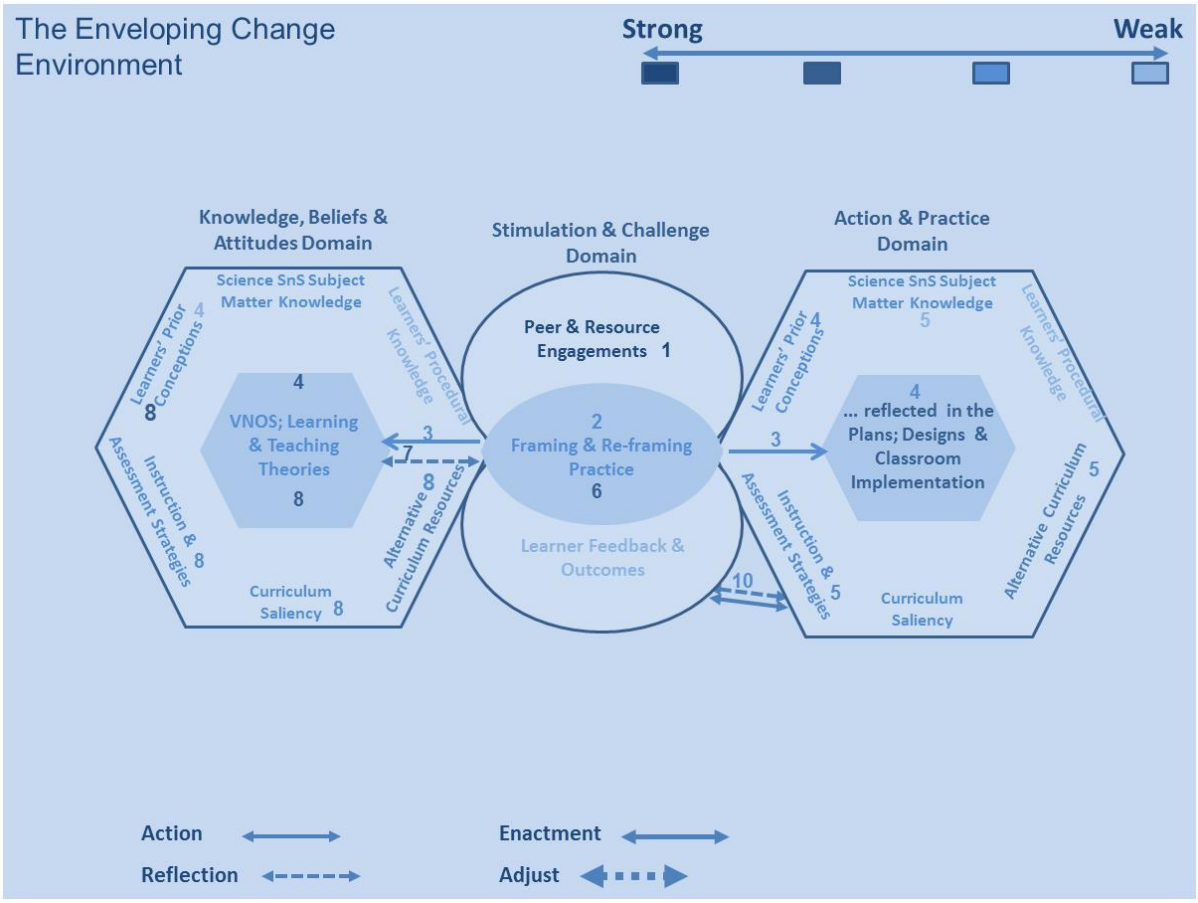


Figure 15: Noma's Growth Pattern

Deepening of both her science content knowledge (8) and her knowledge of the role of learner prior knowledge (8) in teaching, happened during construction of the CoRe, which was an activity at the planning stage of peer engagements (1). Her strategic curriculum knowledge (5), the 5E instructional strategy (5) and the classroom curriculum materials (4) she adopted for her project were all developed or modified through framing and reframing (6) during peer engagements activities.

Analysis of each teacher's practice was presented in chapter 6, in the form of *artefacts* which were meant to reveal the nature and pedagogical features inherent in the tasks the teachers used in their classrooms, and the pedagogical strategies inherent in the lessons presented as *episodes,* which revealed the actual dynamics of how the lessons unfolded, to make evident the complexity of each teacher's practice. Noma structured her lessons according to the big ideas derived during the development of the CoRe, a move that lent focus and conceptual coherence to her inputs.

In one of the episodes discussed in chapter 6, elements of abstraction became evident in Noma's practice when she used particulate theory as an explanatory model of a phenomenon, thus linking what the learners observed at macroscopic level with the explanatory theory of how the particles behave at microscopic level.

This is a reflection of the teacher's effort to promote a strongly coherent learner conceptual understanding (9) of the topic and can only stem from a strong science content knowledge (8) on the part of the teacher. This constructive engagement with learners' conceptions reflects a sophisticated knowledge base on Noma's part and places her as a *reform based teacher* in that aspect of her PCK.

This is also indicative that Noma was able to sustain the learning she claimed to have undergone during her planning phase, as captured in excerpts (iii) and (iv) in the earlier section. This strong aspect in her PCK is however totally undermined by the instructional strategy (8) she chose to adopt, as well as how she positions her learners in learning (22) in this session. On this aspect of her PCK, this places her as a *didactic teacher* whose sole focus is to transmit knowledge in a structured environment, where learners are expected to pay attention and receive that knowledge.

Sipho

It is clear that Sipho also had a unique profile and it is regrettable that he did not complete the study – a great loss. Using the limited data to map Sipho's profile reveals a tentative picture below:

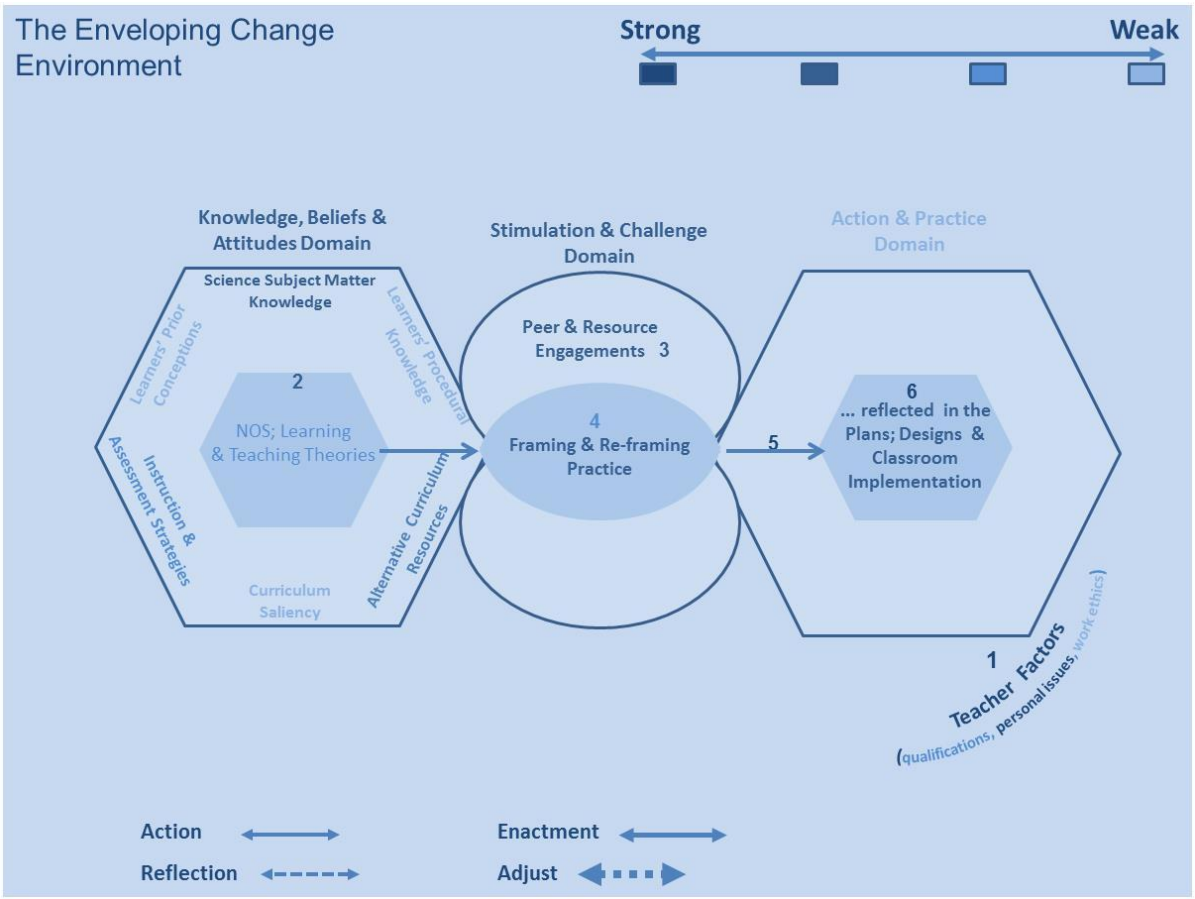


Figure 16: Sipho's Incomplete Growth Pattern

Sipho's experience in the process was sparse, due to missing sessions because of combinations of personal (ill health) and professional (GDE and school management) issues. Nonetheless Sipho's relatively stronger content knowledge, compared to Noma and Bongani, allowed him to make substantial inputs and add to meaningful participation in the sessions he attended.

Bongani

Besides the apparent lack of uptake and substantial learning in Bongani's case, his growth patterns bear a strong resemblance to those of Noma. The learning that happened for Bongani was minimal and hardly discernable during discussions at the planning stage, but only became apparent during classroom implementation. The learning was so minimal that it makes descriptions of what happened almost impossible and leaves no option but the use of a deficiency model of describing missed opportunities to present Bongani's case.

8.4 Methodological findings – Critical engagement with the procedures, resources, strategies and processes adopted in supporting teacher learning

8.4.1 Assertion 9

PCK focused self-studies show a great potential in capturing and addressing curriculum innovation challenges

The South African Norms and Standards for Educators (1998) calls for reflective practitioners. Research on reflective practice (Roth, 2007; Schön, 1983) justifiably argues that teacher reflection should form a central and critical part of professional educator responsibility, as it provides a continuous avenue for the teacher to consider many factors which should inform the decision on how to act in particular and varied situations. *Chemical Systems* is a new topic in the curriculum and therefore unfamiliar to many teachers. In line with the argument raised above, the four teachers in the major study undertook self-studies to learn how to teach *chemical systems* in their FET classrooms as part of their honours projects. The focus of this broader PhD study was to draw from research-based strategies, and available teaching and learning resources, to create a rich environment to support the teachers, as they engaged in the planning and the delivery of this new topic.

Loughran, Berry, & Mulhall (2006) assert that for teachers, thinking about teaching is a complex task, and that it is important to promote ways of sharing teachers' professional knowledge of teaching to further enhance understanding of teaching and learning in science. Coupled with the development of meta-cognitive skills which are about managing your knowledge, your thinking and enactment processes in the context of teaching science, this study was geared to engaging the participating teachers on the complexities of curriculum innovation.

Self-study as a research methodology has several critical features in its nature, such as reflection, collaboration, openness, situated inquiry, organic and ongoing framing and re-framing of practice. Self-study has focus on the development of the self and it is therefore a situated inquiry; central to its features is reflective practice within a collaborative and open forum of peers. It is organic and ongoing in nature. Its nature necessitates collaborative and open participation.

Morrow (2007, p.70) argues that modern society is born out of and is hence dependent and prized on a kind of knowledge which continuously opens up new possibilities and that to gain access to that kind of versatile knowledge, requires systematic learning. The process within the self-studies of the major study, involved engagement with peers, which was a forum that served not only to offer support and critical inputs, but also to validate their findings, as part of the requirement of self-study. The teachers' peer engagements did not only involve activities within research group sessions, but they also presented their work at a local teacher's workshop, at a National Teachers' conference (SAASTE 2008 Bi-annual Conference) and at a regional conference (SAARMSTE, 2009).

In some ways, one can argue that the self-studies the four teachers undertook in the major case study went far beyond the standards of an honours project, not only in their authenticity to deal with complex issues related to curriculum implementation, but also in terms of execution, and the written presentation. The scientific content or theoretical concept in the context of these studies had a broader perspective, because the content of the studies was about development of PCK, which, as a construct, is far more than just a focus on science content. Of course, part of the gains is that it set the participants on a clear path of professional growth in terms of participation at conferences, because they had generated new knowledge which they could share, as well as continued growth in their classroom practices.

It is also evident that the CoRe, as a conceptual tool in research, is not just a data representation tool, but is in itself an intellectual design and product, which demonstrates and portrays the development of the teacher's PCK. In this study, the CoRe was used to capture, portray and monitor changes in PCK of the participating teachers, as well as a training tool for reflective practice. Typical data for teachers' initial knowledge for teaching the topic was collected through construction of the CoRe, which was further consolidated at different stages of the process to capture the teacher's growing content knowledge. These CoRes, in themselves, served as evidence of the depth of the teachers' complex knowledge base for planning to teach chemical systems. They revealed a lot about thought processes, content and reflections prior to the teaching phase and how these capabilities grow, as the process progresses.

Even though the process was very intensive, highly pressured and even frustrating and intimidating at times, the results reflect that engaging in self-studies helped the four teachers to develop their content knowledge for teaching chemical systems at FET level, as well as

enhance their meta-cognitive skills in planning and reflecting on their teaching, which in turn effected fruitful engagements with learners and colleagues. From the teachers' excerpts, it is evident that they also experienced a deep sense of fulfilment, as a result of a newly awakened commitment and confidence to systematize their teaching efforts, by taking an experiential outlook on their practice.

For me as a researcher, teacher educator and supervisor of the projects, the study shed light on effective strategies of linking academic programme with school and classroom practices, to ensure that the theory promoted in academic programmes is translated into practice. I also gained insights into the teachers' personal practical knowledge, as well as on how to use self-study as a strategy for supporting the development of science teachers' PCK. Specifically, I gained insights into the realities and constraints impacting on the teachers' classroom operations, curriculum change issues, as well as their own personal issues and how self-study can offer a sustainable and on-going strategy of response to change in the face of all those realities.

8.4.2 Assertion 10

The LTtP model offers a comprehensive framework for organising teacher learning for innovation

LTtP is one of the theoretical contributions of this thesis and in this section, I appraise and critically engage the LTtP model through reflections on the whole study, to evaluate its potential as a framework for organising teacher learning. This study did not initially seek to investigate contextual issues surrounding the development of the teacher's PCK, but these overwhelmingly emerged in the minor case study, and therefore justified slightly modifying the focus of the study.

The emerging data was captured and described in terms of *the enveloping change environment* construct with its four factors (school management and ecology, teacher factors, learner factors and resource and time constraints). On-going review of literature, and hindsight reflection on the data related to the *enveloping change environment* construct, further strongly reveals two more factors which seem to be playing a role in contributing to an environment, which can sustain initiated curriculum innovations in a school set-up. One such factor is *school collegiality.* A case for this factor is clearly apparent in the types of collegial issues which emerged in the minor study and were discussed in chapter 4. These

issues, which were raised by the acting deputy principal, and those which arose with efforts of trying to integrate the new science teachers who joined the school later on, were such powerful forces that the whole process was undermined, and a breakdown followed.

In the literature, studies (Loucks-Horsley at al., 1998; Powell & Anderson, 2002) make assertions that, in a school setting, for any form of curriculum innovation to succeed in translating the reform agenda into real practice, a school must be geared as a community of practice, characterised partly by sustained collegial support from the whole school community, which is itself oriented towards the reform vision. Therefore, vision building and planning should have sustained influence on all factors of the enveloping teacher change environment through collegial relations. Further support to this notion is the study by Malcolm et al. (2000), who found that high schools with similar infrastructure and physical resources produced very different matric results. A closer look at these cases revealed that successful schools were characterised by a visible ethos of learning and working together as teachers, principals, learners and their parents towards a shared vision.

As reflected in figure 17 below, the sixth factor which was strongly apparent in the minor case study in chapter 4, but was somehow conflated with the *school management and ecology* factors, is *external factors*. These constitute factors that originate outside the school, such as policies, agencies, departments of education and the local community. These factors may either be supportive to the on-going processes within the school or may serve as hindrances. In the minor case study, it can be argued that Lerato's move, to force her subordinates to be part of the programme against their wishes, was due to the pressures which she herself experienced as an HOD, from the meeting with the MEC where they were expected to present their turn-around strategies of improving their matric results.

Data point to the centrality of the teacher's science content knowledge and its influence on other aspects of PCK to almost the same degree as the beliefs they hold about learning and teaching of science. In line with this, there is a need for adapting the model, to put what is noted as one of the six aspects of teacher PCK at the centre, together with teachers' beliefs. The sixth aspect which seems to be a useful lens and is included in the model is *managing resources and learning context*

On further review of literature, as well as pulling together and reflecting on all findings of chapters 4 and 5, two more context-related issues which can clearly be justified in chapter 4's data interpretations and dicussions came to the fore.

As discussed fully above, both *school collegiality* and *external factors* were strongly apparent in chapter 4, but these were conflated with school ecology and management. Incorporation of these two notions *teacher and school collegiality* and *external factors* in the TLtP model, as well as placing *science SMK* at the centre and *learner positioning in learning* as the sixth aspect of PCK, results in the modification of the model as reflected in figure 17 below.

In line with Shulman's notion of the use of powerful analogies and representations in teaching, as a strong PCK indicator, what became apparent when analysing data used in chapter 7 was that in instances where Noma used these special representations, they stood apart from any of her ordinary teaching strategies. Hence inclusion of *representation forms and alternatives* as the sixth sub-domain used to trace PCK development in the LTtP model.

The *representation forms and alternatives* sub-domain pertains to a range and forms of subject and topic specific representations 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.

The LTtP model offers a useful framework that captures the mechanism through which PCK can be developed.

