

**A self-study on the Development of my Topic Specific
PCK while teaching stoichiometry within a lesson study**

By

Edmore Thabo Sibanda

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DECLARATION

I declare that this research report, titled: **A self-study on the Development of my Topic Specific PCK while teaching stoichiometry within a lesson study** is my own work and that all sources that I have used or quoted have been indicated and acknowledged by means of complete references. It is being submitted for the degree of Masters of Science at the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted before for any degree or examination purposes at any other university.



E.T Sibanda (Student number 584250)

Abstract

The following research report is a self-study that integrates lesson study and PCK which are action learning methodologies drawing from cognitive constructivism, socio-cultural and situated orientations to learning. Self and lesson study approaches are generally often ignored in programmes that are directed towards professional development of practising science educators. Hence their potential benefits or impact on PCK development and consequently learner understanding of concepts may not be tapped. The study was a self study on the development of my PCK as I taught stoichiometry concepts to grade 11 learners. Subsumed within this development were the metacognitive skills, the knowledge of my learners and how they learn including the creation of positive learning environments.

In order to gain an understanding of kind of PCK needed to teach stoichiometry and to improve my classroom practices I had to engage in some kind of learning to teach process in a particular context that was guided by a variety of theoretical constructs and methodologies. Such an approach acknowledges the situated nature of learning that it is social and contextual. In order to ensure that a holistic picture from diverse and dynamic environment was captured, a multidimensional analytic framework called the Learning for Teaching through Participation (LTtP) model developed by Nakedi (2014) was adopted.

Data from reflective teaching journals, teaching and learning artefacts, CoRes, TSPCK tool and video recordings were compiled and analysed using typological data analysis. Categories were drawn from the LTtP model and colour coded accordingly.

Shifts in my content knowledge (CK) for teaching stoichiometry concepts were traced through the aspects drawn from the LTtP model which served as lenses to discern the teachers' topic specific PCK. These aspects were Learners' Prior Conceptions/misconceptions (LPC), Learners' Procedural Knowledge (LPK), Curriculum Saliency (CS), Representations, Models and Analogies (RM&A) and Science Oriented Instructional Sequencing (SOIS).

The results obtained indicate a substantial shift in the way I engaged on PCK aspects which impacted positively on the learning environment and metacognitive skills and the knowledge of my learners. This occurred as a result of the learning process that I subjected myself to within a lesson study group.

Key words: Self-study, lesson study, pedagogical content knowledge, constructivism

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Dedication

I dedicate this piece of work to my mother Ethel and my late father, Robert for their love and inspiration. Over and above to the almighty God who takes care of me day and night.

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List of abbreviations

CAPS: Curriculum Assessment Policy Statement

CK: Content Knowledge

CS: Curriculum Saliency

LPC: Learners' Prior Conceptions/misconceptions

LPK: Learners' Procedural Knowledge

LTtP: Learning for Teaching through Participation

NCS: National Curriculum Statement

NSC: National Senior Certificate

PCK: Pedagogical content knowledge

RM&A: Representations, Models and Analogies

SMK: Subject Matter knowledge.

SOIS: Science Oriented Instructional Sequencing (SOIS)

TSPCK: Topic Specific Pedagogical Content knowledge

VNOS: Views about the Nature of science

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CHAPTER 1

INTRODUCTION

Introduction

This research is a self-study on the development of my own content knowledge for teaching a specific science topic in a specific school grade. In this chapter I present an overview of the study, by first giving the introduction and background which outlines the South African science education system as the broader context of the study. I then moved onto the specificity of the context and the research site which provided the context for the learning, the topic of focus, the problem statement, motivation and justification for doing the study and purpose of the study. A brief background to the development of research questions and positionality of the researcher is also presented. To give an outlay of the whole report I end the chapter with synopsis of what ensued in each chapter.

1.1 Background

Poor performance in science at exit levels in secondary school education and the need to maintain high levels of performance in some settings has necessitated the evolution of some innovations to foster the acquisition of scientific concepts amongst learners. In addition to equipping schools with learning resources such as textbooks, mobile lab kits and provision of science laboratories, recently, a greater focus has been directed to the development of science teachers in the Gauteng province of South Africa. The latter attempt is evidenced by in-service programs for practicing educators at various institutions of higher learning. Other developmental programs have taken forms of workshops held periodically at district levels such as '*teach a teacher*' sessions and professional learning groups (PLCs) in which teachers discuss how to teach particular topics. However, such innovations seem to have cosmetic effects on teacher practices within science classrooms. The practices have been that of encouraging rote learning for the sake of passing final examinations. This is the situation where schools are rated according to their pass rate, as in the case of South Africa, thus promoting teacher tendency to teach towards the examination, and focus on the aspects of the examination that have the greatest return on investment (Biggs, 1996).

Modisenyane and Rollnick (2004) note that at present, teacher professional development programs take the form, of seminars, college courses or workshops. Nilsson (2014) note that these professional development approaches have little long term influence on their practice in the classrooms. The implication is that the intentions of such workshops may not change the

status quo within classrooms, and hence alternative strategies such as participation in lesson study, which is initiated by the teachers themselves and engaging in self-study, could have desirable effects on actual classroom practices.

The reasons why such innovations as professional development fail to meet their intended objectives are varied and ranging. Some of which are from teachers' attitude towards such programs, lack of competencies in subject matter and strategies, foreign innovations that are not tailored to meet the needs of learners within their contexts. Loss of interest from teachers may also be due to the fact that some decisions are forced on them by policy formulators in a 'top-down' fashion without proper consultations and leading them to reject such initiatives. Such a 'top-down' approach on teacher professional development, where the people (teachers) responsible for implementing the changes have little if any influence on the construction of such changes is assumed not as successful as a 'bottom up' approach where teachers conduct their learning in response to their perceived personal needs, issues and concerns (Nilsson, 2014). This then calls for approaches that would involve the educators as the initiators and participants within actual teaching contexts in authentic classroom activities. Boyle, While and Boyle (2004) have argued that approaches such as study groups in which teachers are engaged on regular collaborative interactions are more likely to make a positive impact on their practice than traditional approaches such as workshops. In the section that follows I briefly discuss the curriculum innovations that have characterized the South African education system.

1.2 The South Africa education system

In South African context, a number of curriculum innovations have been instituted since the fall of apartheid and the dawn of democracy. These changes have been necessitated by the desire to better the lives of the majority of the people through provision of quality education by upholding the principles of equality and inclusivity amongst others in the curriculum. Curriculum 2005 was introduced by the 'new' democratic government as a way of overcoming the educational inequities of the past and preparing citizens for full participation in a democracy (Rogan and Grayson, 2003). Hoadley (2011) highlights the new changes occurred when the National Curriculum Statement (NCS) was reviewed in 2009. The Review team of the NCS strongly suggested that outcomes based education be discontinued and argued that it failed to give adequate specification of essential learning (Hoadley, 2011). The content had been underspecified and unclear for the purposes of generic skills. As a result of

an unclear and underspecified curriculum, the NCS work schedules were implemented in an attempt to provide greater content specification and guidelines for teachers on what to teach (Hoadley, 2011).

The changes in the curriculum have met both positive and negative criticisms from various stakeholders including politicians and educationalists. Rogan and Grayson (2003) note that one of the important reasons for the failure of curriculum reform programs in South Africa is due to lack of clearly thought out implementation strategies that take into account the local context, its diversity as well as psychological factors that influence learning and change. This implies that while these changes are noble, they may fail in the implementation phase that could be critical in the achievement of the aims and goals of such reform programs.

When a policy like the NCS is implemented in schools, both experienced and inexperienced teachers need to get used to it and be trained for the new system (DoE, 2000). In support of this notion, Ramroop (2004) states that if people who need to be the driving force behind the change are not fully equipped with knowledge, skills and attitude of being a positive force of change, then any change attempt is sure to fizzle out. Van der Merwe (2002) contends that teachers are more likely to respond positively to initiatives if they are given additional support during its planning and developmental stages. According to Serrao (2008) and Kgosana (2006), poor teacher training is a significant challenge that hampers the successful implementation of the NCS in secondary schools. Most teachers who are currently in the system received their baseline professional training under the auspices of the old apartheid curriculum. Therefore, they are most likely to experience difficulties in implementing a new curriculum effectively. However, I believe that this might have shifted as significant number of teachers who are working at schools continued to learn and are products of most recent teacher training courses at institutions of higher learning.

In an attempt to understand and express the extent to which the ideals of a set of curriculum proposals are being put into practice through a theory of curriculum implementation, Rogan and Grayson (2003) proposed a construct called a *profile of curriculum implementation* in addition to the *capacity to support innovation*, and *support from outside agencies* constructs. In their model *The profile of implementation* is, in essence, an attempt to understand and express the extent to which the ideals of a set of curriculum proposals are being put into practice (Rogan and Grayson, 2003). This construct is therefore critical in the classroom where teaching and learning takes place. Considering the vast diversity of schools including

knowledge and skills of teachers, therefore, the context within which the curriculum is implemented should therefore be taken into account. As Lelliott, Mwakapeda, Doidge, du Plessis, Hollo, Msimanga, Mundalamo, Nakedi & Bowie (2009) noted, the context for curriculum planning can be regarded as stable and documented, as evidenced in the constitutional and political goals, while that of curriculum implementation is dynamic and ever changing. The changes are necessitated by new innovations that are born out of the continuous researches that are conducted by different scholars, and the need to keep abreast with international standards. Self and lesson studies seem to be gathering momentum and more recognition in recent years in the educational field and hence there is need to align professional development programs with the current trends.