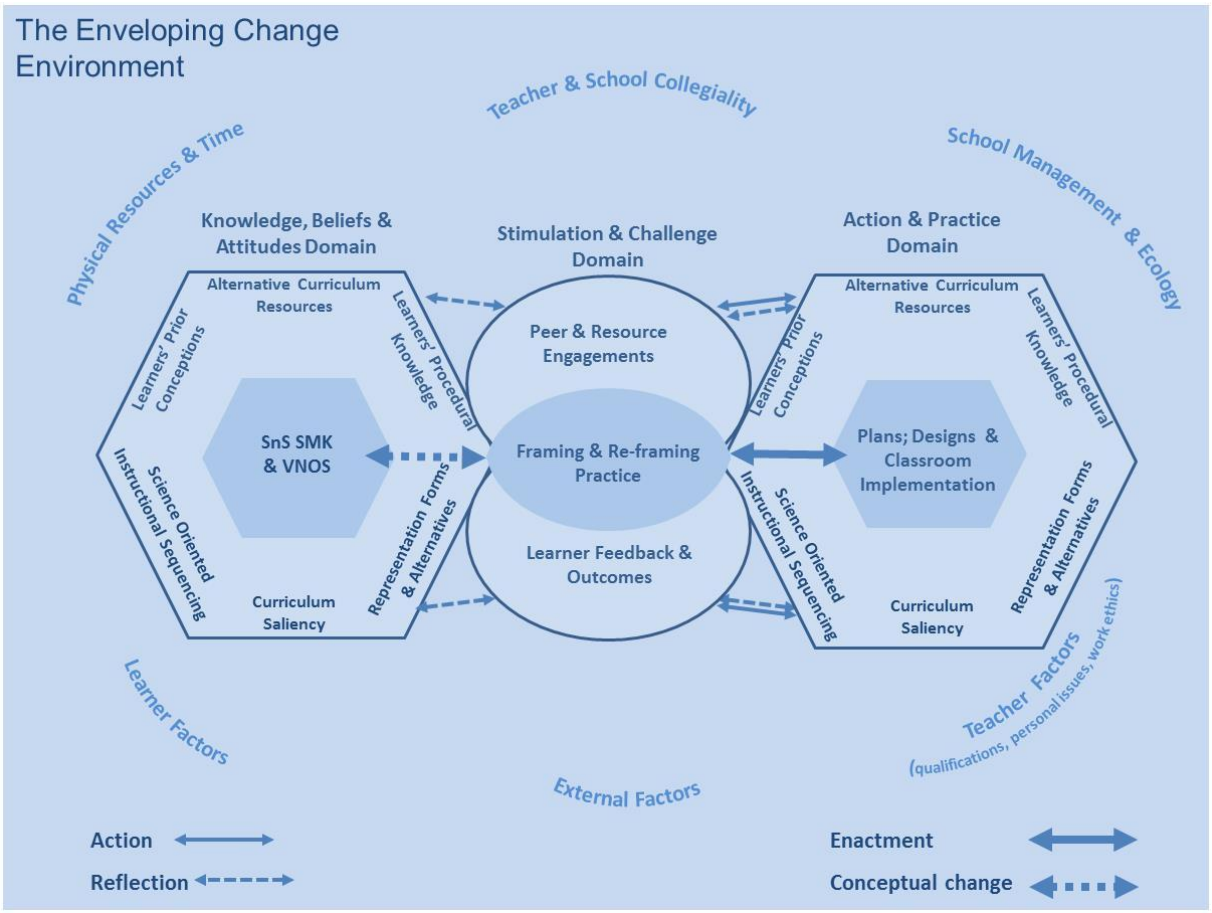


Figure 17: LTtP model - the Final Version

8.5 Reflections and Limitations

Several issues emerged during the process and the three discussed below bordered on tension between the researcher and teacher developer roles. This is the account of how I tried to deal with these tensions. Coming from a background of teacher, and learning and teaching materials development with few research skills, I struggled to balance my training and development agenda with my research agenda. I found myself engulfed and more inclined to respond to the teachers' development needs than to integrating research. I had to be mindful not to lose critical moments for data collection, as well as to continue reading for my literature review. It was a great challenge. There was a need to establish a working understanding of action research methodology – issues of attaining rigour (dialectic, convergent interviewing) – as the study progressed. To overcome this tension, I and four colleagues established a reference team, one doing masters and the other three also doing their PhD's, where we continued to present the challenges we were faced with in our work and give critical feedback on an on-going basis.

A dilemma arose as the teachers became comfortable with me and started approaching me to seek advice and share the frustrations they experienced at work. This became an issue because I did not know how to handle or report on such privileged information, which ranged through insights, incompetence and irresponsible acts, professional jealousy, sabotage and back stabbing. While I understood the gravity of such acts in undermining a collaborative spirit, I really did not know what to do with such information, except to always try to flip discussions in a positive direction. I later realised that I could use the information strategically when we met together, to try to highlight how it undermines collaboration. In one of our meetings, I used this information to encourage and foster group cohesion by actively guiding the group from an informed position, and that seemed to work.

The second dilemma bordered on issues of ethics and the realities on the ground. One of the subtle aims of the programme was to promote teacher autonomy and emancipation – therefore easy and typical power strategies (e.g. prescriptive, mandatory or coercive) went against the spirit of the programme, as well as the Wits ethics requirements. This became a challenge when the school decided to adopt the programme as their turnaround strategy, because Lerato (T1) kept on insisting that the new teachers should become part of the programme whether they liked it or not. Besides these challenges, there was also a tension between the Wits ethics principles agreed to for this study and the realities on the ground. I faced a dilemma on how to handle issues of coercion from the school senior management, aimed at forcing the teachers to participate in the programme, while, at the same time, honouring the ethics requirements of ensuring that all participants should participate voluntarily and could withdraw from the process anytime they wish. I kept on insisting that all teachers should participate voluntarily from an informed position, without feeling compelled to take part.

Issues in the processes of the Major case study

One weakness of the study, which was however a deliberate move to create a contrast between the minor and major case study, is that with the major case study, I did not visit the schools myself, but worked with classroom data that the teachers brought.

I also have to accept that, because the honours projects happened within a period of 6 months of intense activities, alongside which data were collected, the procedures were open to the Hawthorne effect. The latter comes about when subjects modify or improve their behaviour,

to try to match expectations because they are aware that they are being studied. In this present study, this does not become an issue because the whole aim of the study, and that of the self-study methodology, is to initiate and carry out experimentation about one's practice.

Working with CoRes

Completion of the CoRe is such an intellectually challenging and time consuming process that it can easily put the teachers off. In this study, the teachers were supposed to generate a post-CoRe after teaching, but because of time constraints, that did not happen. Also, the team-generated water cycle and atmospheric chemistry CoRes had gaps and were never completed. This, however, did not pose a threat to the study because the data which were collected from these CoRes, as well as other sources, was very rich.

8.6 Conclusions

The main focus of this study was to study how the participating senior/FET phase science teachers handle change by initiating and exploring the nature of collaborative inquiry that emerged, and its influence on the development of their pedagogical content knowledge and meta-cognitive skills, as they endeavour to implement the new curriculum in their classrooms. In this section, I will discuss how each of the following research questions which guided this study, was answered.

1 What professional and pedagogical content knowledge base do participating teachers need to sustain their efforts of implementing change in their classrooms?
   1.1. What knowledge base do the participating science FET teachers have concerning the new curriculum and the topic of chemical change/chemical system?
   1.2. Are there any relationships between their beliefs about the learning and teaching of science and their actual classroom practices?
   1.3. How is their knowledge base for teaching science within the new curriculum framework shifting as they plan, design, teach and reflect on their practices?
   1.4. How are their meta-cognitive capacities evolving as they plan, design, teach and reflect on their practice?
2 What is the nature of support needed to inspire the participating teachers to initiate and sustain curriculum aligned change efforts in their practice?
   2.1 What are the key strategies and tools that played a valuable supportive role in the transformation of the teachers' PCK as they participate in these settings?

2.2 What dynamics serve to support or constrain teachers' efforts in effecting curriculum aligned changes in their practice?

Broadly, question 1 which speaks to the professional and pedagogical content knowledge base the participating teachers need in order to sustain their efforts of implementing change in their classrooms was addressed in chapters 4, 6 and 7. The cognitive and meta-cognitive aspects of this question were addressed in chapters 4 and 6 while the epistemic and pragmatic aspects were addressed in chapter 7. This study did not only engage with knowledge but also with teachers' views and beliefs and how they interfered with efforts of implementing curriculum innovation.

Chapter 6 shows how the process offered teachers support to explore the conceptual structures of the new topics that were not directly accessible from the curriculum in the most authentic ways. Three main types of knowledge come to the fore and these are: Syntactic and substantive topic specific CK; knowledge of learners' prior conceptions; knowledge of learners' procedural skills as well as strategic curriculum knowledge. In this chapter, the findings across these two chapters are drawn into two assertions in response to this research question. Assertion 4 which states *strong teacher content knowledge and comprehension skills are central in pushing the boundaries of innovation* shows the centrality of strong content knowledge and comprehension skills across the four teacher cases to ensure maximum participation and learning in the set processes. Assertion 5 states *the limits set from ignoring learners' prior knowledge and the interplay between the teacher's SMK and curriculum saliency in strategic decision making during planning and implementing of innovations* shows through Noma and Colleen's cases how interplay between their content knowledge and curriculum saliency is a factor in strategic and logical decision making, during planning and classroom implementation of innovation.

As to sub-question 1.2 whether there is any relationship between their beliefs about the learning and teaching of science and their actual classroom practices? All three teachers' classroom implementation experiences reveal the limits set from their views and beliefs about learners and learning – ignoring learners' prior knowledge in pushing the boundaries of innovation.

For research question 2, the factors are divided into those which are contextual and extrinsic to the teacher and those that have to do with the teacher's inherent capacities. This question was partly addressed in chapter 4, which dealt with the extrinsic factors and partly in chapter

6 which dealt with intrinsic factors. Assertion 1 which states *School dysfunctionality serves as a threat to subject-focused teacher professional development because school collegiality is a critical criterion in the school's capacity to support innovation* and assertion 2 which states *Key participants' prevailing commitment, collegial and learning spirit is the driving force for change and is easily achievable in formalised as opposed to non-formalised professional programme settings* – addressed the factors which are contextual and extrinsic to the teachers' internal world. Assertion 6 which states *The interplay between teacher beliefs and the inert character of curriculum aligned materials in supporting teacher orientation to reform based approaches* on the other hand, is drawn from data from the three teachers, which illustrate how teachers' beliefs interface with the use of curriculum-aligned materials to either impede or facilitate implementation of reform-based approaches.

In response to research question 3, one needs to appreciate that all ten assertions discussed in this chapter point to some critical aspects which constitute the nature of support needed to inspire teachers to initiate and sustain curriculum-aligned change efforts in their practices. As already discussed at the beginning of this chapter, these aspects can be divided into those which are external to the teacher's intrinsic world, those which are part of the teacher's intrinsic world and those which have to do with processes which need to be put in place to give the teacher an opportunity to enact change. Seven of the assertions have already been discussed in answering research questions 1 and 2 above and the remaining three have a more direct relation with this last research question.

In answering research question 3, Assertion 8 which states *teacher growth patterns are idiosyncratic, topic-specific and shifting because teacher change is bound to time, place, person and teachers are knowledge producers rather than knowledge receivers* draws from the findings in chapters 5 and 6 to make a case that teacher growth patterns are idiosyncratic and shifting, because teacher change is time, place and person bound, and because teachers are knowledge producers rather than knowledge receivers. From this it follows that any conceived teacher support effort should cater and give opportunities for multiple possible teacher growth patterns, as well as engage the teachers with appreciation that they only learn through participation in the production of knowledge, rather than in receiving knowledge produced by others.

I have also shown in chapters 5 and 6 that engagement in PCK-focused self-studies enhanced the quality of the participating teachers' content knowledge for teaching a new topic, and

initiated them into a culture of systematic use of a reflective and evaluative approach to their own teaching towards curriculum-aligned orientations. With assertion 9 in this chapter which states *value of PCK-focused self-studies in capturing and addressing curriculum innovation challenges* I crystallised the findings in these chapters to illustrate the ingenuity and authenticity of PCK-focused self-studies in capturing and addressing curriculum innovation challenges. I have also shown in these chapters, that peer collaborative and reflective elements of self-study methodology, as well as the use of planning meta-cognitive tools such as the CoRe and structured journal format, led to improved meta-cognitive skills in planning and reflecting on practice, as well as in gaining a vocabulary of representing and communicating their insights in teaching the topic.

8.7 Future Research Directions

My thesis sought to explore and investigate the types of learning environments which can be created to support physical science teachers in their efforts to enact curriculum change in their classrooms.

Towards that end, one of its outcomes is a framework which captures the various socio-cultural, cognitive, meta-cognitive as well as epistemological issues underpinning teacher learning during curriculum innovation. Some recommendations:

- Wider use of PCK-focused self-studies as a teacher support strategy to develop content and curricular knowledge in both pre-service and in-service teacher development programmes
- Wider use of the proposed LTtP model as a framework for planning comprehensive teacher learning environments
- Use of the LTtP model to trace teams of teachers' growth patterns with a focus on studying the interrelationship between external factors in their enveloping professional environment and their intrinsic resources and capacities.

Qualification, and therefore, strong or weak content base and comprehension skills which facilitate teacher uptake, emerged as a strong factor in determining the teacher's capacity to push boundaries of innovation. Further studies could explore the types of intellectual and procedural skills necessary to support teachers' maximum uptake in their own learning processes.

What became very evident in Bongani's case is that insecure content knowledge leads to teachers frequently adopting more generic pedagogic strategies as opposed to content-specific strategies in their teaching efforts. What was also strongly evident is that the CoRe as a conceptual tool in research, is not just a PCK data representation tool, but is in itself an intellectual design and product, which demonstrates and portrays the development of the teacher's PCK and SMK.

One of the most substantial criticisms levelled at OBE is that the skills based approach rather than knowledge base failed the schooling system because it conceals content knowledge. This study was able to demonstrate that the two approaches can coexist because they are not mutually exclusive and they are inherent in the Physical Sciences NCS. Specifically, this study was able to successfully illustrate the unity in what had been perceived as dichotomous in the eyes of OBE and NCS critics such as skill-based versus knowledge based approaches, intervention versus evaluative etc. Another criticism levelled at the new curriculum is that the vagueness of concepts presented in the curriculum makes it inaccessible to most teachers. This point is supported by data from this study as it was apparent that the teachers were not able to abstract the big ideas directly from the curriculum documents on their own. This study was able to facilitate such learning and engaged the participating teachers in activities that allowed them to gain skills and knowledge of deeper and more effective engagement with curriculum documents.

One of the contributions of this thesis is to the three staged use of the CoRe by the teachers involved in this study to trace the development and shifts in their PCK through construction of pre-, during- and post- teaching CoRes. The CoRes which were generated by the teachers are in themselves evidence of the depth of their complex knowledge base for planning to teach chemical systems. They provide a lot of information on thought processes, content and reflections prior to the teaching phase and how these capabilities grow as the process progresses. From the experience above, one can argue that the capacity of the CoRe as a training tool is varied and not yet fully exploited. Exploration studies involving use of the CoRe as a conceptual and practical tool in varied teaching contexts:

- to explore sustained procedural skills and attitudes inherent in rigorous planning and reflective procedures
- to develop communal vocabulary aimed at raising level of engagements and exchanges of good practice amongst collaborators of teachers

- to inspire and empower teams of teachers to engage in self-studies aimed at capturing, portraying and articulating their knowledge of practice in ways that are meaningful to others

Drawing from experiences accrued from this study while using the CoRe, the following modifications and extensions which could be explored in future studies are recommended:

- To promote continuity in the teacher's strategic curriculum knowledge (curriculum saliency), incorporation of the following prompt, which is aimed at bridging the concepts across the preceding and the current grade is suggested:
  - What leaner prior knowledge is foundational to these big ideas?
- The findings of the teacher's classroom strategies which limits learner interactions points to a need for explicit emphasis through modelling on the role of learner conceptions and social discourse in the classroom. There is a need to employ research based tools which can challenge and acculturate teachers to open spaces in their lesson presentations to cater for both the sense-making and social discourse aspects of the nature of generation of scientific knowledge. Most of the prompts of the CoRe deal with the substantive structure of the topic and therefore an extension has been made in this study to capture the syntactic structures which incorporate the procedural knowledge of the doing of science. Also, the following prompt is suggested to probe and capture the teacher's knowledge about the special procedural skills inherent in each big idea which the learners need to acquire.
  - What procedural and intellectual skills do your learners need in order to learn this topic best?
- In chapter 6, there are discerned consistencies and inconsistencies in the teacher's beliefs about learners and learning and what they actually do in their classrooms. This might point to the fact that they try to practise what they have not yet understood cognitively and would suggest tools which can assist teachers to make explicit their beliefs about how learners learn and engage with them continuously. The following prompt is suggested to capture the teacher's beliefs about the learning of the topic.
  - How do you think learners can best learn this big idea?

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APPENDICES

Appendix A: Minor Study Programme & Schedule (April 2007)

1. Introduction & Pre- testing phase (4 days)
    - 1.1 Introduction, proposal and negotiations
    - 1.2 Pre-testing and pre-interviews with individual teachers
    - 1.3 Pre-classroom observations
2. Pre-reflection & Planning session (4 hours)
    - 2.1 Outline of the research agenda, processes and goals`
    - 2.2 Consult & Agree on implementation schedule
    - 2.3 Exploration of Rogan & Grayson classroom implementation levels
    - 2.4 Teacher brief of lesson & its aims
    - 2.5 Viewing of video lessons.
    - 2.6 Discussions and feedback.
3. Classroom learning/teaching strategies workshop (4 hours)
    - 3.1 Confronting own misconceptions
    - 3.2 Exploration of common learner misconceptions
    - 3.3 Exploration of useful teaching & learning strategies
    - 3.4 Exploring practical work with microscience equipment
    - 3.5 Exploring the three learning outcomes
4. Planning & Reflective Practice workshop (2 hours)
    - 4.1 Exploration of experiential reflection cycle
    - 4.2 Classroom reflective practice tools
    - 4.3 Exploration of CoRes and Pa-PeRs &
    - 4.4 Setting teaching improvement and research agenda.
    - 4.5 Identifications of teaching target areas for improvement.
5. Classroom Learning & Teaching material development (6 hours)
    - 5.1 Modify/develop work schedules
    - 5.2 Identify/modify/develop lesson plan structures
    - 3.3 Identify/modify/develop 1st week teaching, learning & assessment tasks
    - 5.3 Targeting Learning Outcome 1 & others
6. Implementation & Reflection Cycle (9 weeks)
    - 6.1 Classroom implementation & observation
    - 6.2 Implementing teaching & research agendas
    - 6.3 Continuous feedback, reflections, support and coaching

Emerging possible teacher inquiry focus:

- Planning & use of high order questioning techniques for effective teaching in the classroom
- Setting challenging LO1, 2 & 3 targeted tasks for learners
- Improving learner participation through questioning and answering approaches
- Involving learners in open investigation (LO1) and contextualised (LO 3) tasks.
- Effective integration of the 3 LOs in practical work
- Identification and selection of effective learning and teaching resources
- Constructivist learning and teaching strategies

Research Process

1. Collaborators:
   6 senior phase science teachers
   1 EDO/LAF
2. Duration**:** (9 weeks with 4 cycles)
   4 planning, training & reflection sessions
   9 weeks of teaching, observations & Reflections
3. Natural Science Core Knowledge:
   Matter & Materials

5 Stages:

Pre-testing

Training session

Planning session

Classroom implementation

Reflection sessions

Appendix B: Minor Study Detailed Research Action Schedule (2007)

Core Knowledge: Matter & Materials **Observer & Individual critical self-reflection**						
Dates	**Duration**	**Stage**	**Researcher Role**	**Collaborators Role**		**Research Process Outcome**
				Teachers	**EDO**	
	1 week	Programme Planning + Pre-testing/interviewing session; pre- classroom observations	Facilitator/researcher	The researcher Participant planner	Co-facilitator (to be discussed, might have research interest)	Clarify research purpose & process; cement rapport; cultivate collaboration & learning spirit Agreed plan & commitment **Pre-intervention data**
12, 13, 16, 21 April	14 hours	Training + lesson planning sessions **Grade 7- Matter & its States** **Grade 8 - Matter & its States; Mixtures & Pure Substances** **Grade 9 - Matter & its States; Mixtures & Pure Substances**	Trainer/facilitator/ participant observer, co-material developer, research group leader	Learners, participant planners, co-material developer	Co-facilitator (to be discussed, might have research interest)	**Working with Common misconceptions** Exploration of M&M teaching, learning & assessment strategies; Lesson planning; hand over classroom resources
23 - 27 April 30 April – 4 May	Week 1 & 2	Cycle 1 Classroom implementation & Observations **Grade 7- Matter & its States** **Grade 8 - Matter & its States;**	Participant-observer, collaborative, reflective & action researcher; mentor, research group leader	Teacher (mediator, assessor, subject-specialist etc); collaborative & reflective practitioner	-	**Researcher & individual teacher** (pre-discussions; lesson observation; post-lesson discussions) **Classroom observation data**

		Mixtures & Pure Substances **Grade 9 - Matter & its States; Mixtures & Pure Substances**				Video tape **Reflective journal updates**
Saturday 5 May	6 hours	Cycle 1 Reflections + Cycle 2 lesson planning sessions **Grade 7- Mixtures & Pure Substances** **Grade 8 – Mixtures & Pure Substances** **Grade 9 - Exploring Chemical Change**	Facilitator/ Participant-observer, collaborative & reflective researcher, co-material developer, research group leader	Active participant, collaborative & reflective practitioner, co-material developer	Co-facilitator (to be discussed, might have research interest)	View, reflect & feedback on individual lesson sessions; lesson planning
7 – 11 14 – 18 May	Week 3 & 4	2nd round Classroom implementation & Observations **Grade 7- Mixtures & Pure Substances** **Grade 8 – Exploring Chemical Change** **Grade 9 - Exploring Chemical Change**	Participant-observer, collaborative, reflective & action researcher; mentor, research group leader	Teacher (mediator, assessor, subject-specialist etc); collaborative & reflective practitioner	-	**Researcher & individual teacher** (pre-discussions; lesson observation; post-lesson discussions) **Classroom observation data** Video tape **Reflective journal updates**
Saturday 19 May	6 hours	Cycle 2 Reflections + Cycle 3 lesson planning sessions **Grade 7- (Electric charge & charging of materials)** **Grade 8 – Exploring Chemical Change** **Grade 9 – The Acids & Bases in**	Facilitator/ Participant-observer, collaborative & reflective researcher, co-material developer, research group leader	Active participant, collaborative & reflective practitioner, co-material developer	Co-facilitator (to be discussed, might have research interest)	View, reflect & feedback on individual lesson sessions; lesson planning

		our lives				
21 – 25 28 May – 1 June	Week 5 & 6	Cycle 3 Classroom implementation & Observations **Grade 7- (Electric charge & charging of materials)** **Grade 8 – Exploring Chemical Change** **Grade 9 – The Acids & Bases in our lives**	Participant-observer, collaborative, reflective & action researcher; mentor	Teacher (mediator, assessor, subject-specialist etc); collaborative & reflective practitioner	-	**Researcher & individual teacher** (pre-discussions; lesson observation; post-lesson discussions) **Classroom observation data** Video tape **Reflective journal updates**
Saturday 9 June	6 hours	Cycle 3 Reflections + Cycle 4 lesson planning sessions **Grade 7- (Magnets & magnetising materials)** **Grade 8 – Exploring Chemical Change** **Grade 9 – The Acids & Bases in our lives**	Facilitator/ Participant-observer, co-material developer, research group leader	Active participant, collaborative & reflective practitioner, co-material developer	Co-facilitator (to be discussed, might have research interest)	View, reflect & feedback on individual lesson sessions; lesson planning **Cycle 1 Post-intervention data**
11- 15 18 – 22 June	Week 7, 8 & 9	Cycle 4 Classroom implementation & Observations **Grade 7- (Magnets & magnetising materials)** **Grade 8 – (Electric charge & charging of materials, Magnets & magnetising materials)** **Grade 9 – (Electric charge & charging of materials Magnets &**	Participant-observer, collaborative, reflective & action researcher; mentor, research group leader	Teacher (mediator, assessor, subject-specialist etc); collaborative & reflective practitioner	-	**Researcher & individual teacher** (pre-discussions; lesson observation; post-lesson discussions) **Classroom observation data** Video tape **Reflective journal updates**

		magnetising materials)				
18 – 22 afternoon Saturday 23 June	12 hours	Cycle 4 + Overall reflections, work schedule modification, post-testing & interviews	Facilitator/ Participant-observer, co-material developer, research group leader	Active participant, collaborative & reflective practitioner, co-material developer		

Appendix C: Project Brief

University of the Witwatersrand
B Sc / B Ed Hons in Science Education
RESEARCH PROJECT IN SCIENCE EDUCATION
TOPICS 2011

Building a Community of Practice around the Teaching of Chemical Systems in FET classrooms - Personal Journeys

Background to the Problem

Most studies (Shulman, 1986; Wilson et al, 1987; Cochran et al., 1993) have come to the recognition that when teachers prepare to teach their content as well as during instruction, they develop knowledge that is enriched and enhanced by other types of knowledge such as, knowledge of the learner, knowledge of the curriculum, knowledge of the context, knowledge of pedagogy. In South Africa, the challenge we face is that new topics have been introduced in the curriculum and there are not many resources to support the teachers in their classrooms. Another challenge is that the management of the three science learning outcomes (LOs) with their lofty ideals is yet another unfamiliar territory which teachers have to face in their classrooms.

Some research (Roth K. J. in Abell & Lederman, 2007; Schön, 1983) alludes to the fact that teacher reflection should form a central and critical part of professional educator responsibility as it provides a continuous avenue for the teacher to consider many factors which should inform the decision on how to act in particular and varied situations. Loughran et al, (2006) assert that for teachers, thinking about teaching is a complex task and that it is important to promote ways of sharing teachers' professional knowledge of teaching to further enhance understanding of teaching and learning in science. Self study is a current methodology which draws from teacher reflection studies and action research to encourage teachers to study their own practice in a posture of humble learning. (Samaras & Freese (2004) describe self study as an inquiry that is personal, reflective, collaborative and constructivist in outlook.

Project Description

This project is about using self-study to frame and trace the development of your PCK in addressing the three science LOs while teaching a topic of your choice that integrates the themes of chemical change and chemical systems at grades 10, 11 or 12. The project will expose you to powerful research based strategies and classroom resources which you could draw from as you endeavour

individually and collectively with your collaborative team to further learn and then teach the topic in your classroom.

Possible Research Focus Questions

Individual Honours students have to use the first question and choose or adapt any other two (or more) from the other six, to guide their study:

- How do I transform my content knowledge for teaching *chemical systems* at Grade 10/11/12?
- How do I create rich learning environments for my learners and colleagues?
- How is my planning and reflective practice affected as I participate in the process?
- How is the climate in my classroom affected as I transform my PCK?
- How is my management of the three science learning outcomes affected as I participate in the process?
- How does the process support me to build a *community of practice* in my school?
- What are the key tools that played a valuable supportive role in transforming my PCK?

Research Methods to be used

The study will employ PCK as a conceptual framework and self-study as a methodological framework. Data can be collected variably through reflective journals, construction of CoRes, PaPers and concept maps, interviews at different strategic stages.

References

Geddis, A.N. (1993). Transforming subject-matter knowledge: the role of pedagogical content knowledge in learning to reflect on teaching. *International Journal of Science Education, 15*, 673-683.

Loughran, J.J., Mulhall, P., & Berry, A. (2004). In search of Pedagogical Content Knowledge in Science: developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching*, 41 (4), 370 391.

Rogan, J. M. and Grayson, D.J. (2003). Towards a theory of curriculum implementation with particular reference to science education in developing countries. *International Journal of Science Education*, 25(10): 1171 – 1204

Samaras, A. & Freese A. R. (2006). *Self-Study of Teaching Practices.* New York: Peter Lang Primer.

Supervisor: Mpunki Nakedi

Appendix D: BSc Hons (Science Education) Research Project - Time Table 2008

Science Hons Programme Coordinator	Tony Lelliott	(Room M 45)
Science Hons Project Coordinator	Fhatuwani Mundalamo	(Room M 47)

Sessions are on Tuesday (except if otherwise arranged by supervisors)

Plenary sessions are in M 69 (Marang) at 16h00; Other sessions by arrangement with supervisor

You should do your best to keep this schedule. You should make arrangements to collect your data as soon as your supervisor has indicated that you are ready to do so.

05/02	**PLENARY: General introduction about written report. Introduction of supervisors. Split into groups to which you have been allocated and meet with supervisor.** Get started on reading.	**Tony & Supervisors**
12/02	**PLENARY: Literature Review & Theoretical Framework** Write Chapter 1	**Marissa & Supervisors**
19/02	**PLENARY: Research Design and Methodology** Hand in 1st draft of Chapter 1 Further discussions of requirements for Chapter 2	**Meg & Supervisors**
26/02	Working with supervisors	**Supervisors**
04/03	Hand in 1st draft of Chapter 2	**Supervisors**
11/03	Hand in 1st draft of Chapter 3	**Supervisors**
18/03	**PLENARY: Progress report by all groups. General overview of where you have got to, and what still needs to be done, and any general problems that might have been encountered.**	**Fhatuwani & Supervisors**

Midterm break

20/03 – 28/03

(use this to get up-to-date)

01/04	**PLENARY: Discussing Research Results/ Analysis** Hand in 2nd draft of Chapter 2	**Elaosi & Supervisors**
08/04	Hand in 2nd draft of Chapter 3 (excluding data perhaps). Ongoing work towards Chapter 4	**Supervisors**
15/04	Corrections to Chapter 1. Hand in 1st draft of Chapter 4	**Supervisors**
22/04	Corrections to Chapter 2	**Supervisors**
29/04	Corrections to Chapter 3. Hand in 2nd draft of Chapter 4	**Supervisors**
06/05	Corrections to Chapter 4	**Supervisors**
13/05	**PLENARY: Presentations (Oral), Written report, and Plagiarism**	**Fhatuwani, Tony, Dale & Supervisors**
19/05-13/06	**Hand in drafts of complete report**	**Supervisors**

MID YEAR BREAK – make any required revisions & corrections, print and bind

Thursday 24 July 2008: Hand in research project

Saturday 02 August 2008: Oral presentation

Appendix E: NCS Science Learning Outcomes

Science Learning Outcome 1							
The learner will be able to act confidently on curiosity about natural phenomena, and to investigate relationships and solve problems in scientific, technological and environmental contexts.				**The learner is able to use process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts**			
Assessment standard	We know this when learners are able to …			**Assessment Standard**			
	Grade 7	Grade 8	Grade 9		Grade 10	Grade 11	Grade 12
Planning investigations	plan simple tests and comparisons, and considers how to make them fair.	identify factors to be considered in investigations and plans ways to collect data on them, across a range of values.	plan a procedure to test predictions or hypotheses, with control of an interfering variable.	**Conducting an investigation**	Plan and conduct a scientific investigation to collect data systematically with regard to accuracy, reliability and the need to control one variable.	Plan and conduct a scientific investigation to collect data systematically with regard to accuracy, reliability and the need to control variables.	Design, plan and conduct a scientific inquiry to collect data systematically with regard to accuracy, reliability and the need to control variables.
Conducting investigations and collecting data	Learner organizes and uses equipment or sources to gather and record information.	Learner collects and records information as accurately as equipment permits and investigation purposes require.	Learner contributes to systematic data collection, with regard to accuracy, reliability and the need to control a variable.	**Interpreting data to draw conclusions**	Seek patterns and trends in the information collected and link it to existing scientific knowledge to help draw conclusions.	Seek patterns and trends, represent them in different forms to draw conclusions, and formulate simple generalisations.	Seek patterns and trends, represent them in different forms, explain the trends, use scientific reasoning to draw and evaluate conclusions, and Formulate generalisations.
evaluating data and communicating findings	Learner generalizes in terms of a relevant aspects and describes how	Learner considers the extent to which the conclusions reached are reasonable	Learner seeks patterns and trends in the data collected and generalises in terms of simple	**Solving problems**			

	the data supports the generalisation.	answers to the focus question of the investigation.	principles.	**Communicating and presenting information and scientific argument**			

Science Learning Outcome 3							
The learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment.				**The learner is able to identify and critically evaluate scientific knowledge claims and the impact of this knowledge on the quality of socio-economic, environmental and human development.**			
Assessment standard	We know this when learners are able to …			**Assessment Standard**	We know this when learners are able to … identify and critically evaluate scientific knowledge claims and the impact of this knowledge on the quality of socio-economic, environmental and human development.		
	Grade 7	Grade 8	Grade 9		Grade 10	Grade 11	Grade 12
understanding science as a human endeavour in cultural contexts;	Compares differing interpretations of events.	Identifies ways in which people build confidence in their knowledge systems.	Recognises differences in explanations offered by the Natural Sciences Learning Area and other systems of explanation.	**evaluating knowledge claims and specified concepts science's inability to stand in isolation from other fields;**	Discuss knowledge claims by indicating the link between indigenous knowledge systems and scientific knowledge.	Recognise, discuss and compare the scientific value of knowledge claims in indigenous knowledge systems and explain the acceptance of different claims.	Research, discuss, compare and evaluate scientific and indigenous knowledge system knowledge claims by indicating the correlation among them, and explain the acceptance of different claims.
understanding sustainable use of the earth's resources.	Understands sustainable use of the earth's resources: Analyses information about sustainable and unsustainable use of	Understands sustainable use of the earth's resources: Identifies information required to make a judgement about resource use.	Understands sustainable use of the earth's resources: Responds appropriately to knowledge about the use of resources and environmental impacts.	**evaluating the impact of science on human development;**	Describe the interrelationship and impact of science and technology on socio-economic and human development.	Identify ethical and moral issues related to the development of science and technology and evaluate the impact (pros and cons) of the relationship from a personal viewpoint.	Research case studies and present ethical and moral arguments from different perspectives to indicate the impact (pros and cons) of different scientific and technological applications.

	resources.						
				evaluating science's impact on the knowledge environment and sustainable development	Discuss the impact of scientific and technological knowledge on sustainable local development of resources and on the immediate environment.	Evaluate the impact of scientific and technological knowledge on sustainable development of resources and suggest long-term and short-term strategies to improve the management of resources in the environment.	Evaluate the impact of scientific and technological research and indicate the contribution to the management, utilisation and development of resources to ensure sustainability continentally and globally.

Appendix F: Profile of Implementation (Rogan & Grayson, 2003)

Level	***Classroom interaction***	***Science Practical Work (LO1)***	***Science in Society (LO3)***
1	***Teacher:*** Presents content in a well organised, correct and well sequenced manner, based on a well designed lesson plan. Provides adequate notes. Uses textbook effectively. Engages learners with questions. ***Learners:*** Stay attentive and engaged. Respond to and initiate questions.	Teacher uses classroom demonstrations to help develop concepts. Teacher uses specimens found in the local environment to illustrate lessons.	**Teacher** uses examples and applications from everyday life to illustrate scientific concepts. **Learners** ask questions about science in the context of everyday life.
2	***Teacher:*** Textbooks are used along with other resources. Engages learners with questions that encourage in depth thinking. ***Learners:*** Use additional (to text book) sources of information in compiling notes. Engage in meaningful group work. Make own notes on the concepts learned from doing these activities.	**Teacher** uses demonstrations to promote a limited form of inquiry. Some **learners** assist in planning and performing the demonstrations. Learners participate in closed (cook-book) practical work. Learners communicate data using graphs and tables.	**Teacher** bases a lesson (or lessons) on a specific problem or issue faced by the local community. **Teacher assists learners** to explore the explanations of scientific phenomena by different cultural groups.
3	***Teacher:*** Probes learners' prior knowledge. Structures learning activities along 'good practice' lines (knowledge is constructed, is relevant, and is based on problem solving techniques). Introduces learners to the evolving nature of scientific knowledge. ***Learners:*** Engage in minds-on learning activities. Make own notes on the concepts learned from doing these activities.	**Teacher** designs practical work in such a way as to encourage learner discovery of information. **Learners** perform 'guided discovery' type practical work in small groups, engaging in hands-on activities. Learners can write a scientific report in which they can justify their conclusions in terms of the data collected.	**Learners** actively investigate the application of science and technology in their own environment, mainly by means of data gathering methods such as surveys. Examples here might include an audit of energy use or career opportunities that require a scientific background.
Level 4	***Learners:*** Take major responsibility for their own learning; partake in the planning and assessment of their own learning. Undertake long term and community-based investigations projects. ***Teacher:*** Facilitates learners as they design and undertake long term investigations and projects. Assists learners to weigh up the merits of different theories that attempt to explain the same phenomena.	**Learners** design and do their own 'open' investigations. They reflect on the quality of the design and collected data, and make improvements. Learners can interpret data in support of competing theories or explanations.	**Learners** actively undertake a project in their local community in which they apply science to tackle a specific problem or to meet a specific need. An example might be on growing a new type of crop to increase the income of the community. Learners explore the long term effects of community projects. For example, a project may have a short-term benefit but result in long term detrimental effects.

Appendix G: Profile of Outside Support (Rogan & Grayson, 2003)

Level	Types of Encouragement and Support			Dominant Change Force Evoked by Agency	Monitoring Mechanisms and Accountability
	Physical resources	**Design of professional development**	**Direct support to learners**		
1	Provision supplements what exists, but not enough to support the intended changes. Provision is in one category only	Information on policy and expected changes are presented to school-based personnel. Typical mode is short, one-shot workshop	Provision of basic needs, such as lunches and places to study	Bureaucratic, change is brought about by top-down directives to bring about change	Inspections by authorities are undertaken
2	Provision completely covers what is required to effect the intended change in one category, or partly sufficient in two categories	Examples of ‘‘new’’ practices as suggested by the policies are presented to school-based personnel, who are given an opportunity to engage in these practices in a simulated situation. Typical mode is a series of short workshops lasting for 1 year	Basic academic needs are catered for in the form of extra lessons	Charismatic change is Brought about by top-down inspiration and encouragement	Inspections are Undertaken in collaboration with school-based personnel
3	Provision completely covers what is required to effect the intended change in two categories, or partly sufficient in three categories	Professional development is designed by school-based personnel depending on which new practices they wish to implement, and implemented using both inside and outside support Typical mode consists of both external and school-based INSET for 2 to 3 years	Enriched academic needs are catered for in the form of field trips and other enrichment type activities	Professional change is brought about by encouraging role players to embrace codes of conduct and standards of teaching and learning	School-based personnel monitor own progress, but report to authorities
4	Provision completely covers what is required to effect the intended change in three categories, or covers two categories and is partly sufficient in all four categories	Communities of practice take full responsibility for their own continued professional growth, and for school governance and curriculum implementation, calling on outside support as appropriate Typical mode consists of on-going school-based and directed professional INSET	Complete academic and personal support is provided, usually in the form of bursaries	Learning community change is brought about by developing communities that develop shared values and goals regarding educational practice and a commitment to put these into practice	All monitoring is undertaken by school based personnel

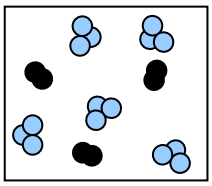
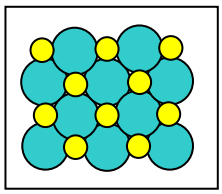
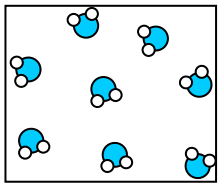
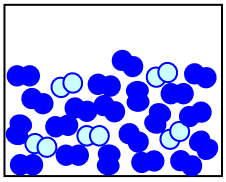
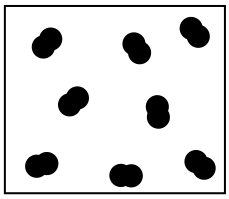
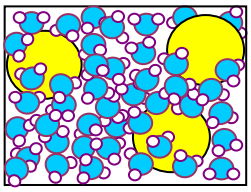
Appendix H: Profile of the capacity to support innovation

Level	Physical resources	Teacher factors	Learner factors	School ecology and management
1	Basic buildings – classrooms and one office, but in poor condition. Toilets available. Some textbooks – not enough for all.	Teacher is under-qualified for position, but does have a professional qualification.	Learners have some proficiency in language of instruction, but several grades below grade level.	*Management* A timetable, class lists and other routines are in evidence. The presence of the principal is felt in the school at least half the time, and staff meetings are held at times. *Ecology* School functions i.e. teaching and learning occur most of the time, albeit erratically. School is secure and access is denied to unauthorized personnel.
2	Adequate basic buildings in good condition. Suitable furniture – adequate and in good condition. Electricity in at least one room. Textbooks for all. Some apparatus for science.	Teacher has the minimum qualification for position. Teacher is motivated and diligent. Enjoys his/her work. Teacher participates in professional development activities. Teacher has a good relationship with and treatment of learners.	Learners are reasonably proficient in language of instruction. Learners attend school on a regular basis. Learners are well nourished. Learners are given adequate time away from home responsibilities to do school work.	*Management* Teacher attends school/classes regularly. Principal is present at school most of the time and is in regular contact with his/her staff. Timetable properly implemented. Extramural activities are organized in such a way that they rarely interfere with scheduled classes. Teachers/learners who shirk their duties or display deviant behaviour are held accountable. *Ecology* Responsibility for making the school function is shared by management, teachers and learners to a limited extent. A School Governing Body is in existence. Schools functions all the time i.e. learning and teaching always take place as scheduled.
3	Good buildings, with enough classrooms and a science room. Electricity in all rooms. Running water. Textbooks for all pupils and teachers. Sufficient science apparatus. Secure premises. Well kept grounds.	Teacher is qualified for position and has a sound understanding of subject matter. Teacher is an active participant in professional development activities. Conscientious attendance of class by teacher. Teacher makes an extra effort to improve teaching.	Learners are proficient in language of instruction. Learners have access to quiet, safe place to study. Learners come from a supportive home environment. Learners can afford textbooks and extra lessons. Parents show interest in their children's progress.	*Management* Principal takes strong leadership role, is very visible during school hours. Teachers and learners play an active role in school management. *Ecology* Everyone in the school is committed to making it work. Parents play active role in School Governing Bodies and in supporting the school in general.
4	Excellent buildings. One or more well equipped science laboratory. Library or resource centre. Adequate curriculum materials other than textbooks. Good teaching and learning resources (e.g. computers, models). Attractive grounds. Good copying facilities.	Teacher is over-qualified for position and has an excellent knowledge of content matter. Teacher has an extraordinary commitment to teaching. Teacher shows willingness to change, improvise and collaborate, and has a vision of innovation. Teacher shows local and national leadership in professional development activities.	Learners are fluent in the language of instruction. Learners take responsibility for their own learning. Learners are willing to try new kinds of learning.	*Ecology* There is a shared vision. The school plans for, supports and monitors change. Collaboration of all stakeholders is encouraged and practised. *Management* There is a visionary, but participatory, leadership at the school.