Teacher factors may stall effective implementation of the otherwise noble and pragmatic initiatives. Gess-Newsome (1999) argues that well-qualified novice teachers resort to reliance on algorithms, rules, and textbooks. This is also confirmed in the South African context by Stoffels (2005) who asserts that even highly experienced science teachers still ascribe high authority to learner support materials and follow textbooks and the national curriculum document verbatim. To explain such actions Stoffels (2005) argues that this is not necessarily a reflection of their reluctance or inability to make pedagogical reasons but that the pedagogical shifts required of them are too high and they feel unprepared.

In an attempt to effect change within classroom environment there is need for a drastic shift from the traditional mind set of assuming that learners have nothing to contribute during lessons to recognising them as key participants in the teaching and learning process. Jita (2004) found that changing practice requires a significant shift in the teacher's identity and that a teacher's personal resources e.g. their experiences in the past, contribute to their ability to shift in practice. This becomes very significant in settings such as townships schools that may be plagued by a number of socio-cultural issues and lack of physical resources. For individual teachers in such settings, action research may be an appropriate way in which one can engage in order to change their own practice (Lelliot et al, 2009). It becomes apparent that the nature of the curriculum and the contexts in which teaching and learning takes place, demand shaping and reshaping of teacher roles, functions and responsibilities (Lelliot et al, 2009). What this meant in this study for me was to focus on my practices in the classroom and engage in planning and reflection where I tried to create an effective learning

environment that supported learners in their knowledge construction pertaining to the topic of interest.

According to Rogan (2004), the most common type of teaching in South Africa is the transmission mode where teachers stand in front of the classroom and teach, while students listen and take notes, with little interaction between teachers and students. This seems to be at variance with what the National Curriculum Statement (NCS) proposes as the guiding principles of the enactment of the Physical Sciences curriculum. Two of the National Curriculum Statement Grades R – 12 principles are:

- *Active and critical learning: encouraging an active and critical approach to learning, rather than rote and uncritical learning of given truths;*
- *Progression: content and context of each grade shows progression from simple to complex.* (CAPS PHYSICAL SCIENCES-FINAL DRAFT-2012)

Some of these transmission modes are influenced by some teacher beliefs such as that learning occurs in quiet classroom environment. In some cases, even when teachers have been exposed to constructivism approaches, due to lack of classroom management skills they still resort to such unproductive approaches with respect to meaningful learning. In order to ensure that an active and critical learning environment prevails, it implies that educators should have a deeper understanding of the subject matter and their learners in order to design teaching strategies that engage learners and foster the acquisition of requisite scientific skills. At the same time learners' conceptions should be used to build scientific concepts and in order to ascertain concept progression, it implies that the educator should continuously assess learners' understanding of concepts during teaching. One of the distinguishing features of the CAPS curriculum from other curriculum documents is its demand for high knowledge skills on the part of learners. Teachers therefore need some kind of skill to make this knowledge more accessible and comprehensible to learners. Taking consideration of learners in the design and implementation of instruction may help learners to shift to higher levels of cognition. The context and site in which the research was carried out is described below.

1.3 Context and site of the study

The school is located in the high density western suburbs of Johannesburg in Krugersdorp. This is the school where I was working as a physical sciences educator at the time of conducting the study. Like many schools in metropolitan cities; the student population reflects the diverse cultures that exist in the South African society. The most common

languages are isiZulu, isiXhosa and Setswana. English language is used as the Language of Teaching and Learning (LOTL), although it is rarely used by learners during their day to day interactions. During lessons some learners end up expressing their ideas in vernacular due to challenges experienced when communicating in English language. Most learners have poor socio-economic backgrounds and a significant number of them are exempted from paying school fees. This has great implications for the resourcing of the school. There is a serious shortage of materials such as science equipment, chemicals, textbooks and furniture. Overcrowding is the most common feature in classes as they have an average of between 40 and 50 learners. As a result, teaching approaches tend to be biased towards traditional where knowledge is presented by educators to learners without equivocation or contestation. Learners generally have poor background knowledge in chemistry and usually do not perform well in this subject specifically in grade 10 and grade 11. Stoichiometry is one of the topics that are generally not well understood hence this topic became the focus of this study.

1.4 Topic of focus: Stoichiometry

The National Senior Certificate (NSC) Diagnostic reports for 2013 and 2014 examinations note that stoichiometry calculations were poorly done as students failed to work with the mole ratio (NSC examinations, Diagnostic Report, 2013, 2014). To address this problem, stoichiometry should be properly taught in grade 10 and 11 and revised in grade 12 as well as applied in the topics of chemical change and chemical systems (NSC examinations, Diagnostic report, 2013). This study therefore focused on the revision of stoichiometry concepts and in particular, the mole concept at grade 11 level, in order to uncover the critical features that are required for the development of PCK and the impact on learner understanding. The choice of the grade level was based on my belief that the science conceptions at grade 11 have a greater impact on learner performance at higher levels of learning chemistry. Of critical importance is the mole concept as it forms the basis for other stoichiometry concepts and it cuts across other topics such as chemical equilibrium and rates of reactions (Potgieter & Davidowitz, 2010). The implication is that stoichiometry is a fundamental topic that is of significance in basic chemistry topics.

Students and teachers alike may find this topic too abstract and difficult to understand, yet the topic is critical even in other topics (Potgieter & Davidowitz, 2010). If teachers find it difficult to comprehend the concept, it implies that learners may not be exposed to the correct ideas and this may lead to incorrect concept formation by learners which may then result in

poor performance. This is precisely what motivated focus of this study to offer the participating teachers, and in this case myself within a collaborative forum, conceptual as well as pedagogical tools of handling this critical topic in the classrooms.

1.5 Problem Statement

In the South African context, science teachers have been found not to be good in science knowledge and this affects their teaching (Rollnick, Bennett, Dharsey & Ndlovu, 2008). These authors further assert that in South Africa, one of the legacies of apartheid is that teachers from traditionally disadvantaged groups, often had only limited opportunities to formally develop their understanding of science (and other) subjects. They seem to hold the view that the apartheid system did not give such educators coming from the marginalised settings, opportunities to acquire the requisite scientific skills. At the same time the problem may be compounded by the view that teachers may lack the experiences and knowledge to effectively integrate science practices into classroom instruction (Pruitt, 2014). However, Wessels, Wessels & Nieuwoudt (2006) found that teachers' knowledge of subject matter and the development of statistical thinking, especially in the formative years in primary school, is not yet up to standard. Under these circumstances teachers may resort to some traditional classroom practices that do not foster student conceptual understanding. Rote teaching and learning is a result of the lack of subject matter especially in situations where subject matter knowledge is lacking (Rollnick et al 2008). These authors claim that as a result South Africa does not perform well in international studies. This necessitates that practicing teachers engage in self-directed learning in order to gain a deeper understanding of their subject matter so that they enhance learning of scientific concepts by their students.

For my own professional growth as an educator, I undertook a significant number of professional courses which involved workshops conducted by the Department of Education aimed at capacitating teachers to teach some science topics in addition to familiarization with the new CAPS syllabus. However, despite all those efforts, I still felt that there was a gap which worried me between my beliefs, practices and learner understanding which continued to undermine my efforts in the classes that I taught. Because of its strong pedagogical experiential approach, self-study as a research methodology emerged as most appropriate in exploring that which is critical to know as a teacher, in order to foster student achievement and the kind of pedagogical content knowledge that is required to ensure an ideal learning environment.

1.6 Purpose of the study

The study sought to explore the development of my PCK when teaching stoichiometry concepts. In this study, I carried out a self-study within a larger lesson study, to focus on improving my own practice. Such approaches are generally often ignored in programs that are directed towards professional development of practicing science educators and hence their potential benefits or impact on PCK development and consequently learner understanding are left untapped. The study sought to establish how my content knowledge and metacognitive skills evolved and the type of learning environment evoked as I focused on improving my practice through teaching of stoichiometry concepts. To address all the diverse aspects of interest, this study used the Learning for Teaching through Participation (LTtP) model to pull the cognitive, social and situated aspects of the teachers' pedagogical and professional roles into a cohesive framework.

1.7 Background to the development of research questions

Claims have been made about the nature of PCK as being a knowledge base unique to teachers which is a complex topic specific phenomenon. Shulman (1987) stated that effective teachers need PCK rather than just knowledge of a particular subject matter. Teaching involves the teacher putting into action the designed plans during interaction with learners. At the same time learners should comprehend the issues that arise during the discourse. It then calls upon the educator to have some skills in making the concepts to be easily understood by learners. While PCK is essential for effective instruction, it is also complex and difficult to observe and document (van Driel, Verloop, & de Vos, 1998). The complex nature of PCK implies that a serious thought should be given to try to identify the key aspects or attributes that lead to the understanding of concepts and possibly attempt to identify any shifts that may possibly occur which enhance the acquisition of science concepts. This can be achieved through adopting a systematic approach to scrutinise one's practice. A focus on the self also challenges teachers to become more conscious of and thoughtful about aspects of their teaching practice which they might have previously not noticed or perhaps avoided to think about (Loughran, 2004).

Since PCK is complex as well as topic specific, it means that transfer from one topic to another is neither automatic nor easy. For instance, PCK that is related to chemical equilibrium would be different to PCK related to stoichiometry. This opens up an unlimited scope in which PCK could be studied and unravelled. This study focused on me as I sought

to uncover that which is critical to ensure acquisition of stoichiometry concepts by learners, in essence Topic Specific Pedagogical Knowledge (TSPCK).

To achieve the main objective of the study, the following main question and its sub-questions were addressed:

Main research question: How is my content knowledge for teaching stoichiometry to my grade 11 learners evolving as I engage in a self-study within the learning study?

- 1: How is my knowledge of learners and how they learn, specific to the topic of stoichiometry shifting, as I engage in self-study?
- 2: How is my knowledge of creating effective learning environments shifting as I participate in this study?
- 3: How are my metacognitive skills of planning, reflecting and enacting in my own and my learners' learning affected as I participate in the self study process?

This study used a variety of qualitative data collection instruments such as video recordings, reflective journals and transcriptions amongst others. All the three research sub-questions are interlinked and draw from different aspects of the data sources employed in this study. To address my main research question I needed to capture the aspects of PCK by identifying and tracing any changes throughout the research process, from my initial practice approaches (pre) to the post lesson engagement when I reflected.

The first research sub-question relates specifically to the shift on my knowledge of learners and how they learn. This knowledge encompasses a wider range of issues such as knowing their prior instruction conceptions, how they reason about stoichiometry concepts to their procedural knowledge on problem solving. It also includes other student conceptions that may hinder or help acquisition of science conceptions that may arise during the teaching and learning process.

The second research sub-question relates specifically to what happens in my classroom. In other words it concerns the learning atmosphere, classroom organization and the interactions that took place during my practices. Hence even though data drew from the different data sources: video recordings, reflective journal and lesson study transcriptions, focus here was on the kind of the learning environment and discourses generated between me and the learners as well as interactions between the learners themselves. However, it has to be noted that the focuses of the research questions are interlinked for instance the learning

environment in the classroom is informed by the planning and teaching artefacts which in their own right are products of metacognitive skills.

The third sub-question relates to metacognitive skills that are not only necessary for the planning stage but also required and employed during the enactment of the lessons. In this study the teaching process encompasses the preparation, enactment and post enactment of the lesson stages such as when I reflected on my actions. Hence there was a need to look into the evolution of these skills during the study. Based on these ideas the data collection tools namely the CoRes, teaching and learning artifacts, reflective journals and transcriptions of the videotape recordings among others were seen fit to address these questions as they enabled a range of data to be collected and analyzed using the LTtP model.

1.8 Motivation and justification for the study

It was during the time when I had enrolled for my BSc honors degree course at the University of the Witwatersrand that I heard of the concept of PCK. During that time the PCK concept had never been a part of the courses that I had registered for even though my lecturers and colleagues occasionally referred to or mentioned it in passing during formal and informal discussions. The talk about the PCK concept became even more profound when I had enrolled for the Master's degree course at the same institution. Unfortunately, even then, the construct was not part of the courses that were on offer during the time although other streams were offering PCK as a course or module. It was during one of the discussion that we had in one of the sessions in the Science in Developing Countries course that I got convinced that PCK was a fundamental concept in teaching although the discussion did not delve into the core of the concept. Issues that were raised during the robust discussion convinced me that PCK was the distinguishing feature of teaching as a profession from other professions. I had a conviction that it makes a difference between a trained qualified teacher and an untrained teacher, experienced and inexperienced educators in the same field. Henceforth I saw a need for me to fully understand and be conversant with the construct.

My interest in the concept was further stimulated when a senior professor in the department revealed that there were plans to undertake a large project based on PCK that would involve teachers and subject specialists. It is then that I grabbed the opportunity with both hands in an attempt to learn and understand this seemingly elusive concept that I had been deprived of over the past years of my quest for personal professional development.

I then participated in lesson study group meetings in which the scope and framework of the large project were discussed. I then took it upon myself to ‘dig deeper’ through reading to try and understand this concept that was first put forward by Shulman (1987). I was later surprised to discover that a number of models had been propounded by various researchers in the field hinging around the PCK concept. Some of the researchers that have crafted various PCK models include Schneider, Rollnick & Mavhunga, Kind, Magnusson Krajcik, & Borko as documented by Kind (2015) and Nakedi (2014) amongst others. Due to the emergence of these various models, it can be gleaned that the concept is complex and therefore subject to different interpretations depending on the context. As Mulholland & Wallace (2005) noticed, it is interesting to see that PCK is interpreted in many different ways to suit the research context. For example, some researchers include knowledge of curriculum (Grossman, 1990), while others exclude this knowledge aspect (Cochran, DeRuiter, & King 1993).

Self-study as research methodology was introduced to me by my project supervisor even though I had heard of it before, I was skeptical about its value in the research field, an illusion that most people are couched in. I saw it befitting my study based on my naïve beliefs that I had about learning: that learning is context bound and it is upon an individual to want to learn; and that it is incumbent upon individuals to put into practice what they acquire through learning, which I consider to be a critical aspect for self-directed professional learning. Stoichiometry concepts are critical in the general understanding of chemistry topics. Hence there is need to ensure that learners are capable of accessing these concepts. In order to ensure the accessibility of these concepts it implies that Topic Specific Pedagogical knowledge (TSPCK) should be inherent in the teachers that teach these concepts.

1.9 Positionality of the researcher

Having decided to engage in self-study within a lesson study group I made a choice to take the role of a learner by enacting a lesson and interact with members of the lesson study group and to make reflections based on my experiences in these learning environments. In order to benefit from this role, it meant that I become an active participant within the group by way of seeking to get an understanding of the seemingly hazy ideas that I had about the various aspects such as PCK construct in relation to stoichiometry teaching. In addition, I had to give feedback based on my actions in practice and critique some of the videotaped lessons that had been taught by other members of the lesson study group. By engaging with other members in the lesson study group I was in a way embracing the socio-cultural learning perspective.

Inherent in this perspective is the notion that action emerges in particular context and is shaped by that particular context rather than as a result of the existence of some knowledge in one's mind.

According to Hafpor (2007) how we act (*including how we think*) depends not only on what we know but also on the context; what is being done and with what means; where we are; and with whom and for what purposes. My work environment provided the context where I worked with learners teaching a specific concept in chemistry while the lesson study group provided a learning environment in which I interacted with the 'more capable peers' or critical friends. Henceforth taking the role of a *learner* I had to take action as we learn by doing.

1.10 Study outline

This project is presented in six chapters. In this first chapter I gave an introduction of the report. Literature based on the various aspects and constructs that are relevant to this study is reviewed in the second chapter. In particular I delve deeper into self-study as a research methodology and issues surrounding pedagogical content knowledge and its components. The conceptual framework that guides and shapes the study is presented in chapter 3. In this chapter I draw upon Learning for Teaching through Participation (LTtP) model designed by Nakedi (2014). A variety of PCK models have been propounded by different researchers as highlighted earlier but I chose this model as it appears to draw from a variety of theoretical constructs such as situated and individual cognitive perspectives of constructivism and can be adapted to any context. In addition, this chapter will reflect the stance that I take within the research field.

The analysis of data is presented in chapter 4. This chapter will describe how the instruments used to collect and analyze data were designed and detail the methods used. Categorization and coding of data are some of the aspects that will be dealt with. The findings of the project will be presented in chapter 5. Any shifts in some aspects of PCK will be discussed. An attempt to relate the findings of this study to the findings of previous researches will be made. Chapter 6 will present the conclusion, limitations and recommendations that will emerge from this study. Significance of the study will also be highlighted. A list of my references and appendices will be presented at the end of the report.

CHAPTER 2

LITERATURE REVIEW

Introduction

Literature that relates to constructivism, pedagogical content knowledge (PCK) self-study, lesson study, stoichiometry and stoichiometry teaching would be reviewed in this section. Constructivism and PCK are very critical in this study as they form the theoretical basis of the study. Abell (2008) states that teaching science is not about having a bag of tricks and gimmicks, but the merging of context, subject matter knowledge (at a topic and discipline specific level), and teaching methods to form meaningful instruction. Meaningful learning derives from metacognitive skills of planning and reflection and a consideration of learners' knowledge. These aspects together with the learning environments and interactions would be discussed. A brief description of Bybee's 5Es stage learning cycle will also be presented. Some researches that have been conducted in the past that are related to this study would be highlighted.

2.1 Constructivism: A theoretical perspective to learning

Firstly I delve into the aspect of constructivism that underpins my self-study. Constructivism as a perspective is a theory of knowledge that is used to explain how people come to understand their world (Lorsbach & Tobin, 1992). This perspective has been subject to a wide range of views from different scholars. However, these ideas do seem to be committed to the general view that learning is an active process of constructing and that instruction is a process of supporting rather than communicating (Duffy & Cunningham, 1996). This view disregards the notion of learning as a process of acquiring knowledge but rather that knowledge is constructed within a particular context. Constructivism is viewed from many perspectives. These are individual cognitive and sociocultural approaches (Cobb, 1994) in addition to the situated perspective.

The proponents of the individual cognitive approach include Piaget (1997), and von Glasersfeld (1992). In the cognitive approach the individual is responsible for his or her learning. Learning is an activity of an individual as he attempts to make meaning of the world. When the expectations of the individual are not met disequilibrium will occur in the schema of an individual. Learning will then take place when the conflict occurs to resolve the discrepancy. These ideas have an implication both on the teacher and students' learning environments as will be seen later in this section.

The sociocultural approach focuses on the social and cultural aspects of learning as opposed to individualism. Vygotsky (1978) is the main proponent of the social constructivism approach. Learning is seen to take place as a result of social interactions. The changes in the way individuals participate in social interactions are indicative of learning. Learning is seen to take place in two planes, the internal and external planes (Wertsch, 1991). The internal plane relates to processes that take place within an individual while the external plane relates to the individuals pronouncement of their mental processes to the outside world. Hence there is a link between the internal and external planes. This interaction between the two planes needs that social tools like language is appropriated by individuals for their full participation. Learning is therefore a process of acculturation where individuals are introduced into the cultural practices of a community.