Appendix I: Chemistry Concept Diagnostic Questionnaire

Please study each question and instruction carefully and provide the answer.

1. Study and complete the table below:

Substance	**Is it a gas, liquid or solid? Give reasons.**	**Is it a mixture or pure substance? Give reasons.**	**If is pure substance. Is it an element or compound? Give reasons.**
			
			
			
			
			
			

Make a circle on the letter of the response of your choice.

2. Which of the following must be the same before and after a chemical reaction?

a. The sum of the masses of all substances involved.
b. The number of molecules of all substances involved.
c. The number of atoms of each type involved.
d. Both (a) and (c) must be the same.
e. Each of the answers (a), (b), and (c) must be the same.

3. Assume a beaker of pure water has been boiling for 30 minutes. What is in the bubbles in the boiling water?

a. Air.
b. Oxygen gas and hydrogen gas.
c. Oxygen.
d. Water vapor.
e. Heat.

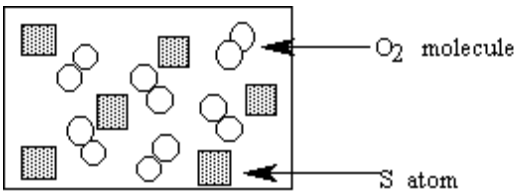
4. A glass of cold milk sometimes forms a coat of water on the outside of the glass (Often referred to as 'sweat'). How does most of the water get there?

a. Water evaporates from the milk and condenses on the outside of the glass.
b. The glass acts like a semi-permeable membrane and allows the water to pass, but not the milk.
c. Water vapor condenses from the air.
d. The coldness causes oxygen and hydrogen from the air combine on the glass forming water.

5. What is the mass of the solution when 1 gram of salt is dissolved in 20 grams of water?

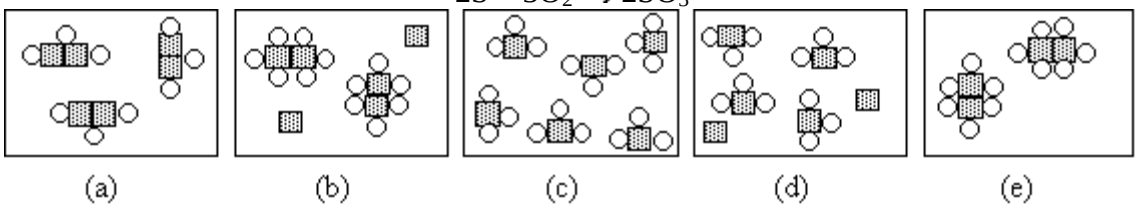
a. 19 grams.
b. 20 grams.
c. Between 20 and 21 grams.
d. 21 grams.
e. More than 21 grams.

6. The diagram represents a mixture of S atoms and O_2 molecules in a closed container.

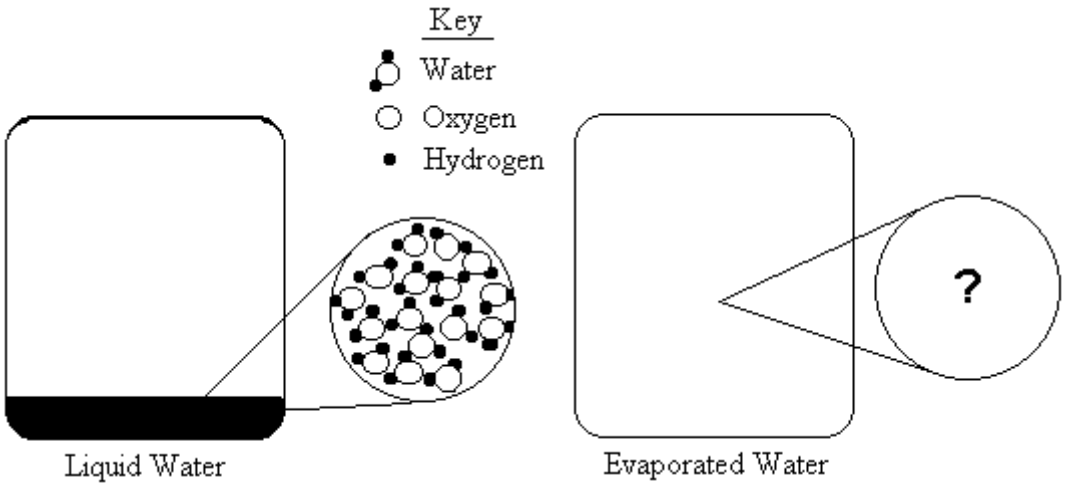


Which diagram shows the results after the mixture reacts as completely as possible according to the equation:

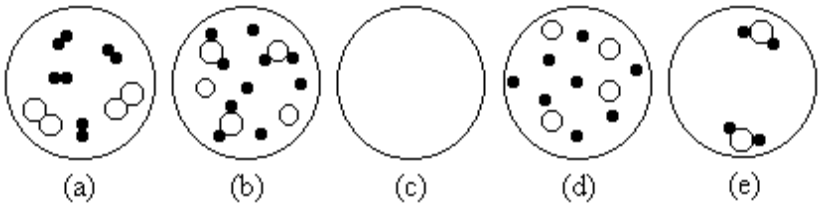
$$2S + 3O_2 \rightarrow 2SO_3$$



7. The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.



What would the magnified view show after the water evaporates?



8. True or False? When a match burns, some matter is destroyed.

a. True
b. False

9. What is the reason for your answer to question 7?

a. This chemical reaction destroys matter.
b. Matter is consumed by the flame.
c. The mass of ash is less than the match it came from.
d. The atoms are not destroyed, they are only rearranged.

e. The match weighs less after burning.

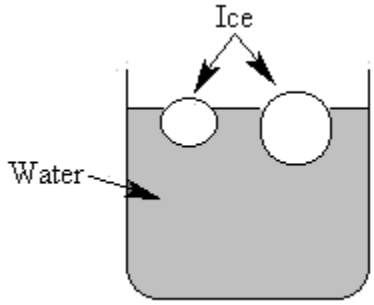
10. Heat is given off when hydrogen burns in air according to the equation

$$2H_2 + O_2 \rightarrow 2H_2O$$

Which of the following is responsible for the heat?

f. Breaking hydrogen bonds gives off energy.
g. Breaking oxygen bonds gives off energy.
h. Forming hydrogen-oxygen bonds gives off energy.
i. Both (a) and (b) are responsible.
j. (a), (b), and (c) are responsible.

11. Two ice cubes are floating in water:



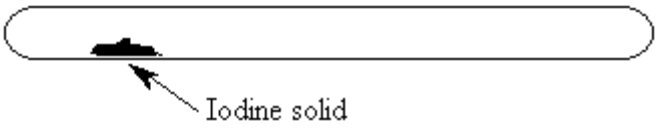
After the ice melts, will the water level be:

a. higher?
b. lower?
c. the same?

12. What is the reason for your answer to question 10?

a. The weight of water displaced is equal to the weight of the ice.
b. Water is more dense in its solid form (ice).
c. Water molecules displace more volume than ice molecules.
d. The water from the ice melting changes the water level.
e. When ice melts, its molecules expand.

13. A 1.0-gram sample of solid iodine is placed in a tube and the tube is sealed after all of the air is removed. The tube and the solid iodine together weigh 27.0 grams.



The tube is then heated until all of the iodine evaporates and the tube is filled with iodine gas. Will the weight after heating be:

a. less than 26.0 grams.
b. 26.0 grams.
c. 27.0 grams.
d. 28.0 grams.
e. more than 28.0 grams.

14. What is the reason for your answer to question 12?

a. A gas weighs less than a solid.
b. Mass is conserved.
c. Iodine gas is less dense than solid iodine.
d. Gasses rise.
e. Iodine gas is lighter than air.

15. What is the approximate number of carbon atoms it would take placed next to each other to make a line that would cross this dot: ▪

a. 4
b. 200
c. 30,000,000
d. 6.02×10^{23}

16. Figure 1 represents a 1.0 L solution of sugar dissolved in water. The dots in the magnification circle represent the sugar molecules. In order to simplify the diagram, the water molecules have not been shown.

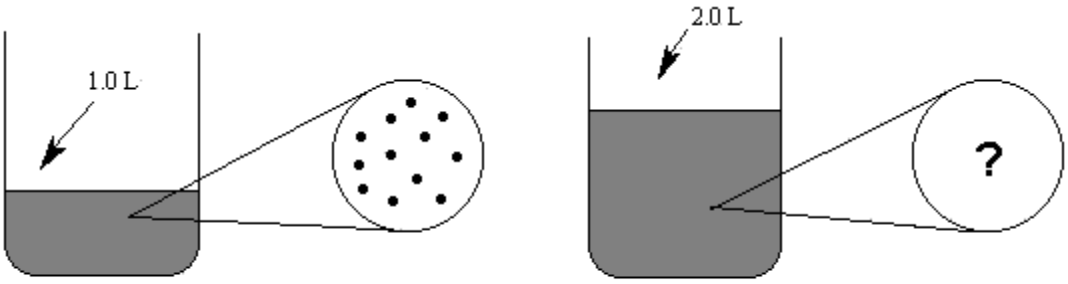


Figure 1 **Figure 2**

Figure 1

Which response represents the view after 1.0 L of water was added (Figure 2).

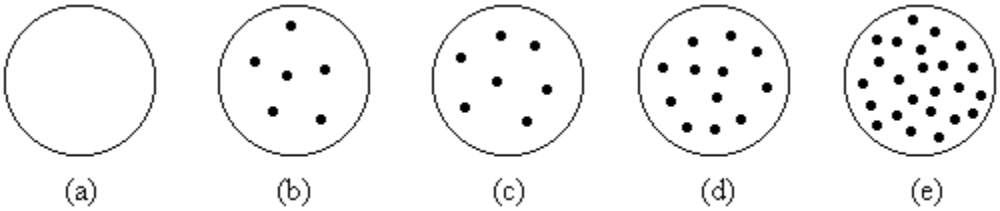


Figure 2

17. 100 mL of water at 25°C and 100 mL of alcohol at 25°C are both heated at the same rate under identical conditions. After 3 minutes the temperature of the alcohol is 50°C. Two minutes later the temperature of the water is 50°C. Which liquid received more heat as it warmed to 50°C?

a. The water.
b. The alcohol.
c. Both received the same amount of heat.
d. It is impossible to tell from the information given.

18. What is the reason for your answer to question 16?

a. Water has a higher boiling point then the alcohol.
b. Water takes longer to change its temperature than the alcohol.
c. Both increased their temperatures 25°C.
d. Alcohol has a lower density and vapor pressure.
e. Alcohol has a higher specific heat so it heats faster.

19. Iron combines with oxygen and water from the air to form rust. If an iron nail were allowed to rust completely, one should find that the rust weighs:

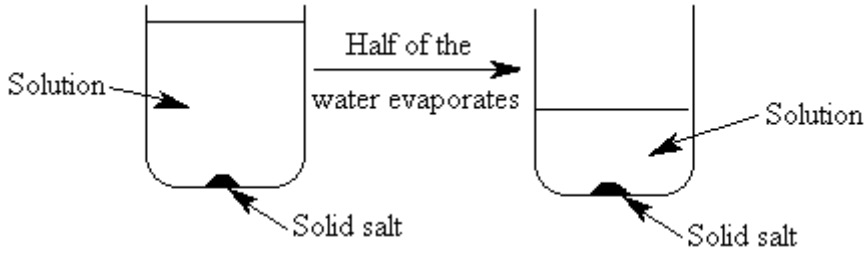
a. less than the nail it came from.
b. the same as the nail it came from.
c. more than the nail it came from.
d. It is impossible to predict.

20. What is the reason for your answer to question 18?

a. Rusting makes the nail lighter.
b. Rust contains iron and oxygen.
c. The nail flakes away.
d. The iron from the nail is destroyed.
e. The flaky rust weighs less than iron.

21. Salt is added to water and the mixture is stirred until no more salt dissolves. The salt that does not dissolve is allowed to settle out. What happens to the concentration of salt in

solution if water evaporates until the volume of the solution is half the original volume? (Assume temperature remains constant.)



The concentration

a. increases.
b. decreases.
c. stays the same.

22. What is the reason for your answer to question 20?

a. There is the same amount of salt in less water.
b. More solid salt forms.
c. Salt does not evaporate and is left in solution.
d. There is less water.

23. Following is a list of properties of a sample of solid sulfur:

i. Brittle, crystalline solid.
ii. Melting point of 113^{o}C.
iii. Density of 2.1 g/cm3.
iv. Combines with oxygen to form sulfur dioxide

24. Which, if any, of these properties would be the same for one single atom of sulfur obtained from the sample?

a. i and ii only.
b. iii and iv only.
c. iv only.
d. All of these properties would be the same.
e. None of these properties would be the same.

Word equations are used to describe chemical reactions. Look at the word equations below. In each case complete the word equation by adding the name of the missing substance. (Explain your answers.)

25. nitric acid + potassium hydroxide → _____+

water

I think this is the answer because _____

_____

_____

26. zinc + _____ → zinc nitrate + copper

I think this is the answer because ---_____

_____

_____

_____

27. _____+ zinc carbonate → zinc sulfate + water + carbon dioxide

I think this is the answer because _____

_____

_____

_____

28. _____ Calcium + chlorine → _____

I think this is the answer because _____

_____

_____

_____

29. magnesium + hydrochloric acid → _____ + hydrogen

I think this is the answer because _____

_____

_____

_____

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Appendix J- Concept Challenge Raw Data Analysis

Phase	**Senior Phase**								**FET Phase**						
School Level	**Primary School**				**High School**				**High School**						
Teacher	T7	T8	T9	T10	T4	T5	T11	T12	T1	T2	T3	T13	T14	T15	T16
Total Score (/45)	11	16	8	11	21	15	22	18	21	22	31	26	37	30	41
Molecular distinction between gases, liquids and solids (Q1 a, d, g, j, m, p)	1/6 d	4/6 d, g, j, m	2/6 d, p	3/6 a, d, j	4/6 d, j, m, p	1/6 d	3/6 a, d, p	5/6 a, d, g, j, m	4/6 d, j, m, p	6/6 a, d, g, j, m, p	5/6 a, d, g, j, m	4/6 a, d, j, m	6/6 a, d, g, j, m, p	6/6 a, d, g, j, m, p	6/6 a, d, g, j, m, p
Molecular distinction between mixtures and pure substances (Q1 b, e, h, k, n, q)	2/6 b, q	5/6 b, e, h, k, n,	5/6 b, e, k, n, q	1/6 b	4/6 b, k, n, q	2/6 b, q	6/6 b, e, h, k, n, q	5/6 b, e, h, k, n	**4/6**	**4/6** b, h, n, q	6/6 b, e, h, k, n, q	5/6 b, e, h, n, q	6/6 b, e, h, k, n, q	4/6 b, k, n, q	6/6 b, e, h, k, n, q
Molecular distinction between elements and compounds (Q1 c, f, I, l, o, r)	2/6 i, o	4/6 c, f, i, l,	0/6	0/6	5/6 c, f, l, o, r	4/6 c, i, o, p	4/6 c, f, l, r	2/6 i, o	**4/6**	**3/6** c, o, r	2/6 f, i	3/6 f, i, o	5/6 c, f, i, l, r	0/6	6/6 c, f, i, l, o, r
Conservation of mass & atoms during chemical reaction (Q2,6,8,9,13, 14,19,20)	2/8 Q13 Q20	1/8 Q2	0/8	2/8 Q6 Q8	2/8 Q6 Q14	2/8 Q6 Q19	4/8 Q2 Q13 Q12 Q20	3/8 Q13 Q19 Q20	**1/8** **Q2**	**5/8** **Q2** **Q8** **Q8** **13** **14**	2/8 Q2 Q8	1/8 Q 13	7/8 Q2 Q8 Q9 13 14 19 20	5/8 Q2 Q9 10 13 14	7/8 Q2 Q6 Q9 13 14 19 20
Conservation of mass, atoms & molecules during physical change (Q3,4,5, 7)	0/4	2/4 Q3 Q7	1/4 Q2	1/4 Q7	2/4 Q4 Q5	1/4 Q5	2/4 Q3 Q5	0/4	**0/4**	**0/4**	2/4 Q3 Q7	1/4 Q4	3/4 Q4 Q5 Q7	3/4 Q4 Q5 Q7	4/4 Q3 Q4 Q5 Q7

Teacher	T7	T8	T9	T10	T4	T5	T11	T12	**T1**	**T2**	T3	T13	T14	T15	T16
Macroscopic v/s sub-microscopic descriptions (Q11, 12, 15, 23, 24)	2/5 Q23 Q24	0/5	0/5	2/5 Q23 Q24	0/5	2/5 Q23 Q24	1/5 Q15	0/5	**2/5** **23** **24**	**0/4**	2/5 23 24	1/5 12	0/5	1/5 12	4/5 11 12 23 24
Energy during physical & chemical change (Q10, 17 &18)	2/3 Q17 Q18	0/3	0/3	2/3 Q10 Q17	2/3 Q17 Q18	1/3 Q10	2/3 Q17 Q18	0/3	**0/3**	**0/3**	1/3 Q 18	1/3 Q 10	0/5	1/3 Q 10	0/3
Solution & concentration (Q16, 21, 22)	0/3	1/3 Q22	0/3	0/3	1/3 Q16	0/3	0/3	1/3 Q21	**2/3** **16** **21**	**0/3**	2/3 16 21	1/3 21	1/3 22	1/3 16	3/3 16 21 22
Word equations for acids-base reactions (25, 26, 27, 28, 29)	0/5	3/5 25, 28, 29	0/5	0/5	1/5 25	2/5 27, 28	0/5	2/5 28, 29	**4/5** 25, 27, 28, 29	**4/5** 25, 27, 28, 29	5/5 25, 26, 27, 28, 29	5/5 25, 26, 27, 28, 29	5/5 25, 26, 27, 28, 29	5/5 25, 26, 27, 28, 29	5/5 25, 26, 27, 28, 29

Appendix K1: Planning and Reflection Questionnaire

In the spaces provided below please explain how you normally go about planning for teaching and learning in your school at these different levels: **school level, phase level, grade level and individual teacher level.**

1. Whole school level (macro planning):

a) Explain in detail how you normally go about planning for learning and teaching at school level. If you don't do it in your school, explain why you don't do it and how you think this affect you as a teacher.