The situated approach views knowledge as situated, being in part a product of the activity, context and culture in which it is developed and used (Brown, Collins & Duiguid, 1989). In essence, meaning making and the learning process are effective if they take place in situations where the knowledge is used and therefore relevant. Brown et al (1989) argued that authentic activity is important because it is the only way learners gain access to the standpoint that enables the practitioners to act meaningfully and purposefully and is the activity that shapes or horns their tools. Authentic activities are activities whose meaning and purpose are socially constructed by members of a community. The members engage in these practices through interaction and these activities can be accessed by members of the community.

It has to be noted that these perspectives have some similarities and differences. For instance they all put more focus on the learner being actively involved in the knowledge construction. The difference hinge around the approach to learning for example the cognitive perspective emphasises the role of the individual in learning while social perspective emphasises the role of interaction in social settings. On the other hand the situated perspective emphasise engaging the learner in authentic practice in a community of practice. The implication is that for learning to take place there must be an activity, context and the availability of information to learners therefore becomes critical. The activity is not viewed as a means of availing the information to the head of the learners as this would reduce learners to passive participants. The constructivists view the learning as the activity in context and the situation as a whole

must be examined and understood in order to understand the learning (Duffy & Cunningham, 1996). The content, context and activity are integral to what is learnt.

Lorsbach & Tobin (1992) asserted that the teachers' beliefs about how people learn whether verbalistic or not, often help people to make sense of, and guide their practice. Strategies that educators use during teaching and learning should draw from constructivism as a belief system. Constructivism as a referent to teaching and learning, assumes that learning is the responsibility of the learner. In other words learning and making sense of what happens, rests ultimately on the individual learner. Learners' pre-instruction conceptions are important for the acquisition of new concepts. Learners should not be viewed as empty containers that should be filled with information but rather as active participants during the teaching and learning process. Learners need time to experience and reflect on their experiences on what they already know and resolve any problems that arise (Lorsbach and Tobin, 1992). I believe that this also applies to teachers' who may be interested in understanding their learning and in order to improve their own teaching practices. Teachers need to engage in practice and reflect meaningfully on their practice.

A number of researches have been conducted on some aspects of constructivism such as learners' prior conceptions and use of everyday knowledge in science classroom in the South African context. The research conducted by Stears, Malcolm and Kowlas (2003) explored what constituted the everyday knowledge of learners from township and informal settlements in the Cape flats, how this knowledge might be introduced and used in science classrooms and how teachers and learners made shifts between formal science and everyday knowledge. They found that learners related strongly to content that dealt with their lives in townships and informal settlements (e.g. fire, cooking, repairing damaged equipment) and thus resulted in deeper engagement with each other and the teacher. In a project on curriculum design in the midlands of the Kwazulu Natal, Keane and Malcolm (2003) noted that community members supported the idea of a curriculum that addressed community needs, such as food security, curbing violence, practical knowledge and skills to solve their immediate problems. Although some of the community expectations seemed to be out of line with traditional schooling, the underlying ideas are relevant to the science curriculum.

These studies emphasise the importance of knowledge being drawn from the learners' immediate environment as learners are in a position to relate to this knowledge and the science that is inherent in this knowledge. Malcolm (2004) argued that the context is much

more than a device for teaching pre-set science concepts; the context has its own integrity, from which particular purposes, concerns and content flow. The context should serve a purpose of determining the kind of learning that goes on in a classroom environment. Scientific concepts should be drawn from the context that is being presented.

When learners encounter concepts that are at variance with what they already know, disequilibrium may occur within the individual and this necessitates resolution through negotiation of meaning within the individual. Discussion can be done when disequilibrium has occurred to facilitate meaning negotiation. According to Lersbach and Tobin (1992) children's prior knowledge of phenomena differs from the teacher's intention, as they construct meaning that fit into their own experience and expectations. The educators need to be more sensitive to children's prior knowledge and the process by which they make meaning. According to constructivism, science is not an attempt to look for truth but a process that assists individuals to make sense of the world that surrounds them. Learners should be encouraged to exploit their own methods to solving problems and draw conclusions based on their findings from investigations. In doing so, learners have to exploit cultural tools such as language. These are some actions that learners were engaged in during this study. Language becomes critical in the negotiation of meaning during discursive practices.

2.2 Language and learning

Language can be viewed from different viewpoints such as being a medium of instruction and its use in the reasoning and formulation of concepts within minds of learners. At the same time each discipline has its own specific language. Explanation of observations and new phenomena is critical in formation and integration of the new knowledge. This explanation stage (as it will be explained later in Bybee's 5Es lesson sequencing) entails the use of language. Language is a critical aspect of the learning cycle. Vygostky (1978) has asserted that learning is a social process and that for students to learn they must be involved in various forms of discourse. However some challenges arise when the language of instruction is different from the language that the learners use at their homes.

Learners whose medium of instruction is different from their mother tongue tend to experience challenges that are totally different from those whose mother tongue is used as the medium of instruction. Lantolf (2003) argues that when second language learners are involved in communicative activities (verbal or written) they develop the repertoire of the symbolic artefacts that they use in the activities. The process of internalization is also

important in the development of these artefacts. This process occurs when an individual has acquired requisite skills and is capable of formulating ideas.

Lantolf (2003) asserts that it is possible to observe at least in part, the process of language learning through analysis of the intrapersonal communication (private speech) produced by learners in concrete objective circumstances in the classroom. The implication is that what learners produce as spoken word, or in the form of written word, or behavior that they exhibit such as taking time before responding to a question is indicative of the thought process tools. This implies that different individuals may acquire different tools. Therefore every effort should be made to accommodate the needs of all learners in class. Hence some knowledge and skill are needed from the educator to teach a particular topic as teaching involves communicating this language to learners and this is dealt with in the next section.

2.3 Pedagogical Content Knowledge (PCK)

Teaching involves the teacher interacting with learners and the subject matter. For effective teaching, the teacher has to use certain strategies that help learners to grasp scientific concepts. In order to teach science in ways that promote students' understanding, Shulman (1986) claimed that teachers need PCK, a special kind of knowledge that teachers have about how to teach particular content to particular pupils. Teachers therefore need to have an understanding of their learners in order to craft teaching strategies that would help the understanding of scientific concepts. Different models of PCK are employed in the studies already cited in section 1.8 in the motivation and justification of the study but my interest is predominantly in topic specific PCK (TSPCK). In this regard TSPCK is considered as the understanding that provides the needed knowledge for transformation of content knowledge in a particular topic (Mavhunga & Rollnick, 2013).

When teaching a topic there is need to consider the different components of PCK in order facilitate learning. These are varied depending on the model used but in general the components are similar in different models. The quality of TSPCK is influenced by both the knowledge of the content specific components as well as their interaction among each other. This description distinguishes TSPCK from the broader PCK in that it has selective focus on content knowledge and the specific knowledge that transforms it. PCK implies a transformation of subject matter knowledge so that it can be used effectively and flexibly in the communication process between teachers and learners during classroom practice (Rollnick & Mavhunga, 2013). As already highlighted in section 2.1 the context of the

teaching and learning process is important in the formulation of strategies and techniques that are relevant to the needs of learners. Learners in different contexts would have different characteristics such as socio-cultural background, linguistic background and ways of thinking in general.

In relation to practice Park & Olivier (2008) note that PCK involves teachers' understanding of how to help a group of students understand specific subject matter using multiple instructional, representations and assessments while working within contextual, cultural and social limitations in their learning environment. The implication is that ideas that learners bring into the classroom, their social upbringing and linguistic background, and the kinds of interaction that occur inside the classroom would be critical in formulating the decisions and the direction that the lesson takes. To achieve this, the educator has to develop an understanding of the ways in which the students think and reason in trying to communicate their ideas. This calls upon the educator to be engaged in a self and lesson study to uncover the critical aspects of learning with the help of colleagues and experts in the science field. As Lewis (2002) note Japanese teachers describe "developing eyes to see children" as the primary benefit of lesson study. This implies getting to understand learners' thought processes which may not necessarily be overt.

Schneider & Plasman (2011) conducted a research to examine the science teachers' PCK in order to refine ideas about science teacher learning progressions and how to support the teachers. The authors note that when teachers reflected on practice and student responses; they had the opportunity to rearrange their ideas in ways that developed their science pedagogical content knowledge (Schneider & Plasman, 2011). The reflections help to identify critical features of the concept which could either hinder or facilitate learning. Teachers get to understand the kind of learners they deal with and devise strategies that would address the needs of their learners. The authors claim that when teachers are engaged in practice their learning progresses over time. Teachers face many challenges as they learn about teaching science since they tend to work in isolated environments separated from other colleagues or experts. Some of these challenges relate to attempts to create effective science learning environments and trying to understand the learners that they teach. Engaging in reflective practice in essence self-study and lesson study could therefore help teachers to be critical of their practices and work towards improving their teaching environments. In the

following sections I describe metacognitive skills, learning environments the knowledge of learners which this study sought to explore.

2.4 Meta cognitive skills

Many cognitive science and educational researchers theorize that much of learning is a conscious process that incorporates metacognitive knowledge and skills as key components (Collins, Brown, & Newman, 1989). The implication is that these meta cognitive skills and knowledge can be acquired through some form of learning. Meta cognition can be defined simply as thinking about thinking (Anderson, 2002). This means that as an educator I have to be conscious of what I am doing in order to be in a position to explain the impact of such actions on the learning process.

Meta cognition can be divided into five primary components: preparing and planning for learning, selecting and using learning strategies, monitoring strategy use, orchestrating various strategies, and evaluating strategy use and learning (Anderson, 2002). These incorporate thinking and reflective processes. It can be inferred from these components that meta cognitive skills have to do with the design processes, planning and implementation of the lesson during the teaching and learning process. This implies that these skills are spread out throughout the course of engagement with the task of teaching and learning in this self study. One important observation noted by Anderson (2002) is that meta cognition is not a linear process that moves from preparing and planning to evaluating. The skills may intersect in that more than one meta cognitive process may be occurring at a time in a learning situation.