_____

_____

_____

_____

_____

b) Put a tick in appropriate shaded box. **Do you find this level of planning**

meaningful?	Very much so		Sometimes		Not at all	
useful?	Very much so		Sometimes		Not at all	
practical?	Very much so		Sometimes		Not at all	
enjoyable?	Very much so		Sometimes		Not at all	

Elaborate, comment or explain:

_____

_____

_____

_____

c) Do you hold meetings to reflect together on the processes of your teaching efforts as a whole group of teaching staff in your school?

Very much so		Sometimes		Not at all	

d) If you do please give details of the processes of your reflections. If you don't do it in your school, explain why you don't do it and how you think this affect you as a teacher.

_____

_____

_____

_____

_____

_____

_____

_____

2. Phase level (Learning Programme):

a) Explain in detail how you normally go about planning for learning and teaching at phase level. If you don't do it in your school, explain why you don't do it and how you think this affect you as a teacher.

_____

_____

_____

_____

_____

b) Put a tick in appropriate shaded box. **Do you find this level of planning**

meaningful?	Very much so		Sometimes		Not at all	
useful?	Very much so		Sometimes		Not at all	
practical?	Very much so		Sometimes		Not at all	
enjoyable?	Very much so		Sometimes		Not at all	

Elaborate, comment or explain:

_____

_____

_____

_____

c) Do you hold meetings to reflect together on the processes of your teaching efforts as a whole group of teaching staff in your school?

Very much so		Sometimes		Not at all	

d) If you do please give details of the processes of your reflections. If you don't do it in your school, explain why you don't do it and how you think this affect you as a teacher.

_____

_____

_____

_____

3. Grade Level (work schedule):

a) Explain in detail how you normally go about planning for learning and teaching at grade level. If you don't do it in your school, explain why you don't do it and how you think this affect you as a teacher.

_____

_____

_____

_____

_____

b) Put a tick in appropriate shaded box. **Do you find this level of planning**

meaningful?	Very much so		Sometimes		Not at all	
useful?	Very much so		Sometimes		Not at all	
practical?	Very much so		Sometimes		Not at all	
enjoyable?	Very much so		Sometimes		Not at all	

Elaborate, comment or explain:

_____

_____

_____

_____

c) Do you hold meetings to reflect together on the processes of your teaching efforts as a group of science teachers teaching the same grade in your school?

Very much so		Sometimes		Not at all	

d) If you do please give details of the processes of your reflections. If you don't do it in your department, explain why you don't do it and how you think this affect you as a teacher.

4. Class/Individual teacher level (lesson plan):

a) Explain in detail how you normally go about planning for learning and teaching of your learners at **individual** level. If you don't do it, explain why you don't do it and how you think this affects you as a teacher.

b) Put a tick in appropriate shaded box. **Do you find this level of planning**

meaningful?	Very much so		Sometimes		Not at all	
useful?	Very much so		Sometimes		Not at all	
practical?	Very much so		Sometimes		Not at all	
enjoyable?	Very much so		Sometimes		Not at all	

Elaborate, comment or explain:

c) Do you reflect systematically on your own by keeping any records of your reflection efforts e.g. reflection diary or notebook to record your thoughts?

Very much so		Sometimes		Not at all	

d) If you do please give details of the processes of your reflections. If you don't do it, explain why you don't do it and how you think this affects your teaching efforts.

Appendix K2: Lesson Planning/Reflection Process Interview Schedule

Lesson Planning /Reflection Process Interview Schedule

1. What work have you covered with your learner in science so far? Mention the topics.
2. Take me through the process of how you normally prepare for your lessons.
3. Do you always have a lesson plan for each lesson you deliver?
4. What resources do you normally use to prepare for your science lessons?
5. Do you think you have enough resources in your school to help you with preparations for you lessons?
6. If not, what resources do you think you need?
7. Do you normally reflect on your lesson after delivering it?
8. If yes, explain to me how you normally do it. How often do you do it?
9. Do you keep records of your reflections?
10. Do you ever involve your other science colleagues in your lesson planning or lesson delivery or lesson reflections? If yes, explain to me how you do it.
11. Do you ever get involved with your colleagues in team teaching or invite them to observe you in your classrooms? If yes, explain to me how you do it.

Appendix L: Water cycle Pre/post CoRe cross case analysis Matrix

Sipho code **Noma code** **Bongani code**

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
Big idea / **Prompts**	Phases of water (S-pre) Sun as major source of energy (N-plan) The sun as the main source of energy that drives physical and chemical changes (N & R)	Particulate theory (S-pre) Polarisation??? (N-plan) The relationship between macroscopic phase changes and microscopic energy transfers of water (S & R)	Properties of water (S-pre) Movement of water from the ocean and land controlled by energy and sunlight (N-plan) The unique and special properties of water and its effects in nature (S & N)	Conservation of water (S-pre) Intermolecular forces & polar nature of water (N-plan) The abundance and conservation of water in the cycle (S & R)	Human Impact on water cycle (R)
1. What you expect learners to know already about this idea	Water has three phases (S-pre) Speed of light (N) They would know that the sun is the main source of energy (it gives them warmth, provides light etc) (S) The sun provides energy for photosynthesis; (S) *Energy is transferred through biological or physical systems, from*	Basic shape of a water molecule (S-pre) They should know energy can be stored in a system as potential energy, either by the positions of the bulk parts of the system or by its particles (atoms and molecules) which have the potential to react with each other and release energy; Water changes its form as it moves in a cycle between the hydrosphere,	Water remains at 100^{o}C (0 – 4 ^{o}C) during boiling and freezing until all water molecules have evaporated or frozen (S-pre) Water plays an important role in ecosystems, sustaining both plant and animal life The atmosphere is a mixture of nitrogen and oxygen in fairly constant proportions, and small quantities of other gases that include water vapour. The atmosphere has different properties at	Water is not lost during phase change (S-pre) *With each energy transfer, some of the energy becomes less available for our use, and therefore we need to know how to control energy transfers;* Energy sources such as wind, sun, and water in high dams are renewable *the atmosphere is a system which interacts*	Industrial, agricultural and domestic activities may have a serious impact on the quality and quantity of water available in an area; Human activities and natural events can slightly change the composition and temperature of the atmosphere. Some effects of these small changes may be changes in annual weather patterns and long-term changes in rainfall and

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
	energy sources. They know that the sun rays move through the atmosphere before reaching the ground; (N) When energy is transferred, it causes changes in the system and the system's surroundings; When the energy has gone into heating the surroundings, we can no longer use that energy to do work for us; Hot objects transfer their energy, as heat, in three ways: by conduction, by convection and by radiation. These transfers may be useful or wasteful; Light travels away from a light-giving body until it strikes an object. The object may then absorb the light, or refract it or reflect it. Light transfers	atmosphere and lithosphere in what is known as the 'water cycle'; Some changes to materials are temporary but other changes are permanent. (water & nitrogen cycles) Substances change when they receive or lose energy as heat. These changes include contraction and expansion, melting, evaporation, condensation and solidification; A particle model of matter can explain physical changes of substances such as melting, evaporation, condensation, solidification, diffusion and heating by	different elevations. (nitrogen cycle & Grade 11) The atmosphere is the most important factor in keeping the earth's surface temperature from falling too low or rising too high to sustain life. (Grade 11)	*with the land, lakes and oceans and which transfers energy and* *water from place to place;* Most of planet earth is covered by water in the oceans. A small portion of the planet is covered by land that is separated into continents. At the poles there are ice caps. Only a small amount of the water is available for living things on land to use and only a small portion of the land is easily habitable by humans.	climate.

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
	energy to other objects; Dark-coloured surfaces get hotter than light-coloured surfaces when exposed to radiating sources of energy like the sun; Dark coloured objects radiate their energy as heat more readily than shiny light-coloured objects The sun is the major source of energy for phenomena on the earth's surface, such as growth of plants, winds, ocean currents, and the water cycle; The atmosphere protects the earth from harmful radiation and from most objects from outer space that would otherwise strike the earth's surface; *Our planet is a small part of a vast solar*	conduction; The dissolving of a substance in a solvent depends on variables which affect the rate of dissolving; (hydrosphere);			

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
	system in an immense galaxy.				
2. What you intend students to learn about this idea	Bonding causes different phases of water (S-pre) Water absorb IR (N-pre) Solar energy drives the weather (the movement of water from the ocean and land surface to the atmosphere is controlled by energy in the sunlight) (Noma) The types of radiation constituting solar energy (IR, UV & visible light)	The shape of water molecule does not change despite the phase water is in (S-pre) The shape of the water molecule does not change irrespective of the phase in which water might be in. The absorption of IR (low energy) does not lead to change in chemical composition of	Temperature remains constant until all water molecules have vapourized/frozen (S-pre) Polar nature of water molecule ensure that it absorbs infrared radiation and therefore leading to the sea being a reservoir of heat therefore serving as the Earth's thermostat .strong hydrogen bonds (intra-molecular) leading water to have high specific	Water is conserved (S-pre) 80% Earth is water yet we have to use energy to purify water because only 1% is fit for drinking. Water exist in nature as a mixture of substances Water is a universal solvent Water molecules are neither destroyed nor	

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
	UV and visible light are radiations with high energy and IR radiation with low energy (N, S &R) Absorption of IR is responsible for the water cycle/weather conditions (R & N) Water cycle is a cycle of physical changes (R) Absorption of UV and visible light leads to chemical changes (R)	water molecule. At water's melting point, irrespective of the heat supplied, its temperature will remain constant until all the ice has melted. To understand and differentiate between internal, kinetic and potential energy and their relationship to macroscopic changes	heat capacity, (Sipho) The solid state of water is less dense than its liquid (Sipho) and therefore water serves as an insulator for aquatic life during adverse weather. Water expands when it changes from liquid to solid (freezing) therefore contribute to mechanical weathering of rocks. (Noma)	created and we therefore have same number of water molecules being recycled over and over again. The inter-phasing of water cycle with all other global spheres	
3. Why is it important for students to know this?	To differentiate phases Understand and appreciate the vital contribution of the sun in our daily life (S) That all life is linked and sustained by the sun's energy (R) To understand and appreciate that the movement of water through global systems is	To understand evaporation and condensation So that they can understand and appreciate that the chemical composition of water does not change during phase change. To appreciate and understand that the absorption of IR radiation does not lead to	To understand the influence of water on the climate They need to understand and appreciate that size of the water molecule remain constant during expansion	To know that water circles in our planet(i.e it can never be used up – but can be stored in other bodies)	

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
	as the result of the sun's energy. (S) To appreciate and understand the nature of the different solar radiation and their positive and negative impact in their lives. (R & S) To understand and appreciate the roles played by different types of solar radiations in their environment. (S)	chemical decomposition but only leads to increasing the kinetic energy of the molecules. To understand and appreciate that water has the capacity to absorb and release large quantities of energy during phase change (e.g. at melting and boiling points)			
4. What else do you know about this idea (which you do not intend your learners to know yet)?	The 4th phase (plasma)	The water molecule can accommodate the 3rd H atom	Water is capable of withholding/absorbing energy for longer periods because there are many hydrogen bonds to be broken	Dynamic equilibrium. During precipitation some water is deposited deep under the layer of the soil but later resurfaces as ground water that flows into streams while the other water is trapped in wells	global warming, greenhouse effect, ozone depletion GW and OD are two separate unrelated phenomena (R) Advancements in industry lead to more pollution to the environment. (Bongani) Relations between population growth and

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
					demand (Bongani)
5.Difficulties/limitations connected with teaching this idea	Learners' difficulty in relating micro and macroscopic changes Dealing with abstract concepts they cannot see It's an integrated theme which draws from various learning areas and if learners are not clear about the underpinning concepts and beyond physics & chemistry is geography and biology (R) A challenge to concretise the abstract concepts such as IR. It is a theme which is underpinned by the triad in clear understanding of chemistry (micro- macro & symbolic)	Learners find it difficult to relate micro and macroscopic changes Even though the environment is the resource, but to explain what learners observe macroscopically involves abstract microscopic descriptions. Models always have their own limitations and may perpetuate misconceptions.	If taught theoretically	Measuring and comparing water that has evaporated with water that precipitated.	
6. Knowledge about learners' thinking which influence your	Water disappears They view solar energy as one continuous form	Water separate into H and O atoms when heated and both combine during/ when	Temperature continue to rise and drop during boiling/freezing	Accounting for water that has evaporated Water's clear appearance and its association with	

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
teaching of this idea	of energy (S) The challenge of relating macroscopic observations and microscopic descriptions (e.g. surface evaporation and absorption of photons of light) (R & S)	temperature decreases Learners think that the shape of the water molecule changes as the phase of water changes.	Boiling is the same as evaporating Most learners think that the size of the water molecule enlarges during expansion	purity may present a problem to learners' appreciating that water in nature exist as a mixture of substances;	
7.Teaching models & procedures (and particular reasons for using these to engage the idea)	Using plant and covering it with transparent plastic Allow learners to complete pre-concept map of water cycle Use practical work which links closed, open and contextualised investigations. (R) Use picture and flow diagrams to represent the concepts. (R) Use the environment as a learning resource e.g. using convex lens to focus and concentrate sun rays on one point to produce heat	Building models of water molecules and indicating the points of hydrogen bonding Give learners tasks which allow them to use particle diagrams to represent arrangement of water particles across the three phases. First invite learners to predict what will happen to the temperature of melting ice and then allow them to explore: Allow learners to observe and record temperature change against time as ice melts up until 5 minutes after	Do experiment on temperature reading during boiling and freezing	Heating water in a closed system	Using issue based tasks as a basis for learning: role play; newspaper articles as a resource

CHEMICAL CYCLE – Grade 10: Water Cycle CoRe					
	Use conduction, convection and radiation when describing energy changes. (N)	all the ice has melted. And then translate their data into a graph.			
8. Specific ways of ascertaining learners' understanding or clearing confusion around the idea (teaching & assessment strategies)	Questioning them about the origin of water droplets Use conduction, convection and radiation when describing energy transfers; Including questions which require learners to explain what they see and observe in terms of the behaviour of microscopic particles;	Letting them disengage individual molecules from a sample of 5 bonded water molecules	Letting learners take and compare temperature readings during boiling/freezing over a time interval	Comparing original water before and after then account for the difference	

Appendix M: Grade 11: Atmospheric Chemistry CoRe

CHEMICAL Systems – Grade 11: Atmospheric Chemistry CoRe			
Big idea Prompts	The structure and composition of the atmosphere *Energy as the driving force in the chemical composition of the atmosphere*	The chemistry of the atmosphere and its role in nature	Human impact on the atmosphere
1. What you expect learners to know already about this idea	The atmosphere is a mixture of gases; They should know the % composition of the major constituents of air(nitrogen ~80%, oxygen ~20%, carbon dioxide, water vapour etc); Appreciate the role of the atmosphere as a medium and therefore the source for energy and water transfers necessary to sustain life on Earth.	Appreciate the vital role played by the atmosphere as a shield from harmful radiation from the sun;	
2. What you intend students to learn about this idea	Description of different layers (troposphere, stratosphere, mesosphere & thermosphere) of the atmosphere and how these relate to altitudes of differing change in temperature; The differing composition of each layer of the atmosphere and their role in weather conditions (including ionosphere); The trends in temperature changes terms of increasing altitudes across all the four layers; Appreciate the role of tropopause in ensuring that water is trapped in the troposphere and does not escape to higher altitude layers (so that it does not decompose B) Water cycle which is a series of physical changes, happens in	Identify the chemical species in each layer and how the contribute to the role played by that layer in nature and weather conditions; The chemical nature of greenhouse gases as having polar bonds which allows them to absorb IR; Global warming is about physical changes in the	The greenhouse gases, their sources and impact in nature; Be able to explain the processes leading to global warming and those leading to ozone depletion and that the two are two independent, distinctive phenomena with separate causes

	the troposphere of the atmosphere; Appreciate and understand that the ozone layer is in the stratosphere	troposphere and ozone depletion is about chemical changes in the strato-/mesosphere; Understand and appreciate the role played by oxygen, nitrogen and ozone by absorbing high energy radiation and thereby shielding the Earth from distractive UV radiation from the sun; (B) The role of CFC's in the depletion of ozone layer	
3. Why is it important for students to know this?	Awareness and respect for the environment To be environmental friendly to the atmosphere	Stop using chemicals that harm the atmosphere e.g. CFCs and greenhouse gases	Stop cutting the trees unnecessarily; reduce CO_2 emissions.
4. What else…			
5.Difficulties/limitations			
6. Knowledge about learners' thinking which influence your teaching of	Learner might think that the atmosphere is a continuous whole with temperature and pressure decreasing with increase in temperature; Because the atmosphere appears as clear they may have difficulty understanding is a complex system of mixture of gases and various physical and chemical reactions; They may think of atmosphere as something outside our reach;		Ozone depletion allows more sunlight to pass- to penetrate the atmosphere. (Bongani) Cleaning up residues from beaches will reduce global warming. (Bongani) Reducing the wealth??? in nuclear weapons will also raise (24:36) Global warming is caused by the hole in the ozone layer; (Noma)

this idea	(Bongani) Also that it is an empty space; Also that water is also part of the atmosphere		Global warming due to greenhouse effect results in ozone distraction; (Noma) Both the ozone hole and greenhouse effect are caused by auto mobiles; (Bongani) The holes in the ozone layer triggers the greenhouse effect; The hole in the stratosphere ozone layer increases greenhouse effect. Difficulty appreciating that greenhouse effect and ozone formation are essential and natural phenomena which have been occurring for million of years. May think of CFCs as contributing to smog formation; Ozone is an environmental toxic that is hazarders to humans; Confusion over greenhouse gases (Difficulty to appreciate that global warming and ozone depletion are two independent, distinctive phenomena with separate causes
7.Teaching procedures (and particular reasons for using these to engage the idea)	As a teaching aid a drawing using colour coding reflecting all the different layers of the atmosphere with their various gases; altitudes, pressure and temperature variations		

Appendix N: Samples of Noma's Data

Portion of Noma's PaPeR

ENGAGE LESSON 1	
WHAT HAPPENED?	Activities completed in this lesson were the designing of the poster as well as presentation on the importance of the sun. These activities aimed at assessing knowledge of the learners with regards their environment and its surrounding. I organised learners into 5 groups of 5 members. Using their posters learners gave feedback on what they regard to be the components of the earth [IS]. Learners' responses were as follows: Group1: main components are the solid, liquid, and gas. Group2: biosphere, lithosphere, hydrosphere, and atmosphere Group3: the sun, rain, wind and the clouds Group4: the sun, land, water and air Group5: the crust, mantle, outer core and inner core Using the question and answer method, I engaged learners to give feedback on the importance of the sun [IS]. After learners gave their feedback, I wrapped up the discussion by writing a summary on the chalkboard to consolidate concepts [IS]. I kept on repeating the same statements trying to ensure that my learners grasp the knowledge that i was imparting.
HOW DID I FEEL ABOUT IT?	I had mixed feelings I was excited by the implementation process in my self study, at the same time felt very much intimidated by one group of learners that used the geographical terms such as hydrosphere, lithosphere, atmosphere and hydrosphere. This really caused my level of confidence to drop.
WHAT DID I LEARN?	I learnt about my learners' knowledge of the topic. In this lesson, reflecting on what learners said and marking the learners' books, I gathered ideas of what my learners know and do not know. The following misconceptions emerged in the lesson: [LPC] • Some learners perceive the components of the earth as the structure of the earth. • Some learners confuse phases of matter with the components of the earth • Some learners associate components of the earth with climate • Two of the groups regarded the sun as component of the earth and yet it is another planet • One group of learners had the correct geographic terminology of the components. My practise still reflected a traditional approach other than the learner centred approach [IS].
HOW CAN I DO THINGS DIFFERENTLY?	I realised that I had to revisit the components of the earth address learners' misconceptions. The fact that I felt that learners had some background knowledge of this topic motivated me to go and make a thorough preparation for my next lesson. In my presentation allow learner participation as much as I can [IS].
ENGAGE PHASE LESSON 2	
WHAT	I employed the presentation method to revisit the components of the earth and captured the importance of the sun on planet earth on the chalkboard [IS]. Learners had to complete a

HAPPENED?	multiple-choice question task individually, then discuss in their groups and come up with collective group responses. The task was designed to elicit learners' prior concepts in relation to the particulate nature of matter and designed in such a way that in answering learners are able to demonstrate their understanding of the microscopic representation of particles as well as the macroscopic representation of particles. As learners were responding to the questions I captured their responses on the chalkboard.
HOW DID I FEEL ABOUT IT?	It was an exciting lesson there was a slight improvement in my practise. I managed to engage my learners in the discussion and allowed them to answer before interrupting. It was also frustrating in a way because I could not handle some misconceptions.
The Explore phase	
Explore phase involves investigative work. During this lesson learners conducted a closed investigation with focus on the phases of water. The activity aimed at making the learners appreciate the presents of water in the atmosphere.	
What happened?	Learners worked in their groups when doing the activity. The worksheet was design to It was a good experience because learners were excited all of them were engaging in the process. A number of misconceptions emerged in the lesson 4 Some learners believe that taking the reading of the temperature of ice outside the classroom will differ than when it is taken inside the classroom. They think the sun will have an effect. 5 The water outside the beaker is due to the ice melting inside the beaker. 6 Learners argue that in the activity they could see three phases of water 7 They think the dry carbon dioxide is iced water
How did you feel about it?	It was an exciting lesson. I did not care much about being videotaped. Concepts discussed were basically everyday science concepts and one is
What did I learn?	Learners were able to use the thermometer and they also have correct reading and recording skills. I could deliver content as planned. I needed to exercise authority in managing the class. It was a good experience because learners were excited all of them were engaging in the process. A number of misconceptions came up in the lesson 8 Some learners believe that taking the reading of the temperature of ice outside the classroom will differ than when it is taken inside the classroom. They think the sun will have an effect. 9 The water outside the beaker is due to the ice melting inside the beaker. 10 Learners argue that in the activity they could see three phases of water 11 They think that the dry carbon dioxide is the iced water 12 Irrespective of our previous discussion some still want to maintain that the glass beaker is wet because of the melting ice inside the beaker

Appendix O: Sample of Noma's Curriculum Material

Explore & Explain Phase:

These series of activities are aimed at introducing the topic by setting the context, raising questions as well as eliciting learners' prior knowledge and beliefs.