The ability to reflect critically on learning experiences and to explain why I engage in some actions including the ability to explicate some concepts constitute some of the meta cognitive skills that this study sought to engage in. These skills have a direct bearing on what the students learn. This then implies that the quality of learning would be determined by the kind of cognitive processes that are triggered when attempting to learn. Teaching is more effective when it encourages processes that stimulate learning and discourages counterproductive cognitive processes (Conati & Van Lehn, 1999). This study incorporated the use of a variety of sources of data as I sought to explore the development of my PCK while teaching stoichiometry concepts. This enabled the meta cognitive skills to be identified and interrogated at various stages of the study while engaging in the learning to teach process in a particular context.

2.5 Learning environment and interactions

Collins, Brown & Newman (1986) note that an ideal learning environment should constitute the following aspects: content, method, sequence and sociology. While expounding these aspects is beyond the scope of this project it has to be noted that these aspects have to do with some aspects of constructivism such as the situated nature of learning in social context, procedural and domain knowledge, learning and teaching strategies such as exploration and reflection. These fit in well with the PCK construct, self-study methodology and the LTtP model that was used as the analytical framework in this self-study. Interactions during the lesson would characterize the learning environment with regards to the social aspect. In general, interaction can be defined as a reciprocal communication process between human and human or between human and non-human (Moore, 1989). A learning environment in a typical classroom can be characterized as active interactions between learner and instructor or between learner and other learners (So & Brush, 2006). At the same time I believe that interactions between the learners and the learning resources or content are equally important in ensuring an active learning environment. In previous lessons the opportunities for these interactions were often limited in learning environments due to a number of factors such as my planning and the need to rush over the syllabus for examination purposes amongst others.

2.6 Knowledge of students

Knowledge of students is one of the knowledge bases for teaching that has been identified by research experts in the education field (Gees-Newsome, 2015). Knowledge of students encompasses student cognitive and physical development, understanding student differences that might require instructional differentiation and how to capitalize on personal and community assets to enrich instruction (Gees -Newsome, 2015). This study sought to explore aspects of this knowledge that related to cognitive processes that learners engaged in and community assets such language and social interactions that took place during the teaching and learning process. Knowledge of students would therefore include knowledge of how students think about, know, or learn this particular content (Ball & Stephen, 2008). The manner in which students learn relates strongly to their learning styles. However this study did not seek to explore the different learning styles that existed in my classroom but rather on the kind of knowledge that relates to their thinking process and how they learn; including an understanding of their prior instruction conceptions. Self and lesson study methodologies were used in this study and are described in the sections that follow.

2.7 Self-study

Self-study involves the study of one's self, one's actions, one's ideas and the not one's (LaBoskey, 1998). It therefore involves intentional and systematic inquiry into one's own practice to reveal knowledge about practice (Dinkelman 2003). This implies that self study is an active process requiring a set of procedures to be followed in attempting to uncover those elements that may contribute to the growth and development of an educator. Knowing one's practice is not an end to the process, but there is need to explore opportunities for improvement in one's practice.

A focus on the self challenges teachers to become more conscious of and thoughtful about aspects of their teaching practice they have previously not noticed or perhaps avoided thinking about (Hamilton, Smith and Worthington, 2008). Whitehead (1993) spoke of experiencing oneself as a living contradiction and this idea has rung true for many as they have been confronted by the differences between their practices and beliefs in teaching. Thus self studies are initiated by individuals who would want to seek an understanding of their practice and then try to learn in order to improve these practices.

Self- study also involves a thoughtful look at text reads, experiences had, people known and ideas considered (Hamilton et al, 2008). These assertions illuminate the way in which self studies should be conducted and the kind of data sources that could be used. The significance of self-study is offered by Hamilton et al (2008) who sees the focus for self-study scholars as contributing to the professional knowledge base of teaching as well as generating understanding of the world. This highlights the value of, and contribution that self study could have in the education field.

As an indicator of the value of self-studies, literature documents a number of researches that have been conducted on self-studies in the South African context. Self studies have been used to support and enhance teachers' professional development and lifelong learning in the pre-service and in-service programs (Freese, 2005). Nakedi and Rollnick (2012) also reported on self studies conducted by practicing teachers while teaching specific topics in science. The narratives of the teachers involved in the studies indicate a shift from their general understanding to a deeper understanding of their teaching and learning. As noted by Nakedi & Rollnick (2012) engaging in self-studies helped the four teachers involved in their study to develop their content knowledge for teaching chemical systems at FET level and enhanced their metacognitive skills in planning and reflecting on their teaching. It is hoped that these

developmental shifts have a positive impact on learners' understanding of science concepts and ultimately performance in science. Samaras & Freese (2006) highlighted some of the benefits of self study as to: better understand one's self, one's teaching and one's students learning, and to develop practical knowledge for personal, professional and classroom implementation, which in essence is what I hoped to achieve in this study. Self studies present a number of disposition features of which reflection is one of them.

2.8 Lesson study

According to Lewis, Perry & Murata (2006) a lesson study is a translation of Japanese words *jogyo* (instruction, lessons or lesson) and *Kenkyuu* (research or study) of the term *jogyo kenkyuu* which encompasses a large family of instructional improvement strategies. It involves a group of teachers and a researcher who observe live classroom discourses, collect and analyze data in a collegial process to enhance the learning of concepts by learners. The observed lessons are regarded not as an end in themselves but as a window on the larger vision of education shared by the group of teachers (Lewis et al, 2006). The implication is that critical features of a lesson are identified and developed to address learner needs in subsequent lessons. These features could be related to students' thinking which could expose some misconceptions that students could possess and the strategies employed by the teacher in an attempt to help learners to understand the scientific concepts. In this study, audio and video recorded lessons were observed and analyzed instead of live lessons. My participation in the meetings was critical in this study as I sought to monitor any shifts or gains that would impact on my practices as a science teacher. Lessons that were conducted by other colleagues were critical in my own reflection as I hoped to gain some understanding on other strategies that could be used to approach the same topics differently.

One major challenge posed by lesson study is the adaptation of its aspects to meet local needs. This is especially true in settings such as in South Africa that are diverse in terms of socio-cultural background, economic and resource availability and the fact that the approach is relatively new in the South African context having originated in Japan and spread to the United States of America. Lesson study in the US may focus on teacher moves rather than on student learning, make impressionistic notes rather than thorough observational records; and engage in discussions that emphasize debate rather than listening and reflection (Lewis et al, 2006). With regards to the South African context attention could be paid to how students think, how their prior instruction hinder or facilitate learning, how the educator responds to

the new demands that emerge during the lesson and hence how the teacher's pedagogical content knowledge evolves. This could be in line with the constructivism approach to teaching and learning that is recommended by the National Curriculum Statement.

Engaging in lesson study also exposed me to another opportunity to learn as a science educator. Lewis (2009) identified the types of educator learning during lesson study as development of knowledge; development of interpersonal relationships; and development of personal qualities and dispositions. These aspects augment some of the characteristics and dispositions of self study such as knowledge development, ongoing and situated inquiry. Hence these two approaches are integrated in his study as I endeavored to develop knowledge when teaching stoichiometry concepts. I used **the lesson study as a reference from which some of these aspects were drawn or exposed and also as an environment that provided some learning opportunities**. In the following section I present the lesson strategy that I intended to incorporate during the lesson enactment.

2.9 Bybee's 5Es lesson sequencing

This project integrated demonstration or practical activity and the 5Es lesson sequencing strategy that promotes conceptual change as teaching strategies. The five Es stages in Bybee's learning cycle are Engage, Explore, Explain, Elaborate and Evaluate as per their sequence.

In the Engage phase learners' interests and prior knowledge are taken into consideration. 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 (Bybee, Taylor, Gardner, Van Scotter, Powell, Westbrook, and Landes, 2006).

This stage is then followed by the Exploratory stage in which learners' get involved in activities to discover some phenomenon. 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 (Bybee, et al, 2006). This is an active stage in which the students interact directly with objects and materials (Hassard & Dias, 2009). This stage can be structured with clearly spelt out instruction or can be left open ended. In this stage students observe, collect data and experience new phenomena much akin

to accommodation in conceptual change theories in which new structures are built to integrate new information by learners.

In the Explanation phase concepts and definitions are given. As highlighted earlier this stage involves the use of language, a cultural tool that not only helps in communication but critical in concept formulation. Explanations about phenomena are constructed and justified based on the observations made during the exploration stage. The Elaboration stage is the application part of the cycle. It is designed to provide the students with active learning situations where they can apply; test and extend new ideas and concepts (Hassard & Dias, 2009).

The last stage is the Evaluation stage in which students make decisions about the phenomena. 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 (Bybee, et al, 2006). This stage also helps to reflect on issues that emerge in the activities. Such a strategy was adapted to suit the teaching and learning of stoichiometry concepts. The choice of stoichiometry as topic of focus was discussed in section 1.4; in the next section I describe this topic and its teaching.

2.10 Stoichiometry and stoichiometry teaching

The branch of chemistry dealing with the description in mathematical terms of quantitative relationships is called stoichiometry (Schmidt, 1990). Therefore, the understanding of the key relationships between quantities and calculations thereof are critical in stoichiometry topics. Feedback from chemistry teachers, however, shows that teaching stoichiometric calculation in the classroom is a difficult task (Schmidt, 1990). Dierks (1981) assert that students in introductory chemistry courses always find stoichiometry and the mole concepts very difficult. In lay terms, the mole concept is a collective noun for a very large number of atoms or molecules, to allow counting by weighing (Rollnick et al, 2008).

The causes of the difficulty are varied ranging from the abstract nature of the concepts to the way these concepts are taught by teachers. When expressed in these simple terms, it underplays the difficulties for both teachers and learners of this topic (Gauchona and Méheutb, 2007). Some researchers such as Mitchell and Gunstone (1984) have hypothesized that the unsuspected children's science may contribute significantly to this difficulty. This relates to the learners' prior instruction conceptions, that if these are not interrogated properly they may result in learners failing to grasp the fundamental stoichiometry concepts. It therefore calls upon for teaching strategies that encourage learners to be critical in order to

internalize the stoichiometry concepts; the kind of classroom practice that could make it easier for the teacher to convey this difficult part of chemistry to the students. Conceptual change strategies such as Bybee's 5Es strategy could be employed in this regard.

Chemists refer to chemical phenomena at three different levels of representation macroscopic, symbolic and sub microscopic that are directly related to each other (Johnstone 1982). It implies that in order to have a deeper understanding of chemistry there is need to understand all the three levels of chemical phenomena. The three levels are interconnected, for instance to explain what happens at large scale the sub micro level is used to enable understanding of these ideas. However the use of two or more representations at the same time has been shown to reduce the alternative conceptions that students may have (Boujaoude and Barakat, 2000). At the same time unintentional migration between these levels may curtail learning as students may not understand these representational levels.

Studies have shown that competence in algorithmic problem solving is independent of competence in conceptual questions (Stamovlasis, Tsaparlis, Kamilatos, Papaoikonomou and Zarotiadou, 2004). These results demonstrate the limits of usual teaching of stoichiometry through the use of formulas and algorithms (Gauchona and Méheutb, 2007). Other researchers (Lythcott, 1990 & Pickering, 1990; cited in Boujaoude and Barakat, 2000) found that only a small number of students in secondary school and in their first year at universities could solve conceptual problems in chemistry.

Some authors attribute the difficulty of teaching the many physics and chemistry concepts in general and the mole concept in particular to the failure to integrate the meaning of the concepts to the mathematical calculation. The implication is that teachers will tend to substitute numbers into a formula without explaining the underlying concepts. In a study conducted by Rollnick et al (2008) it was found that none of the teachers tried to link the conceptual understanding of the mole concept to the calculation and no exercises for conceptual understanding of the mole were given by the teachers involved in their study.

If teachers do not have in-depth knowledge of a topic themselves, it is clearly difficult for them to provide conceptual depth for their students, hence the importance of PCK and the role of SMK in its development (Rollnick et al ,2008) This then calls for approaches that seek to challenge learners' conceptual understanding such as conceptual change strategies.

Stoichiometry and related concepts are an important part of student learning in Chemistry (Dahsah and Coll, 2007). The ideas that learners have about scientific phenomena could

either hinder or facilitate the adoption of scientific concepts. Horton (2007) notes that identifying the concepts that the students possess contribute to the search for ‘bridging’ the concepts. Students could better understand the new concepts when they build it from the concepts that they are already familiar with. In a study conducted on students strategies in solving stoichiometry calculations Schmidt (1990) concluded that it is very helpful for any chemistry teacher to know beforehand the difficulties of the students in doing stoichiometric calculations and this helps to develop specific teaching activities prior to the teaching situation. Getting to uncover the students anticipated difficulties and designing appropriate strategies are some components of PCK.

Most scholars and policy makers have assumed that PCK not only exists but also contributes to effective teaching and learning (Hill, Ball & Schilling, 2008). This is evident by the inclusion of PCK tenets in curriculum standards documents such as NCTM and the National Board for Professional Teaching Standards (NBPTS). These documents note:

‘the importance of teachers holding knowledge of students as learners (NCTM) and being able to recognize the ‘preconceptions and background knowledge that students typically bring to each subject (NBTS,2006)’.

PCK is composed of 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 (Shulman, 1986). Thus there is need to focus on specific topics in order to uncover the critical features of that topic so that the underlying concepts could be simplified to a level of understanding of learners for the appropriation of the concepts by learners.

2.11 Conclusion

Constructivism and PCK are theoretical constructs that have gained a lot of ground in recent research studies. In addition these constructs have found their way into the curriculum documents for most countries in pursuit of different goals such as enhancing learning and for professional development of teachers. These widely recognized powerful constructs underpin my study. Linked to these constructs is the conceptual change strategy. Bybee’s 5Es stage learning sequence offers an opportunity to explore some of the ideas about the mole concept that learners could hold. Drawing from the motivation of the study as explained in the previous chapter I saw it fit to subject this study to self and lesson study action research

methodologies. This study adopted primarily the former methodology as I was interested in exploring my practices while the later was used for reference group to subject my practices for public scrutiny. I briefly described the teaching and learning of stoichiometry concepts. I highlighted the key aspects that this study sought to focus on such as metacognitive skills, learning environments and knowledge of learners. Some of the aspects that were reviewed are revisited in the next chapter as the literature serves to guide and shape the conceptual framework of this study. I deal with the conceptual framework in the ensuing chapter.

CHAPTER 3

CONCEPTUAL FRAMEWORK

Introduction

Firstly, I present descriptions of some key terms that I believe underpin the purpose of this chapter. These include the terms conceptual framework and paradigm. Secondly I describe the theoretical perspectives to learning in relation to the LTtP framework and make an attempt to position my study within these. In doing so I expound the LtTP model and show how it emanates from theoretical constructs to learning. Thirdly the PCK aspects that are drawn from the LtTP framework are then extensively dealt with in the ensuing paragraphs. Lastly I highlight self study and lesson study as action research methodologies and show how they inform my conceptual framework. It has to be noted, however that some aspects would overlap from one concept to another for instance the learners' prior instruction conceptions would be highlighted in theoretical perspectives to learning, PCK and self-study discussions. Hence such ideas should be viewed holistically rather than as separate entities and it can be argued that this conflation of aspects in a way indicates the interrelatedness of concepts in this study.

3.1 Conceptual framework and Paradigm

Holiday (2001, cited in Henning, Rensburg & Smit, 2010) defines a conceptual framework as covering the main features of the research design and their presumed relationships and forces the researcher to be explicit about what they think they are doing. In a way the conceptual framework helps to position myself as the researcher in relation to the research. It is primarily a place where the ideology inherent in the qualitative research can be addressed (Henning et al, 2010). They further add that a conceptual framework in other words is an alignment of the key concepts of the study. Within this framework vested interests are made explicit because there is no value free or bias free research design (Henning et al, 2010). By highlighting the bias it is possible to see where the questions that guide the study are crafted (Henning et al, 2010). A paradigm is defined as a fundamental orientation perspective of world views which is often not questioned and is subject to empirical test (De Vos, 2006). In addition, Bogdan (2007) describes a paradigm as a loose collection of logically related assumptions, concepts or proposition that orient thinking and research. The methodological approach of the research is positioned ideologically with current studies and theoretical research perspectives such as

constructivism, PCK, self and lesson studies which underpin this study as well as the impact the research will have on the participants and the setting.

3.2 Theoretical perspectives to learning and the LTtP framework

My study is based on an amalgamation of the three different theoretical perspectives to learning namely cognitive constructivism, situated and socio-cultural perspectives. It also focuses on PCK, a theoretical construct that links teacher practice and teacher knowledge. According to Bruner (1996) traditionally, learning is thought of as an act of accumulating propositional knowledge in one's head; action or knowing how, is supposed to follow automatically from certain propositions about facts and theories and the like. This is the view proposed by cognitive constructivists. The merit of the cognitive constructivism is that as alluded to in section 2.1, it emphasizes the constructive activity of the individual as he or she tries to make sense of the world. Cognitive constructivism focuses mainly on the individual and how the individual learns or constructs knowledge. The theory assumes that knowledge cannot be transferred from one individual to another but instead, humans construct their own knowledge (Piaget, 1953 in Powell and Kalina, 2009). With regards to children, schemas are constructed through processes of assimilation, accommodation and equilibration. Hence I adapted **Bybee's 5Es** lesson sequencing strategy during enactment of the lesson. During the lesson, learners were challenged to make predictions and give explanations for their predictions.

Brown, Collins and Duguid (1989) argue that learning and cognition are fundamentally situated. In other words, what is being learnt cannot be separated from the situation or context in which it takes place. Knowledge is produced from situations in which it is inherent. Henceforth seeing learning as situated implies going against the common idea that learning is a mental activity clearly separated from the environment (Hafpor, 2007). This may seem to be slightly different from the cognitivists school of thought described previously but I believe that for effective stimulation of thought processes the environment and interactions thereof augment learning. In this situated perspective, learning is seen as a complex social interplay between people and their environment, and mental activity is reduced to being part of that interplay (Hafpor, 2007).

Situated perspective views learning as a situated social practice in which individuals act or participate in a particular situation or context. Individuals learn by participating in a community of practice and not in isolation (Hanks, 1991). A community of practice is a

certain group of people sharing the same cultural tools in which individuals are expected to contribute to the group in some way. Learners and educators alike are therefore expected to be members of some communities of practice. Due to differing roles and identities, it implies that they belong to different communities of practice. As an educator I belong to a community of practice that is different from those of learners as I have acquired some knowledge and skills, and hold views gained from my experiences in articulating science concepts that are totally different from what the learners have. Hence as the educator I have to take the role of a 'broker' as coined by Lave & Wenger (1991) and try to introduce my learners into the science community through using appropriate cultural tools such as language, and ways of engaging with science knowledge. This in a way feeds into my beliefs and views about the nature of science which lie at the core of the *knowledge, beliefs and attitude domain* in the Learning for Teaching through Participation (LTtP) framework (Nakedi, 2014). The role of 'brokering' demands that as a science teacher I should have some knowledge and skill (aspects of PCK) to help learners move between the boundaries and change their 'identities'. *Learner feedback and outcomes*, which is located within the *stimulation and challenge domain* in the LTtP model, could be used as indicators for any shifts in any of the aspects that are relevant to this study. The lesson study group also provided another learning environment in which I was engaged with colleagues and experts in science education.