LESSON 1

THE WATER CYCLE

Activity 1: LO2 :AS 1,2

1. Draw a concept map of the water cycle.

Activity 2: LO2: AS 1,2,3

1. Design an A3 labelled, colourful poster which depicts the main components of the planet Earth.
2. Prepare a presentation on the importance of the Sun on this planet Earth.

Marking rubric:

levels	Components	Importance of the sun
4	All mentioned	4 and above
3	Only 3	Only 3
2	Only 2	Only 2
1	Only 1	Only 1
0	none	None

Activity 3: read at home

Solar radiation

The Sun is the source of energy for the Earth. Most of the natural occurrences on the Earth's surface are either directly or indirectly driven by the Sun. for example, without the Sun we would have no weather. There would be no changes in temperature, no winds, no clouds, no rain and so on. There would be no life on Earth.

During the day we can see because of the Sun's light. We can also feel the energy from the Sun when we warm ourselves in the sunlight. The energy from the Sun is called solar radiation. Solar radiation is composed of ultraviolet (UV) radiation, visible light and infrared (IR) radiation. UV radiation and visible light have much more energy than IR radiation. UV radiation can harm us. We can protect ourselves against UV radiation by wearing clothes and applying Sun block lotions. The warmth we feel on our skin is due to the lower energy IR radiation.

Not all the solar radiation reaches the surface of the Earth. As it passed through the Earth's atmosphere, its percentage composition is changed. Less UV radiation reaches the Earth's surface than the quantity of UV radiation present in space. Most of the radiation that reaches the Earth is visible light. We cannot see UV or IR radiation. You will learn more about light and sight in Theme 14 Unit 1.

What happens to the incoming solar radiation?

When solar radiation passes through the Earth's atmosphere, some of it is scattered and some of it is absorbed by clouds and dust particles. The clouds, the land and the ocean can reflect the solar radiation that reaches them back into space. Reflected radiation and scattered radiation are different. Reflected radiation goes back in the same direction it came from. Scattered radiation can go in any direction. Some can go down to the surface of the Earth and some can go back into space. The rest of the energy that reaches the Earth's surface is absorbed.

What happens to the absorbed IR radiation?

When IR radiation is absorbed, the energy of the substance increases. When a substance increases in energy, the energy of the molecules of the substance increases. With IR radiation the kinetic energy of the molecules increases and the substance feels warmer to us. The IR part of solar radiation does not cause a chemical change because it is the less energetic part of radiation.

Much of the solar radiation absorbed by the surface of the Earth is emitted back into space as IR radiation. This transfer of solar radiation is one of the driving forces of our weather. People often think that the Sun warms the atmosphere. But the atmosphere is mostly heated by its contact with warmed Earth.

What happens to the absorbed UV and visible solar radiation?

The high energy UV and visible light parts of solar radiation transfer more energy to substances than IR radiation. The molecules of the substances may be changed. Chemical bonds may be broken and electrons may be transferred. These are chemical changes.

For example, during photosynthesis a green plant absorbs the visible light part of solar radiation. This energy is used to begin chemical reaction. Through the breaking and making of bonds, existing substances are chemically changed into new substances.

The chemical equation below represents the simplified process of photosynthesis.

$$6CO_2(g) + 6H_2O(\ell) \xrightarrow{\text{visible light}} C_6H_{12}O_6(s) + 6O_2(g)$$

The substances, carbon dioxide and water, are changed to form new substances, glucose and oxygen.

Consequences of absorbed solar radiation

Whether substances absorb IR, visible light or UV radiation, these transfers of energy have important effects. The weather is one and plant growth is another. The weather in mainly a result of the land and ocean absorbing IR radiation with less energy. Plant growth is mainly a result of plants absorbing the visible light radiation with more energy.

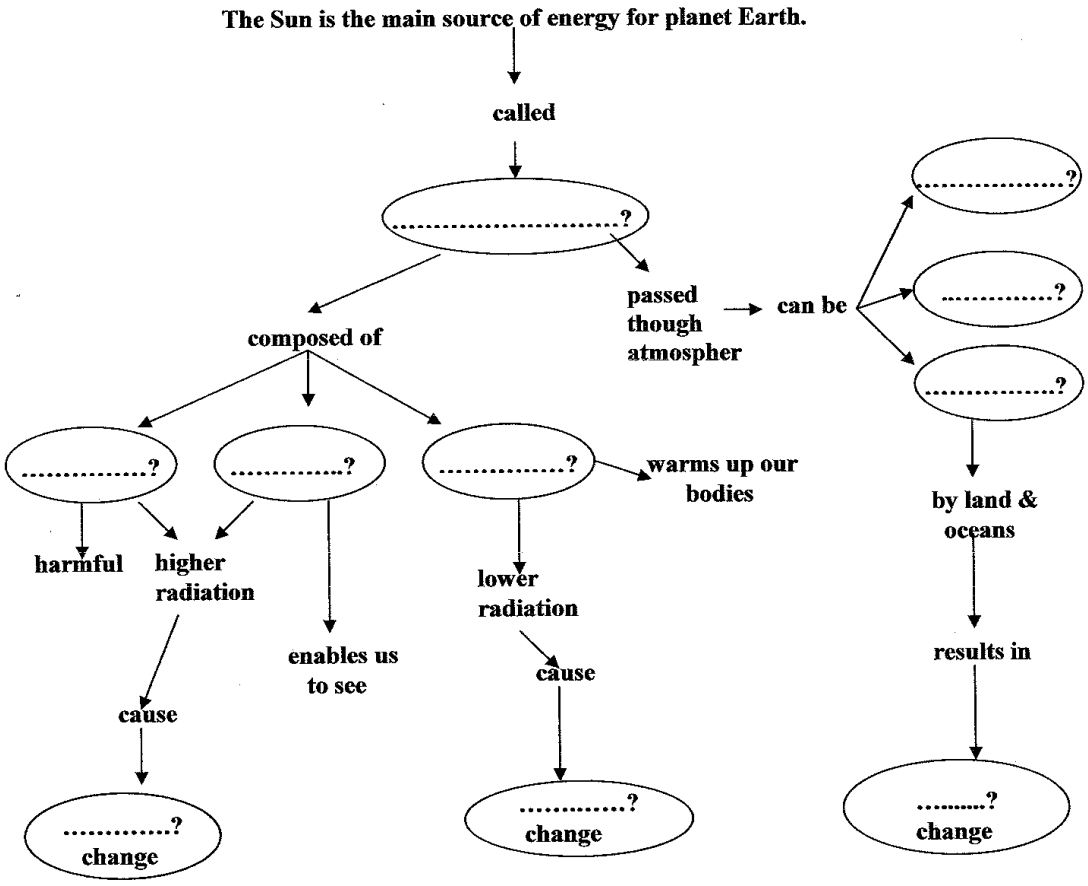
Global cycles, for example the water cycle and nitrogen, are other consequences of the Sun's energy transfers to Earth. In the rest of Theme 9 and in Theme 10 we study these two cycles that play such an important role in our existence. The one cycle is an example of a series of physical changes and the other a series of chemical changes.

(Article taken from: Physical Science for Class room. Grade10. Series Editor: John Bradley)

Activity 4: LO: 2 AS:1,2,3

The energy from the Sun is solar radiation.

Complete the following concept map:



LESSON 2

Activities for lesson 2

Activity 1
Complete the following assessment task on the answer sheet given.

1.1 When air is heated, its particles

a) contract
b) Remain constant
c) Expand
d) Move rapidly

1.2 When water is called, its particles

a) expand
b) contract
c) remain the same size
d) move rapidly

1.3 When a substance changes state, the following things remain the same:

a) The energy of each particle.
b) The particles themselves.
c) The volume of the substance.
d) The temperature of the substance.

1.4 When a substance changes state, the following things change…

a) the distance between particles.
b) the number of the particles.
c) the mass of the substance.
d) the shape of the substance.

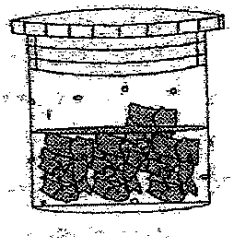
1.5 When the water in the kettle boils, there are large bubbles in the water. These bubbles are made of…

a) air?
b) water vapour?
c) heat?
d) oxygen and hydrogen?

1.6 The water in the puddles disappears after some time. What actually happens to this water?

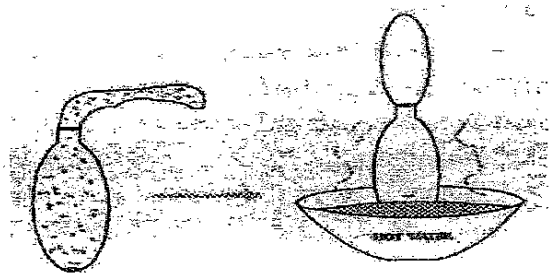
a) it goes into the ground.
b) It just dries up and never exists as anything.
c) It changes into oxygen and hydrogen in the air.
d) It goes into the air as very small bits of water.

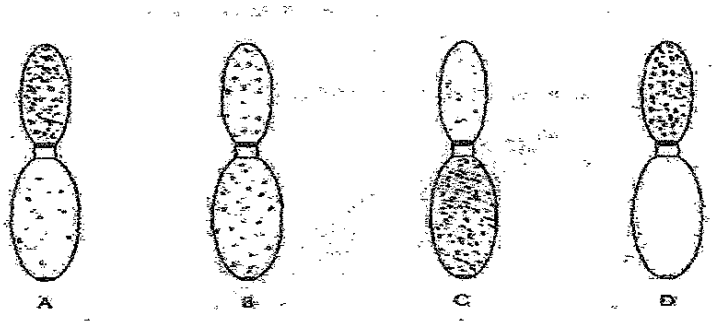
1.7 When a small jar is filled will ice and closed with lid, the outside of the jar becomes wet after some time because,



a) water from the melted ice comes through the glass.
b) coldness comes through the glass and sticks to it.
c) water in the air sticks on to the cold glass.
d) oxygen and hydrogen in the air combines to form water.

1.8 A plastic bottle is fitted with rubber balloon. The air in the bottle is then heated by hot water and the balloon gets inflated. Which of the following diagrams do you think best represents the air particles after the balloon gets inflated?





1.9 If a wet saucer is left on the bench after it has been washed, then after a while it is all dry. What happens to the water the does not drip on the bench?

a) It goes into the saucer.
b) It just dries up and no longer exists as anything.

LESSON 3

Activity 1: The Phase Changes of Water

LO1: AS 1, 2, 3, 4

Statement question: Does air contain water vapour?

You will need:

- Large sample vial
- 1 propette
- Thermometer
- Crushed ice
- Stop watch

STEP 1

Take a clean vial.
Feel its outside with your fingers. Is the vial dry or wet?

STEP 2

Fill the vial to capacity with crushed ice

STEP 3

Leave the vial to stand for a few minutes until the ice starts to melt.

Q1. What is the temperature of the ice?
Q2. Observe the outside of the sample vial. What do you see?
Q3. Where does the water come from?
Q4. Is the water you see outside the vial a solid, liquid or gas?

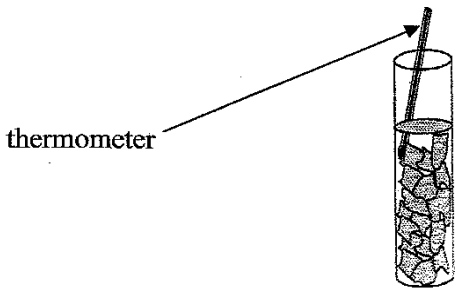
STEP 4

Into the vial with ice, add icy cold water from the fridge.
Observe the water in the vial.

Q5. How many states of water can you see?
Q6. How many states of Water are involved?
Q7. Give the names of these various states of water.
Q8. which is more dense? Liquid water or solid water?
Q9. What do you think is the temperature of the icy water in the vial?

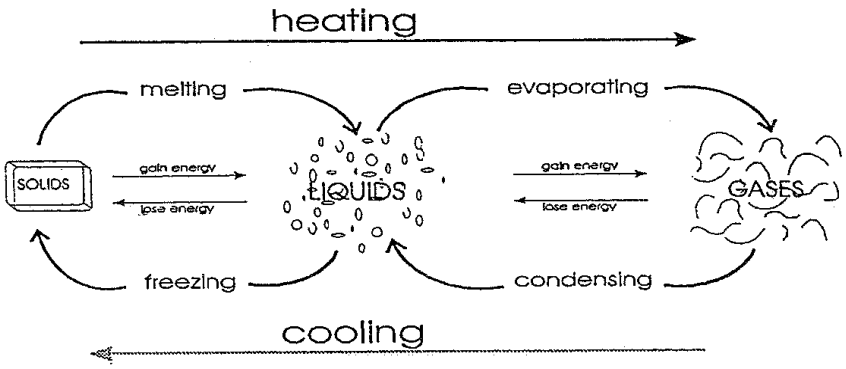
STEP 5

Use the thermometer to find what the temperature of the water is.



Q10. Explain what is happening to the molecules of water in the vial? (in terms of energy)
Q11. What are the changes of state the you have observed in this activity?
Q12. Can you see all states of water?
Q13. If there ids water in the air, in which state do you think it is?
Q14. Explain how this activity applies in nature and in the formation of rain

Q15 Study the diagram below and answer the questions that follow:



a) Explain the relationship between the gaining or losing of energy and heating and cooling.

b) Explain what happens to the particles of a substance when it changes from a solid to a liquid state.

c) Explain what happens to the particles of a substance when it changes from a gaseous state to a liquid state.

Appendix P: Colleen's CoRe

CHEMICAL SYSTEMS CoRe 2008

Key:

CoRe prior to teaching, Preparation stage	
CoRe during teaching phase	
CoRe after teaching phase	

BIG IDEA/ PROMPTS	ECONOMICS AND THE CHEMICAL INDUSTRY	THE FERTILIZER INDUSTRY	THE CHLOR-ALKALI INDUSTRY	ENERGY FROM THE CHEMICAL INDUSTRY
1. What you expect your learners to already know about this idea?	Exploiting the lithosphere-mining and environmental impacts [Sections from grade 10 and 11-Matter and Materials, Chemical Change and Chemical Systems] Global warming, photochemical smog, production of iron and steel, gold and phosphate, Kinetic theory and gas Laws, mole ratios Writing and balancing chemical equations, understanding how to write chemical formulae, understanding charges on ions, chemical calculations, and stoichiometry.	Nitrogen cycle (Biological and geographical systems, Industrial fixation of nitrogen, atmospheric chemistry [Sections from grade 10 and 11-Matter and Materials, Chemical Change and Chemical Systems Composition of the atmosphere, global warming, Kinetic theory and the Gas Laws, air pollution, phosphate mining and production of superphosphates, use of catalysts. Writing and balancing chemical equations, understanding how to write chemical formulae, understanding charges on ions, how distillation works, chemical equilibrium and rates of reaction. Chemical calculations, stoichiometry. Link to grade 10 chemical systems, grade 11 mining and mineral processing, acid base reactions, neutralization and grade 12 rate and extent of reactions, chemical systems, SASOL and the manufacture of fertilizers.	Acids and bases, laboratory acids and standard solutions [Sections from grade 10 and 11-Matter and Materials, Chemical Change and Chemical Systems Electrolysis, oxidation numbers Writing and balancing chemical equations, understanding how to write chemical formulae, understanding charges on ions, shape of molecules, electro negativity, polarity of bonds and molecules, difference between oxidation and reduction, strengths of oxidizing and reducing agents.	Electrolytes in solution, redox reactions, ionization and conductivity, substitution, elimination and addition reactions, energy and chemical change, electrochemistry, galvanic cells, standard electrode potentials [Sections from grade 10 and 11-Matter and Materials, Chemical Change and Chemical Systems Production of coal, oil, alkanes, alkenes and alkynes, other energy resources- bio-fuels, hydro-electric power, nuclear power, solar power, wind power and wave power. Writing and balancing chemical equations, understanding how to write chemical formulae, understanding charges on ions, difference between oxidation and reduction. Chemical calculations, stoichiometry, industrial processes that use elimination reactions [cracking], solubility of salts. Link to grade 11-mining and mineral processing.
2. What do you intend your learners to learn about this idea?	Facts about the chemical industry, designing and operating a chemical plant, cost effectiveness, chemical and economic challenges, manufacture of sulfuric acid [Contact Process}, uses of sulfuric acid, [car batteries and as drying agent] sources of hydrogen and nitrogen for the Haber Process, the Haber Process and ammonia production in SA. Differences between by-products, waste products and feedstock, chain of production	The nitrogen cycle, Plants, animals and nutrients, Fertilizing the soil to grow food, Nitrogen fertilizers, Manufacturing of nitric acid and the Ostwald Process, Uses of nitric acid and the decomposition of nitric acid, phosphorous and potassium in fertilizers, Effects of fertilizers on humans and the environment, risks and benefits. Essential nutrients, functions of NPK in plants, four major elements for human nutrition, utilization	Chlorine and its relationship to health, purification of drinking water, Electrolysis in manufacturing [diaphragm cell, Castner cell and membrane cell], manufacturing soap and detergents, synthetic detergents [wetting ability] and how surfactants work, science and our world- Chemicals deadly or saviors? Challenges to chemists in the	The petro-chemical industry, SASOL, gasification of coal, hydrocarbon synthesis. Production of methanol from synthesis gas, hydro-cracking, other synthesis sites and production options, Electrical energy from batteries, primary and secondary cells, designing batteries, zinc-carbon cell, mercury cell, lead acid batteries, battery ratings, electrolytes and car batteries. Need SA has for