In addition to being a member of the community of practice in my classroom I had the privilege of being a member of another community of practice that comprised experts in the field of science; the lesson study group. This fitted well with the disposition of self-study such as the need for collaboration and reflection. By and large this collaboration allowed me to engage with peers and experts, thus providing a platform for *framing and reframing* of my beliefs and practices within the *stimulation and challenge domain* of the LTtP model and allow my practices and beliefs to be subjected to public scrutiny, a critical aspect in a self-study. The discussions and interactions provided a platform from which ideas were shared and henceforth possible learning opportunities. According to Malcolm (2004) the context has its own integrity, from which particular purposes, concerns and content flow. Hence *reflection in action* as suggested by Granett & Beer (2012) was invoked while the lesson was proceeding, in addition to the *reflection on action* at the end of the lesson. Thus the social interactions and engagement in thought processes during reflection should create an enabling environment for learning to take place.

According to Bandura (1977) in the social learning systems, new patterns of behaviour can be acquired through direct experience or by observing the behaviour of others. He notes that the more rudimentary form of learning, rooted in direct experience is largely governed by the rewarding and punishing consequences that follow any given action. When people are confronted by different situations they must craft some responses to deal with these situations in one way or another. In some cases, some of the responses may be successful while others may not produce desirable effects. Through this process of differential reinforcement, successful modes of behaviour are eventually selected from exploratory activities while ineffectual ones are discarded (Bandura, 1977). This became critical when learners made contributions to the lesson, as a teacher I had to either acknowledge or disapprove their responses or suggestions. I hoped that those responses that were of significance would be used to develop science concepts during the lesson.

The idea of direct experience is further alluded to by Lave and Wenger (1991) who note that taken in relation to a single craft that is taught through 'hands' on legitimate peripheral participation, the ability to learn would develop in close relation to the ability to perform the task. This implies that learning would take place by engagement with the task in actual classroom settings. Lave and Wenger (1991) note that any learning program that consists of instructional settings separated from actual performance, would tend to split the learner's ability to manage the learning situation from his ability to perform the skill. Hence authentic activities were designed and learners engaged in such activities in an attempt to reduce the gap between the ability to learn and the ability to perform the task. It has to be noted that this learning applied to both learners and me as the centre of the study.

I therefore believe that meaningful teacher learning should take place within real settings such as a classroom and in collaborative forums such as lesson study groups where reflection and sharing of ideas could take place. The collaborative environment was enriched by the presence of the experts in the field. These are according to socio-cultural cognitivists are the most 'able peers' who have to offer support in the form of scaffolding. The lesson study group thus provided such kind of an environment that fostered deep thinking on my part on various issues that came to the fore. Thus in a nutshell my learning and to some extent that of my learners was cognitive as it occurred within an individual, social and located in context in which it took place. In the following paragraphs I delve into the framework that was used to guide this study to a greater detail.

3.3 The LTtP model

My research is located within Nakedi's (2014) Learning for Teaching through Participation (LTtP) model as a conceptual framework. I used this model to guide and shape this research due to its multidimensional nature it fitted in well with self-study approach and to some extent lesson studies and constructivism perspective to learning. It also served as analytical framework in this study as it allows for reflection through framing and reframing of practices.

Lave & Wenger (1991) argue strongly that educational field should be based on explicit accounts of its different theoretical perspectives. This study integrated self and lesson studies which are action learning methodologies that draw from cognitive constructivism, socio-cultural and situated orientations to learning and PCK framework. In order to ensure that a holistic picture from diverse and dynamic environment was captured, the multidimensional analytic framework LTtP model based on these three different theoretical perspectives was employed. This model depicted in Fig 3.1, 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 (Nakedi, 2014). The LTtP model is much similar to the model for teacher learning designed by Coenders & Terlouw (2015) that is also characterized by enactment and reflection of class practices and interplay between various domains that leads to growth networks.

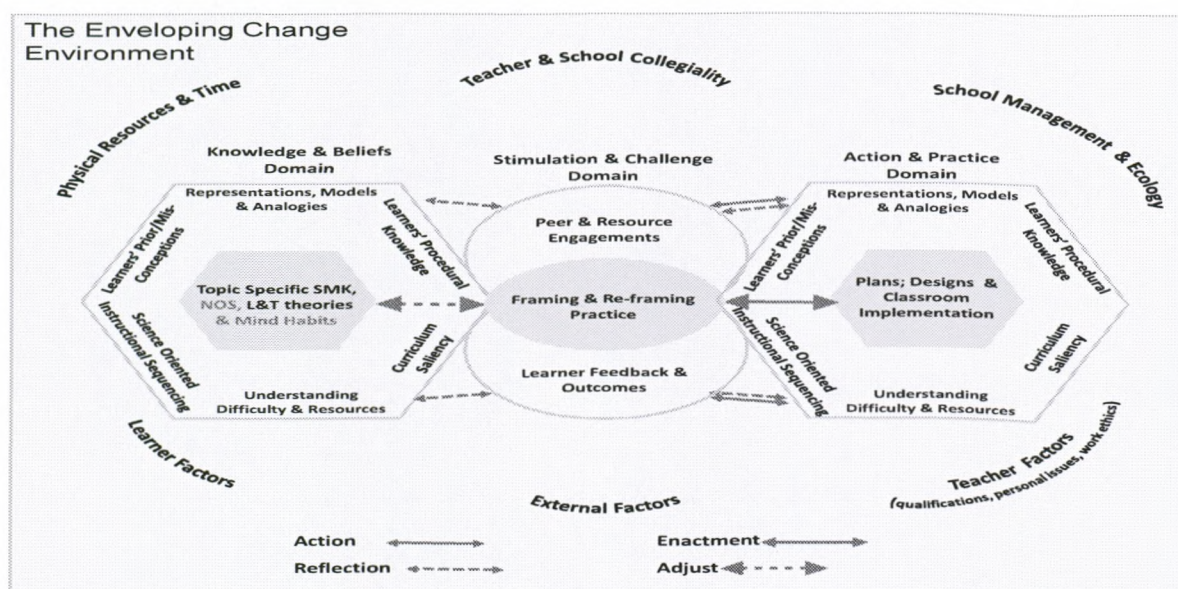


Figure 3.1: The Learning for Teaching through Participation (LTtP) model (Nakedi, 2014)

The framework consists of three domains that are interrelated. In brief, the first domain is about the knowledge, beliefs and attitudes that the teacher holds about the nature of science and subject matter knowledge. At the other end, there is the domain that concerns the application and actual practice of the teacher within the classroom environment. The stimulation and challenge domain which entails framing and reframing of practices as a result of interactions links the other two domains. Within the other two domains, shifts in my content knowledge (CK) is traced through the five aspects which serve as lenses to discern the teachers' topic specific PCK. These are Learners' Prior Conceptions/misconceptions (LPC), Learners' Procedural Knowledge (LPK), Curriculum Saliency (CS), Representations, Models and Analogies (RM&A) and Science Oriented Instructional Sequencing (SOIS).

In the background of all these aspects is the enveloping change environment that is critical in as far as providing support resources for the teaching and learning process during lessons. This environment would include contextual factors that could either enhance or constrain effective learning. Hence this model offers an opportunity to engage with the tenets of PCK both at planning and implementation stages. It provides a handy analytical framework that can be used to trace and document any teacher change behaviors that could be a product of some practical engagement with tasks and ultimately as evidence of teacher learning.

In this study any indicators or themes that were pointers to the aspects of LTtP model were used in order to address my research questions. Some of the ideas overlap amongst the aspects. For example, understanding of the difficulty of the content can be subsumed under curriculum saliency while resource availability could determine the kind of instruction that can be used in the classroom. The framework is broad in scope and thus can be used to analyze a wide range of aspects not only within the classroom environment but also the whole school environment to some extent. It can be seen that some of its tenets are drawn from the theory of curriculum implementation model proposed by Rogan and Grayson (2003) amongst others. This therefore allows this study to focus on what happens within classrooms and why it happens and at the same time allows any shifts in my practices to be identified. In the following paragraphs I describe some the aspects of PCK that were drawn from the LTtP model. It has to be noted that these aspects would depend on the topic that is taught and therefore are topic specific.

3.3.1 Curriculum saliency (CS)

Nakedi (2014) notes that curriculum saliency pertains to the teachers' knowledge about the sequencing of concepts underpinning a topic about which concepts are central and which are peripheral and how they are connected and related to each other as well as foundational and advance knowledge of the topic. This aspect embraces the notion of big ideas in a topic, their sequencing, the requisite pre-knowledge, why it is important to teach the topic and includes what the teachers should avoid dealing with at a particular point (Mavhunga & Rollnick, 2013). Kind (2015) sums up curriculum saliency as reflecting an understanding a teacher has of the place and value of a topic within the curriculum, which influences how and how long to spend teaching it. In essence curriculum saliency has to do with the teacher's ability to decipher the subtle critical features of a topic that may not be clearly visible. In order to be able to do this experience in practice and deep understanding of the subject matter may be critical. Having curriculum saliency in mind would thus allow logical sequencing of ideas, prevent pre mature exposition of some concepts and allow introduction of concepts at key stages of the lesson.

3.3.2 Learners' Prior Conceptions/Misconceptions (LPC)

These are the conceptions that learners bring into the science lessons based on the experiences before any form of instruction in a specific topic. Some of these conceptions may actually hinder the acquisition of science concepts while others may make it easy for learners to understand the science conceptions. Learners make their own constructs; have theories of how and why their constructs work. These constructs are part of the learners' experiential knowledge. Misconceptions, according to von Glaserfeld (1991) are those constructs or theories that may be considered to be incompatible with concepts and theories sanctioned by particular discipline or the teacher at the moment.