		of chemical elements for particular functions- primary, secondary and micronutrients. Sources of NPK, Rates, yields, neutralization, flow diagrams, sources of potash and eutrophication- causes, consequences, prevention, ways to solve the problem, use of fertilizers on humans and environment.	21st century Identify benefits and risks to human kind from three types of cells; give flow diagrams and answer questions on unknown process connected with these products, impact of use of these products to humans and their environment.	chemicals that coal as a resource can meet? Be able to interpret and use data about production, consumption of raw materials, safety, identify social and economic benefits of SASOL production. Identify environmental issues and safety precautions in the plant. W=Vq Cell capacity and use of amp-hour, features of cell structure, internal resistance and distance between the electrodes, current and surface area of electrodes, cell capacity and amount of electrolyte.
BIG IDEA/ PROMTS	ECONOMICS AND THE CHEMICAL INDUSTRY	THE FERTILIZER INDUSTRY	THE CHLOR-ALKALI INDUSTRY	ENERGY FROM THE CHEMICAL INDUSTRY
3. Why is it important for the learners to know this?	Covers all three LOs and ASs, scientific literacy, knowledge and understanding of their environment LO1 Practical Inquiry and problem solving skills, LO2 Constructing and Applying Knowledge, LO3 Nature of science and relationship to science, technology and the environment	Covers all three LOs and ASs, scientific literacy, knowledge and understanding of their environment LO1 Practical Inquiry and problem solving skills, LO2 Constructing and Applying Knowledge, LO3 Nature of science and relationship to science, technology and the environment	Covers all three LOs and ASs, scientific literacy, knowledge and understanding of their environment LO1 Practical Inquiry and problem solving skills, LO2 Constructing and Applying Knowledge, LO3 Nature of science and relationship to science, technology and the environment	Covers all three LOs and ASs, scientific literacy, knowledge and understanding of their environment LO1 Practical Inquiry and problem solving skills, LO2 Constructing and Applying Knowledge, LO3 Nature of science and relationship to science, technology and the environment
4. What else do you know that the learners do not need to know yet?	All grade 12 sections in Matter and Materials, Chemical Change Section is very difficult to teach without having done other chemistry section first as there are large gaps in their content knowledge Learners should have completed the sections on matter and material and chemical change before attempting this section	All grade 12 sections in Matter and Materials, Chemical Change Section is very difficult to teach without having done other chemistry section first as there are large gaps in their content knowledge Learners should have completed the sections on matter and material and chemical change before attempting this section	All grade 12 sections in Matter and Materials, Chemical Change Section is very difficult to teach without having done other chemistry section first as there are large gaps in their content knowledge Learners should have completed the sections on matter and material and chemical change before attempting this section	All grade 12 sections in Matter and Materials, Chemical Change Section is very difficult to teach without having done other chemistry section first as there are large gaps in their content knowledge Learners should have completed the sections on matter and material and chemical change before attempting this section
5. Difficulties/limitations connected with teaching this idea?	Learners find industrial processes difficult and boring, learners cannot visualize production on a large scale Language barriers and literacy skills- some learners struggled with the industrial terms etc.	Learners find industrial processes difficult and boring, learners cannot visualize production on a large scale Learners struggled with the rates of reaction and chemical equilibrium ideas.	Learners struggle with electrochemistry, redox-oxidation, reduction and oxidation numbers. Electro-chemistry in general	Learners struggle with electrochemistry, redox-oxidation, reduction and oxidation numbers. Understanding of electrolytes, solubility, anode and cathode
6. Knowledge about the learners thinking which might influence your	Need to engage the learners in the topic-capture their attention. Need visual material to help! Link hydrogen in Haber process to gasification of coal in SASOL process Need to assess what they	Need to engage the learners in the topic-capture their attention. Need visual material to help! Need to assess what they know before starting the teaching process,	Need to engage the learners in the topic-capture their attention. Need visual material to help! Need to assess what they know before starting the teaching	Need to engage the learners in the topic-capture their attention. Need visual material to help! Need to assess what they know before starting the teaching

teaching of this idea?	know before starting the teaching process,		process,	process,
BIG IDEA/ PROMTS	ECONOMICS AND THE CHEMICAL INDUSTRY	THE FERTILIZER INDUSTRY	THE CHLOR-ALKALI INDUSTRY	ENERGY FROM THE CHEMICAL INDUSTRY
7. Teaching procedures and reasons for using these to engage the idea?	Research assignment to engage the learners in the idea that not all chemicals are safe and some damage our health and the environment. GDE requires grade 12 learners to complete a research assignment as part of their portfolio. May Examination to test knowledge summatively Visual material either video or from internet Could do project from the perspective of "green" chemistry. Concept maps of industrial processes and linking them together to form one large concept map.	Class-work to include mind maps –trying to convey the idea that concept mapping will help learners with there understanding of the material covered. May Examination to test knowledge summatively Visit a manufacturing site such as the ammonia plant at AECI Laboratory demonstration of the catalytic oxidation of ammonia if not already done. Concept maps of industrial processes and linking them together to form one large concept map. Relate new information to personal experiences-role play!	Demonstration of an electrolytic cell, Class-work to include mind maps. May Examination to test knowledge summatively Debate or role play on environmental issues to encourage discussion of new ideas. Concept maps of industrial processes and linking them together to form one large concept map.	Practical on electrochemical cell, video and learners to make a poster [cell disposal] and pre-practical tutorial-required for grade 12 portfolios and needs to cover all 3 LOs. May Examination to test knowledge summatively Relate current energy shortage to plant at Koega-delay in the aluminium smelter process Could do a research assignment on polymer chemistry, designer drugs etc-relating to organic chemistry and "green plastics" Use peer assessment for assessment of posters

Appendix Q: Samples of Colleen's PaPeR

Portion of Colleen's PaPeR

SOURCE OF DATA	REF CODE	DESCRIPTION
LEARNERS' CONCEPT MAPS AND COMMENTS (Reflective Journal 22nd April 2008)	[KL&L]	Learner misconceptions prior to teaching Contact Process: • formula for sulphuric acid as HSO_4 ,HSO_3 • sulphuric acid is a yellow powder/yellow • smells like rotten eggs • sulphuric acid mixes with water in atmosphere • $S + O \longrightarrow SO_3$ • sulphuric acid burns with a violet flame to produce acidic /choking gas SO_2 Learner comments after lesson on Contact Process • "lesson was interesting and easy to understand" • "I realized how dangerous sulfuric acid is and how important it is to industry and people's lives"
LEARNERS' CONCEPT MAPS AND COMMENTS	[KL&L]	• "it made sense but chemical equations were difficult to grasp" • "it helped me remember what we had learnt before" • "Mrs. Newell explained it well" • "The knowledge I had was minimal and I was unsure about it. I found the Contact Process interesting" • "This lesson was very effective" • "I learned a lot and understood most of what was taught" • "I understood half of the stuff but I feel I need to go over it again" • "I gained a lot of info and I understood it all"
VIDEO MATERIAL	[GPK]	Video recording of lesson on primary and secondary cells: After watching the video I realized : • I had tried to put too much content into the lesson and it was too rushed. • I asked questions that I answered myself. • The learners were not involved as much as they could have been. I did too much of the talking.
VIDEO MATERIAL	[KL&L] [GPK]	Video recording of lesson on E_{cell} and table of reduction potentials. [This recording was poor as photographer was not experienced with the camera] • Learners were unsure of concepts of oxidation and reduction • Had never used table of half reactions

		• Did not understand oxidizing and reducing agents • Did not know how to identify anode and cathode • Did not understand about salt bridge and electron flow. • I realized that it is not a good idea to teach Chemical Systems before the learners have done Chemical Change and Matter and Materials as there is too much that they do not understand. • Too much information for one lesson but lesson allowed a lot of interaction from learners.
PREPARATION OF RESEARCH ASSIGNMENT	[KCUR] [KCONT] [KVEP] [KCUR]	In preparing this research assignment I was very aware of the time constraints as well as the requirements of the GDE. I tried to engage the learners by providing some research material and introducing the learners to some controversial aspects of the chemical industry. The requirements for the grade 12 portfolio involve a research task which involves collecting information to understand a particular set of circumstances. [LO3]. The research work should not take more than three weeks. The learners were given just over two weeks to prepare their project and oral presentations were done over a period of a week.

Appendix R: Sample of Colleen's Reflective Journal

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?
School holidays I worked throughout the school break to my term planning and lesson planning on the chemical systems module complete. I feel I have prepared the lessons well given that we are pressed fro time and will not have much time to complete the section. The learners will have a research assignment to do as well as a open-ended practical on batteries. I have also included a video on The Busy Electron before the practical. I hope hat these activities will engage their interest in this topic. **1st week of 2nd term** I have gone through the plans with Anita. She seems to be happy with all the planning. I am to prepare both the cycle test and the exam which will take place in May I have organized with the computer teacher to let the girls watch the video in the centre. I have not managed to get a data projector for the lessons as the deputy in charge of equipment is on a school tour. Section 1 :Introduction to chemical systems and the contact process. The learners were very enthusiastic about their research projects and	**I feel very good about the preparation but the time constraints may mean that the section will not be taught in the detail that I would like.** **My prep for this term is enormous and I am not sure how I am going to manage everything. I am helping with the major production at the school, I have to set and type exams for grade 12 science, grade 10 maths and grade 9 natural science. This is on top of all the marking and the grade excursion to Sci Bono. The grade 12S are also entered into the Mintek quiz.** **I felt very good about how the learners responded to the research project as well as their responses to the lesson. Quite a few of the learners said that the info presented was easy to understand and they found the lesson interesting**	**I learned a lot about planning and time management in the classroom change the way in which we teach and how the content is covered. I seemed to have quite a few good ideas which would have taken too much time. As it is the learners will have to do their project presentations and watch the video in the afternoons as we will not have sufficient time.** **The prep has made me feel more confident about teaching this section.** **Some of the learners did not seem to grasp the industrial context of the lesson. I need to be aware of this next time.** **These are some of the comments from the learners after the lesson.** • **Lesson was interesting and info was easy to understand** • **I have realized how dangerous sulfuric acid is and its impact in industry** • **I understood the lesson and it helped me remember things that I had learned before** • **I understood and it was interesting**	**I would not teach this section in future before covering matter and material and chemical change. There seem to be too many areas that I am not sure whether the learners will have sufficient prior knowledge.** **I needed more time for all the different aspects of my life. My husband is not happy about the amount of time I am working and I home is neglected. Next year should be better when all the prep is done.** **I still think visual material would help learners to come to terms with industrial scale. It is a pity that there is no time for a visit to a chemical plant.**

some asked to do their projects on topics I had not put onto the list. They felt the time limit was short but they accepted that it was best to get it over quickly as they had a lot of work in all their subjects. Before The lesson on the contact process I asked them to write down what they knew about sulphuric acid. They were horrified and most could hardly put pen to paper. Maybe their chem. background is very poor. After the lesson I asked them to comment on the lesson and what they had learned. I have kept the responses as part of my data The Haber Process The lesson went well but I am very aware now that the chem. knowledge is not strong. Because I am new to the school I am not sure what or how they were taught chem. last year. The class listened to 4 project presentation and I was pleasantly surprised at the level of understanding and the amount of prep that they had done. They were not allowed to used their project for the presentation **<u>4 Day long weekend</u>** **I have worked really hard and have set three exams and done the memos for them. I also moderated the maths second paper. I feel like I have not had a break in spite of having one away lest weekend. [I marked 3 set of cycle test while I was away]**	**Seems to be going well and on track. I will video some of the presentations on Monday and a lesson on nitrogen cycle and Ostwald process.** **This research project was worth doing. I do not think the plagiarism was as bad as I had expected and most tried to use their own words. Very pleased with the outcome.** **I feel that most of the girls have had their interest sparked by the research and the lesson. Will deal with Ostwald process and other fertilizers tomorrow.**	• **I understood most of the lesson, there are a few things I want to ask about.** **These girls have a much better work ethic than the Saheti learners. Quite a few of them are trying to get into medicine etc and are determined to do well What a pleasure!!!** **I learned a tremendous amount from their work. I did not realize for example how easy it is to order drugs on-line without a prescription.** **I am glad I set limits to time and length. I feel that the moderators will be happy with the standard of this work**	**I would like all the learners to hear all the presentations but it is not going to be possible this time as we are so limited for time!** **I might set this work to be completed in the Easter school break next year although the work was completed on time.**

Appendix S: Samples of Colleen's Curriculum Materials

RESEARCH PROJECT

INVESTIGATING CHEMICALS

Choose one of the following products of the chemical industry and research about it and then discuss using the headings which are listed in the instructions. Some information will be available in the lab to help you make your choice but must not be removed. A MAXIMUM OF FOUR LEARNERS PER CLASS MAY CHOOSE THE SAME TOPIC AND THEREFORE YOU NEED TO FILL IN YOUR NAME ON THE LIST PROVIDED AND MAKE YOUR CHOICE QUICKLY.

1) **Plastics –(polymers) eg. Polyethylene, polypropylene, PVC [polyvinyl chloride] Teflon, polystyrene.**
2) **Soaps, detergents and surfactants**
3) **Insecticides- eg. DDT[erradication of malaria],**
4) **Herbicides- Fipronil [killing bees]**
5) **Antibiotics (antibiotic overuse and resistance)**
6) **Food Additives**
   - **Anti-oxidants[ascorbic acid]**
   - **emulsifying and stabilizing agents**
   - **anti-caking agents**
   - **colourants [tartrazine, sunset yellow]**
   - **preservatives [sodium dioxide, propyl and methyl paraben, pimaricin, sodium benzoate]**
   - **flavour enhancers [MSG-monosodium glutamate]**
   - **sweeteners [saccharin]**
7) **Fertilizers – phosphates, nitrates and sulphates etc.**

Instructions:

1. **The project should be no more than 8 pages and this includes a title page and a bibliography. It may be typed but you MUST use a font size of 12 and spacing of 1.5x.**
2. **At least five different sources of information should be used and these should be cited in your text and included in a bibliography at the end.**
3. **All the work MUST be written in your own words. Plagiarism is not permitted.**
4. **You will need to make a short presentation of approximately 4 minutes to the class on your project. In this time you will tell the class about the chemical you have chosen and answer any questions that they ask. NB. YOU MAY NOT READ YOUR ASSIGNMENT TO THE CLASS.**
5. **Your project should be divided into the following topics:**
   - **How the substance was discovered and what is it used for? [Historical]**
   - **How does it work? [Chemistry]**
   - **Why do we need it and is it necessary to society?[Commercial importance]**
   - **Discuss and debate safety, health and environmental issues concerning your substance. Include your own opinions and not just what you have read.**
6. **You will be marked on the project as well as your presentation. The rubrics are attached.**
7. **Your have 2 weeks to complete the project. THE DUE DATE IS: TUESDAY 29/4/2008 . MARKS WILL BE DEDUCTED IF THE PROJECT IS SUBMITTED LATE.**

NAME:……..

MARKSHEET FOR RESEARCH ASSIGNMENT	
WRITTEN PRESENTATION	/40
ORAL PRESENTATION	/10
TOTAL	/50

NAME:……..

MARKSHEET FOR RESEARCH ASSIGNMENT	
WRITTEN PRESENTATION	/40
ORAL PRESENTATION	/10
TOTAL	/50

CHEMICAL SYSTEMS

PRACTICAL INVESTIGATION

In this practical you will design and construct an electrochemical cell and predict the potential difference for your cell and investigate the relationship between the concentration of the electrolytes and the potential difference between the terminals. Your group will also have to produce and present a poster on the environmental issues around battery disposal.

Before starting your practical the class will watch a video: The world of Chemistry: The busy electron. [Annenberg Media) You will also be given material to read and you can research the topic before starting your practical. You will work in groups of 5.

LEARNING OBJECTIVES:

Learners will be able to:

- **Design a battery (electrochemical cell)**
- **Identify and label the anode, the cathode, electron low, ion flow, oxidation and reduction reactions, chemicals used as well as the location of each hand in a drawing of your cell before proceeding.**
- **Distinguish between anode materials and cathode materials with regard to energy potential.**
- **Write a hypothesis about their cell before constructing it and calculating the cell potential.**
- **Calculate the cell potential using the table of half potentials**
- **Construct a working battery.**
- **Use different concentration of the electrolytes to draw a graph of concentration vs cell potential.**
- **Interpret the data and the graph**
- **Write up a practical report on the work.**
- **Design and produce a poster about batteries and the environment and the safe disposal of batteries.**

Rubrics are supplied for all three parts of this task. Read these very carefully before starting your work.

South African Institute of Electrochemical Research.

Dear Learner,
You are all invited to take part in a competition for which bonuses will be awarded. This competition is a test of your laboratory, scientific and creative skills which involves the production of a poster and the construction of a battery (electrochemical cell) using the materials listed below:

- **U shaped glass tube**
- **Glass wool**
- **Two beakers**
- **Copper sulphate solutions of varying concentrations**
- **Magnesium sulphate solutions of varying concentrations**
- **Aluminium sulphate solutions of varying concentrations**
- **Lead nitrate solutions of varying concentrations**
- **Zinc sulphate solutions of varying concentrations**
- **Sodium sulphate solution**
- **Magnesium**
- **Copper**
- **Aluminium**
- **Lead**
- **Zinc**

You may work in groups of five learners. You must submit your labeled design to the judges (Mrs. Newell or Mrs. Naidu) before you actually begin the construction of your battery. After getting approval for your plan you must construct your battery. When it is ready bring it to the judge and connect it to the voltmeter provided. You will get a bonus if your team gets the highest potential difference. You will also get a bonus if you team makes the first battery that works. You are allowed to have more than one attempt but the work must be completed in the allocated time. You will also get bonuses for the best poster.

Yours sincerely,
F Newell [Chief Judge]

These questions may help you with your task:

1. **What is meant by oxidation?**
2. **What is meant by reduction?**
3. **What do these terms have to do with how a battery works?**
4. **How is current produced?**
5. **Where do the electrons go?**
6. **How do the ions move?**
7. **Why do the electrons move from the anode to the cathode?**
8. **What is the function of the salt bridge?**

9. What is the function of the electrolyte?

ELECTROCHEMISTRY MARKSHEET
[attach this sheet to the front of your laboratory report]

NAME:……DATE:……

GROUP MEMBERS:

1. ……

2. ……

3. ……

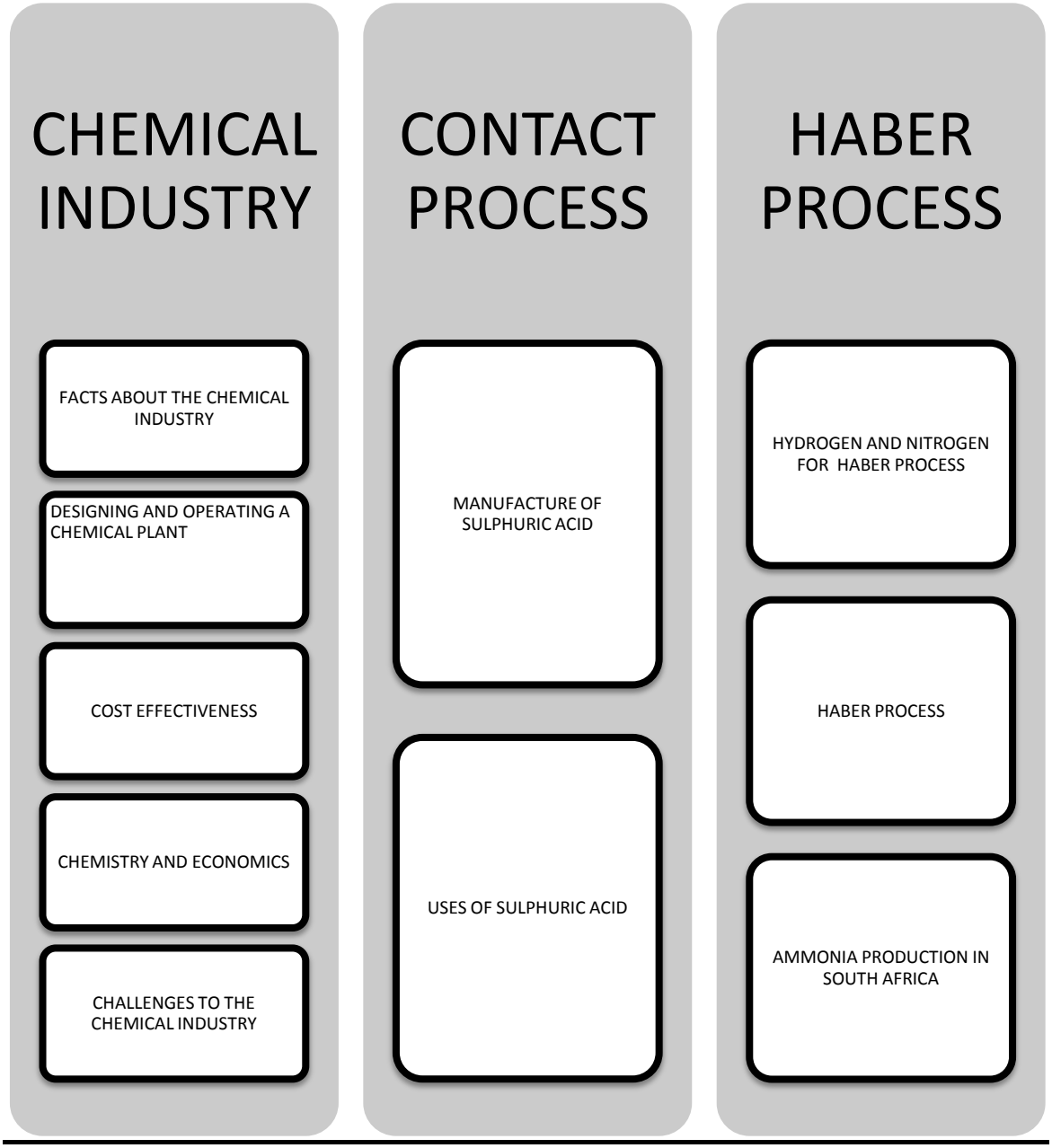
4. ……

5. ……

DESIGN & CONSTRUCTION	/9
LABORATORY REPORT	/48
POSTER	/15
BONUS 1ST WORKING CELL	/1
BONUS HIGHEST P.D	/1
BONUS BEST POSTER	/1
TOTAL	/75

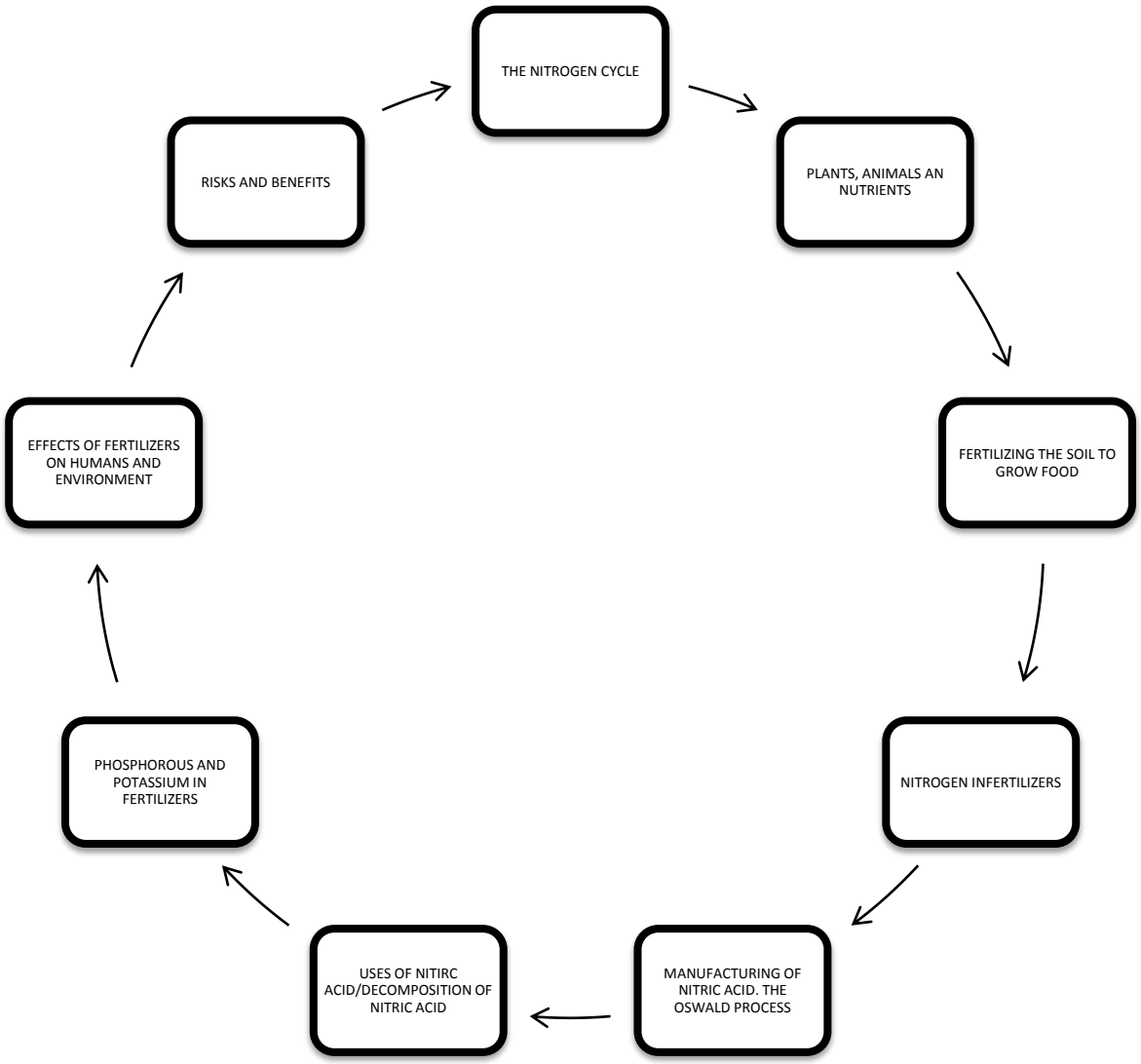
CHEMICAL SYSTEMS

ECONOMICS AND INDUSTRIAL CHEMISTRY



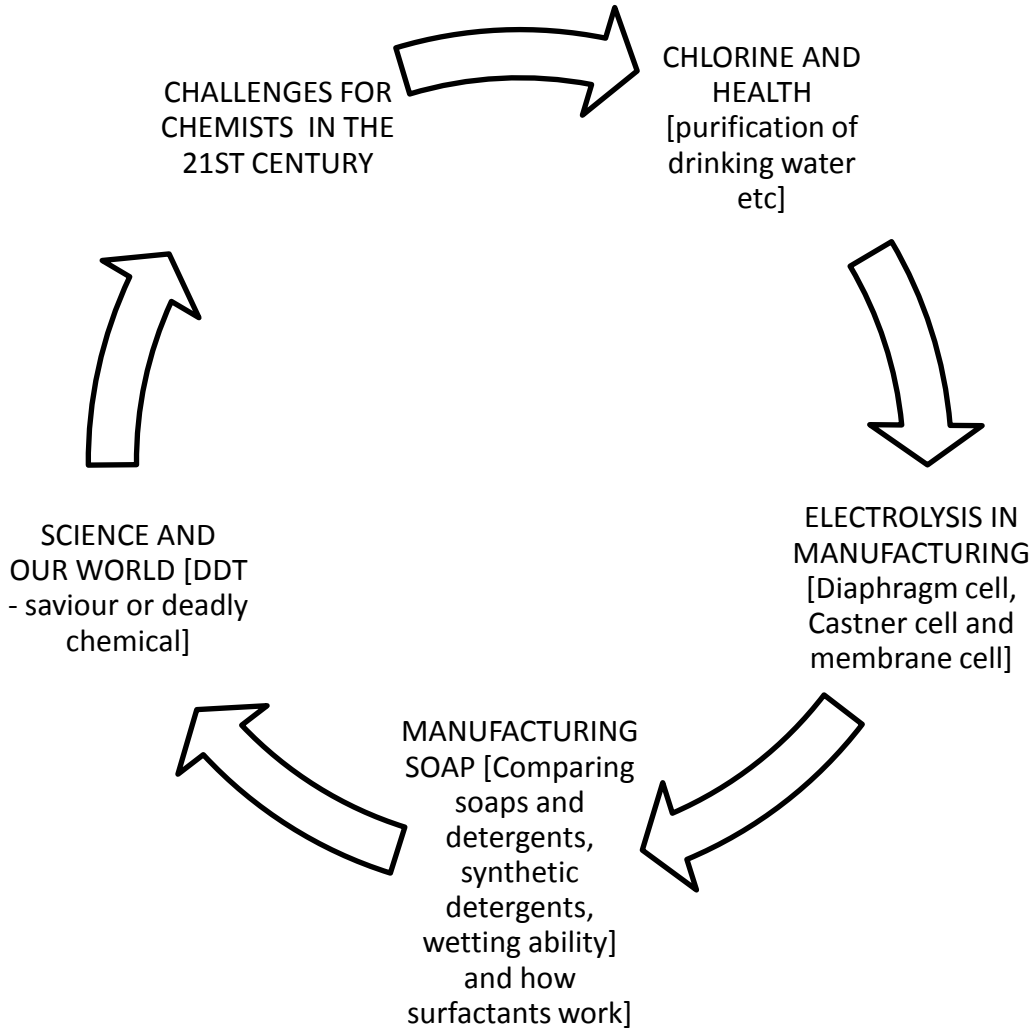
CHEMICAL SYSTEMS

THE FERTILIZER INDUSTRY



CHEMICAL SYSTEMS

THE CHLORALKALI INDUSTRY



FACTS ABOUT THE CHEMICAL INDUSTRY

- **Food, clothing, shelter and transport are our four most common needs. The ways in which these needs are met have been changed over time. Our ancestors used very little of what we consider necessities today. The involvement of science in providing us with these needs has increased over time. Today the chemical industry supplies us with all of the above needs and has revolutionised our everyday world. Our homes, schools, shops and leisure activities are filled with products of the chemical industry.**
- **The chemical industry has contributed to our lives in the following areas:**

1. Chemicals manufactured in large quantities that are often used as raw materials in other manufacturing processes. [sulphuric acid, nitric acid and ammonia].

2. Chemicals manufactured in smaller quantities but with greater cost because of their purity.

3. Fertilizers which are used to ncrease agicultrural productivity.

4. Fuels- transport and plastics

5. Health and medicines

6. Metals

7.Food processing- chemical industry processes and preserves raw food to fill the supermarket shelves.

8. Clothing – naturals fibres such as cotton and wool are no longer sufficient to supply our needs

9. Shelter- made from bricks, mortar and cement. Cement and concrete are modern day replacements for stone.

- **New chemical processes and substances have to be changed into a usable product. This in turn leads to the creation of jobs and wealth. South Africa's chemical industry has grown to cope with the increasing population and the more affluent lifestyle for many.**

LEARNER'S ACTIVITY: HOMEWORK [LO1 AS1 AS4 LO3 AS2 AS3]

[Adapted from Physical Sciences for the Classroom with permission from Heineman . Grade 12 Learner's Book]

Take a look around the food shops and supermarkets available to you, and in your own home to find examples of food and cleaning product labels. Bring samples to class in order to discuss what you find.

1. **What kind of information is on the labels?**
2. **How could you get more information about each product?**
3. **What evidence did you find of the chemical industry's influence on the substances in the product?**

DESIGNING AND OPERATING A CHEMICAL PLANT

- **All chemical plants [the buildings and equipment] need a specific location. This may be chosen for example because it is close to where the raw materials for the process are obtained.**
- **The plant needs the raw materials, reactants and energy to produce a product. These all cost money.**
- **Sometimes by-products are also produced and there are usually some waste products as well. These can contribute to pollution.**
- **The plant is built in such a way as to maximise profit and yield and to minimise waste products. Decisions are based on economic considerations which include cost of energy, the cost of the actual processes, the cost of the raw materials,the types of reactions involved, labour and related costs, the selling price of the product and possibly by-products and the rate of production and the yield. [how much is produced]**

Appendix T: Samples of Bongani's Reflective Journal

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 different next time**
After three sessions I have realised that my learners are not coping with the new topics. I have realised that my learners depend on notes because textbooks were not available at my school. Textbooks were bought but still my learners depend on my notes and reading their textbooks given to them was difficult. When I told them about my research project; they became excited began asking question about the project. What I have realise	I feel that I needed change in my teaching strategy; because also what I have realised is that some of my learners are talking while I am presenting my lesson. It means in other words my teaching is not effective. Other learners are disturbing my lesson by talking to their classmate while the lesson is in progression.	The experience that I have is that learners disturbed the lesson; if the lesson is interesting to them. The other experience that I have is that learners choose subject according to their difficult. Examples are subject like physical science and maths. I have realised that subject like Science are amongst faired subject	I will try to give them opportunity to discuss my lesson in order to capture their opinion about my lesson. It is important to accept their opinion Or criticism from my learners about the lesson. I may try focus on the learners that not performing good in class. Learn how to formulate good inquiry lessons with the purpose of accommodating all the learners.

is that may be it because I am going to use a video camera for my lesson. Maybe my teaching is not interesting enough or my methods of presenting are not accommodating all the learners. I have discovered that my content knowledge is lacking; even my teaching style is accommodative to my learners.			

Appendix U: Samples of Bongani's Curriculum Materials

MAITSE MONYE
GRADE 11C
CHEMISTRY

28/35 KM

Question 1

1.1 Troposphere ✓
Stratosphere ✓
Thermosphere ✓ (4)

1.2 Tropopause ✓

1.3 The Carbon dioxide form a carcoon that trap / absorb radiant rays ~~and~~ water molecules translocate the warm to the air thereby creating warm air.

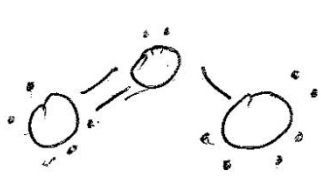
1.4 The is a decrease of temperature with the altitude due to the pressure that is equevalent to the pressure. ~~The~~ is now ~~1.5~~ dissociation of oxygen due to increase radiation energy.

$O_{2(g)} + O_{(gas)} \rightarrow O_{3\ (gas)}$ (7)

The is exothermic reaction whereby heat is given off and cause an increase temperature.

1.5 Nitrogen - N ✓
Argon - Ar ✓
Carbon dioxide - CO_2 ✓
Oxygen - O ✓ (6)

Question 2

2.1  ✓ (2)

2.2 The central atom O is bonded to two O atoms and has LP of electron thereby we can conclude that it is Angular.

2.3 O_2 (g) + O (g) → O_3 ✓ (2)

2.4 Troposphere ✓

2.5
2.5.1 Greenhouse gas ✓
2.5.2 UV - Ultra-Violet ray ✓
2.5.3 Climate change ✓
2.5.4 Cancer ✓ (2)
2.5.5 Greenhouse gas ✗

Question 3

Column A	Column B
3.1 Tropopause	C ✓
3.2 Thermosphere	B ✓ (6)
3.3 Decomposition	A ✓

Kakaki J'laloisane Asaia.

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03/12

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:

   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)

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   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

7. Which of the following is NOT a greenhouse gas?
   a) Carbon dioxide
   b) CFC
   c) Oxygen
   d) Methane
   e) Nitrous oxide

8. Chlorofluorcarbons (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 (NO_x) 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. (Please do not use external resources to answer this question – i.e. textbook, Google, etc.)

Global worming is worming of the planet due to increase the level of pollution. and ~~the global~~ worming have different gases.

Appendix V Sipho's Water cycle Pre-Core

PRE CoRE on Water Cycle

Important Science Concepts	CHEMICAL CHANGE CoRe				
Big idea / Prompts	Phases of water	Particulate theory	Properties of water	Conservation of water	
1. What you expect learners to know already about this idea	Water has three phases	Basic shape of a water molecule	Water remains at 100°C/(0°C-4°C) during boiling and freezing until all water molecules has evaporated or frozen	Water is not 'lost' during phase change	
2. What you intend students to learn about this idea	Bonding causes different phases of water	The shape of H_2O molecule does not change despite the phase water is in	Temperature remains constant until all water molecules have vapourized/frozen	Water is conserved	

3. Why is it important for students to know this?	To differentiate phases	To understand evaporation and condensation	To understand the influence of water on the climate	know that water circles in our planet (it can never be used up - but can be stored in other bodies)	
4. What else do you know about this idea (which you do not intend your learners to know yet)?	The 4th phase (plasma)	The H_2O molecule can accommodate the 3rd H-atom	Water is capable of withholding/absorbing energy for longer periods because there are many hydrogen bonds to be broken	• DYNAMIC EQUILIBRIUM During precipitation some water is deposited deep under the layers of the soil but later resurfaces as ground water that flows into streams while the other water is trapped in wells	
5.Difficulties/limitations connected with teaching this idea	learners' difficulty in relating micro- and macroscopic changes	learners find it difficult to relate the micro and macroscopic	if taught theoretically	measuring and comparing water that has evaporated with water that precipitated.	

9. Preferred assessment strategies or tasks to facilitate learning	Let them draw simple representations of water in each phase	Letting them draw particulate models of water in each phase	Let learners indicate observations by drawing a graph during/ showing phase changes	Practical investigation	
10. other factors that influence teaching of this concept	Kinetic theory of matter: the influence of temperature. Difference between boiling and evaporation	Crystallisation / Crystal lattice	Observation techniques	Observation & Measuring techniques	

Appendix W: Sipho's Incomplete Self Designed Task

Activity 1 Using Models

Focus question: How are water molecules arranged in solid and liquid phase and how does this arrangement influence the behaviour of water?

You will need: two sets of different sizes of polysterine balls
Toothpicks/ Pins

STEP 1 Join two small polysterine balls to a bigger one using toothpicks/pins as in the picture below. Q1 What is the shape of this structure? **Triangular/rectangular/square.** Q2 Which ball(s) represent an oxygen atom and which ball represent a hydrogen atom? Q3 Is this molecule **polar/nonpolar**? Explain	STEP 2 Prepare nineteen more water molecules using the procedure in STEP1. Do each of the molecules look **similar/different**?
STEP 3 Join each of the ten molecules such that they are randomly mixed. Join the other ten molecules such that they form a hexagonal shape. Q4 Which arrangement represent water in a i) liquid ii) solid phase Q5 Why are water molecules joined in this way? Explain. Q6 Supply the name of the bond between the molecules Q7 By inspection, which arrangement will release a molecule easier when equal amounts of energy are added to the system	STEP 4 Place both sets of joined molecules on A3 sheet/table/chalkboard/floor/anywhere, where the surface is large. Draw a square boundary in each set. Remove the models and answer the following question Q 8 Which box is bigger? Answer: solid/liquid. Give a reason for your answer. Replace the molecules and try to cut them in equal sizes and count the molecules. Q9 Which box contains more molecules? Answer: solid/liquid Q10 Which box is more dense? Give a reason for your answer.

Appendix X: Atmospheric Chemistry Conceptual Test

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:
   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

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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

7. Which of the following is NOT a greenhouse gas?
   a) Carbon dioxide
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   d) Methane
   e) Nitrous oxide

8. Chlorofluorcarbons (CFC's) are most closely associated with which of the following?
   a) Urban smog
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   c) Greenhouse effect
   d) Acid rain
   e) None of the above

9. Nitrous oxides (NO_x) 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.

_____
_____
_____
_____
_____

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Appendix Y: Reflective Journal Format

TEACHING & LEARNING REFLECTIVE JOURNAL

Educator Name _____ Date

Grade _____

Teaching Agenda

Lesson Topic _____

Lesson Learning Outcomes _____

_____

_____

_____

Research Agenda

Hypothesis (my assumptions) _____

_____

_____

Problem Statement _____

_____

_____

_____

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?**

Taking Stalk of My Learning

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

_____

_____

_____

_____

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

_____

_____

_____

_____

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

_____

_____

_____

_____

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

_____

_____

_____

_____

What do I need to do to improve quality of what I do?

_____

_____

_____

_____