In dealing with misconceptions, there is a need to take cognizance of the fact that learning is a private mental activity that involve learners' themselves. Teachers should be aware of the pre instruction concepts that learners already have and understand how learners relate to these conceptions. This would enable the teacher to guide the learners to the required conceptions. Teachers should construct models that would make the process to discovering the desired knowledge more accessible to learners. It implies that learners should be aware of the new conceptions and how they fit into the desired conceptions. Von Glaserfeld (1991) highlights the need for conceptual dismantling before a new conceptual build up can begin. This means

that the underlying principle of these misconceptions should be clearly understood by both the teacher and learners before the required conception can be acquired. However, Nakedi (2014) highlights that what should be considered in this aspects is whether the plans that the teacher puts in place, the tasks the teacher selects or develops and the instructional strategies the teacher employs value and integrate the learners' prior conceptions and how these are developed. Thus in a way putting the learners at the centre of the teaching and learning process. Lesson plan activities and engaging learners in talk were used as indicators to consideration of this aspect in this study.

3.3.3 Learners' procedural knowledge (LPK)

Learners' procedural knowledge measures what students do to enhance their learning. The implication is that an educator should design lessons that engage students and varied opportunities for making predictions, estimations or hypotheses and designing ways to test them help students understand the nature of scientific inquiry. Through practice and reflection, students are able to apply these skills in new contexts and recognize their own thinking abilities. The teacher thinks about how the students will represent phenomena, which could be illustrated with a variety of abstractions (e.g. drawing graphs, making sketches, generating diagrams, and mind or concept maps). In essence this aspect constitutes the type of skills and knowledge inherent in how scientific knowledge is generated (Nakedi, 2014). In this study the procedural knowledge of learners was captured when learners made presentations on solutions to problems or findings based on practical activities or when responding to questions that had been posed.

3.3.4 Science Oriented Instructional Sequencing (SOIS)

This aspect relates to the use of science oriented teaching and learning strategies. It deals with the use of science instructional strategies that value and engage learners' prior knowledge as well as promote and capture the cognitive and social dimensions of how scientific knowledge is generated (Nakedi, 2014). A number of such strategies exist. They include conceptual change strategies, argumentation, open enquiry, demonstration, experimentation or practical activity, case studies and role playing amongst others. The use of each of these strategies will depend on the nature of the topic and contextual factors such as learners' ability or socio-cultural background, time constraints and resource availability. This study adopted practical activities (which are rarely used in stoichiometry teaching) subsumed in conceptual change strategy.

3.3.5 Representations, Models and Analogies (RMA)

Nakedi (2014) describes these as pertaining to the range and forms of subject and topic specific representations the teacher employs to package subject matter knowledge in ways that are comprehensible to the learners. They include analogies, examples, illustrations and demonstrations which have been proved to promote and enhance learning emanating from research or experience acquired by the teachers. They try to enable the learner to link the various kinds of worlds that exist in science such as the macroscopic, microscopic and the symbolic. Kind (2015) notes that these are particularly effective in revealing the subtle aspect of a content area; and they are especially useful in understanding phenomena that are not easily or directly observable. One other aspect that is of key importance, is that learners should clearly understand these representations and how they relate to the science concepts to avoid learners using these as substitutes for science conceptions in as much as they should understand how their conceptions relate to the science concepts.

3.4 Subject Matter Knowledge as central in TSPCK

It has to be noted that in order to engage in meaningful practice within a classroom the subject matter knowledge is critical. As can be seen from the LTtP model the subject matter knowledge lies at the core of the knowledge and beliefs domain and is critical in the planning, design and implementation of the activities in the classroom in the action and practice domain. I consider the subject matter knowledge to be one of the critical aspects that pertain to the teachers' PCK. Science subject matter knowledge relates to the knowledge of the science topic and whether the knowledge is deep enough to enable the teacher to be able to dissect and unpack the topic into big ideas (Nakedi, 2014). The big ideas are ideas that teachers see as crucial to students' understanding of a specific topic (Cooper, Loughran & Berry, 2012). Once the teachers have the skill of discerning the big ideas of a topic it enables them to construct what has been termed Content Representations (CoRes). The CoRes have become a powerful data collection tool for unpacking science teachers' PCK (Cooper et al, 2012). The use of the CoRes in this study is discussed later in section 4.6.1.

The LTtP model informs this study in that it is based on foundational principles of constructivism a theoretical perspective to learning on which this project is based. At the same time, it is a framework that incorporates the key components of PCK that can be adapted into a specific science topic. Over and above it incorporates reflection a key element in classroom discourse that is aimed at improving practice. It caters for the framing and

reframing of actions or thought processes during practice. This makes it possible to identify and trace any shifts in practice or knowledge that may characterize a particular learning context. This enables the model to be used as an analytical lens in any course of study that seeks to document any changes taking place as a result of some practice.

3.5 Self and lesson studies as a methodologies

With regards to using self-study as a methodology, Dinkelman (2003) suggests that self-study produces knowledge of two different sorts, both useful for promoting reflective teaching. In the first case, there is the knowledge produced by practitioners that helps them understand how better to approach problems in their own immediate contexts and teaching situations. In the second case, there is a more generalizable kind of knowledge that teacher educators in other settings can draw on and adapt to their own teacher education settings. In order to gain a deeper understanding of my practices it implied documenting not only the classroom practices but the kinds of planning that I engaged in prior to execution of the lesson. It meant that I reflect on my actions and decisions during practice. In respect of the second case mentioned above it emphasises the value of the knowledge produced in self study context in being useful to develop programs that can be used to support other teachers in similar contexts.

With regards to lesson study Lewis (2002) note that engagement in lesson study results in professional development of the teacher as teachers get feedback on their own teaching and new ideas gained from watching others teach. This is much similar to the self study methodology in that the knowledge gained in this way contributes to professional development. In addition Puchner & Taylor (2006) noted that lesson study has the potential to increase teachers' content knowledge. By engaging in lesson study it meant that the study allowed us as teachers to talk about certain topics such as what problems to use in the lesson, how to design lesson manipulatives, what questions to ask students at critical points during the lesson while teaching stoichiometry concepts. This suggests that I together with my colleagues were treading fertile ground for developing pedagogical content knowledge. The aforementioned topics of discussion are natural entry points for teachers to discuss how children think about content and the difficulties they have understanding it as well as to develop strategies to help children extend their thinking (Puchner & Taylor, 2006). This became relevant in as far as getting an understanding of how knowledge of my students and how they learn evolved during this study.

To capture a wide range of data it entailed that I use multiple data sources. These sources as highlighted in my methodological framework included reflective teaching journals, video recordings of lesson study meetings and enacted lesson, CoRes and TSPCK instruments and lesson artefacts such as lesson plans and learners written texts. The collection of data from multiple sources reinforces LaBoskey's fourth element in self-study which is that of employing multiple methods. This is also in agreement with PCK dispositions that to observe and document PCK, multiple data collection methods are needed (Park & Oliver, 2008). At the same time the triangulation of the data establishes trustworthiness.

3.6 Summary

In this chapter I have made an attempt to describe some key terms of this study such as conceptual framework and paradigm. I have highlighted how the theoretical frameworks to learning are used to guide and shape my study. Of significance is the Learning for Teaching through Participation (LTtP) model that is born out of these three theoretical constructs. It is a dynamic model that offers a wide scope that can be used to describe and scaffold teacher learning. Teacher learning entails in this study appropriation of requisite PCK within the mole concept. At the same time, it has to be noted that the LTtP is in essence a PCK construct in that it deals with attempts by teachers to make knowledge accessible to learners. I have made an attempt to show how some aspects of self-study relate to this study. Of huge significance is the use of multiple data sources that would allow triangulation and therefore afford trustworthiness. The data sources are drawn from the self-study and lesson study methodologies. In Chapter 4, I return to these concepts in an attempt to explain the methods that I used to collect and analyse the data.

CHAPTER 4

RESEARCH DESIGN AND METHODOLOGY

Introduction

Even though my study was part of a broader learning study, its specific aim was to engage in a self-study to develop my PCK with a focus on teaching the mole concept in stoichiometry to my grade 11 learners. As such, the broader study involved processes and generated data which given the scope and limitations of this present study, required a careful delineation to mark its boundaries. This then necessitated that I sift the relevant data from the sources that I used in order to address my research questions. Over and above as already mentioned in the earlier sections, self-studies require that multiple sources of data be used. The use of multiple data sources also served to address the aspects of validity and allowed for data triangulation during analysis. In this chapter, I discuss the remaining part of the methodology and the research design used in this study by describing and justifying the research tools that I used to collect data and how I went about with analysis. However, before I discuss these tools and procedures I describe some key terms in the following paragraphs.

4.1 The Research methodology

Henning, Rensburg & Smit (2010) describe research methodology as a coherent group of methods that complement one another and with “goodness of fit” to findings and the research questions. I conceptualize research methodology as the logic and logistics plan for doing research in the field. The plan embraces approach or paradigm that guide (logic) the choice and implementation of design, methods, instrument, data collection procedures and analysis (logistic). All this is done to present and report on valid findings. Different component elements that make up this design and methodological chapter are presented in the ensuing section. These elements and relationships are presented in figure 4.1 as a methodological process that I followed in this study.

The research methodology that is self-study is central and integrates the other aspects that are depicted in the schematic representation. The nature of the research questions and the nature of the study lend into this approach. Of critical importance is the research site that provides a context in which learning took place.

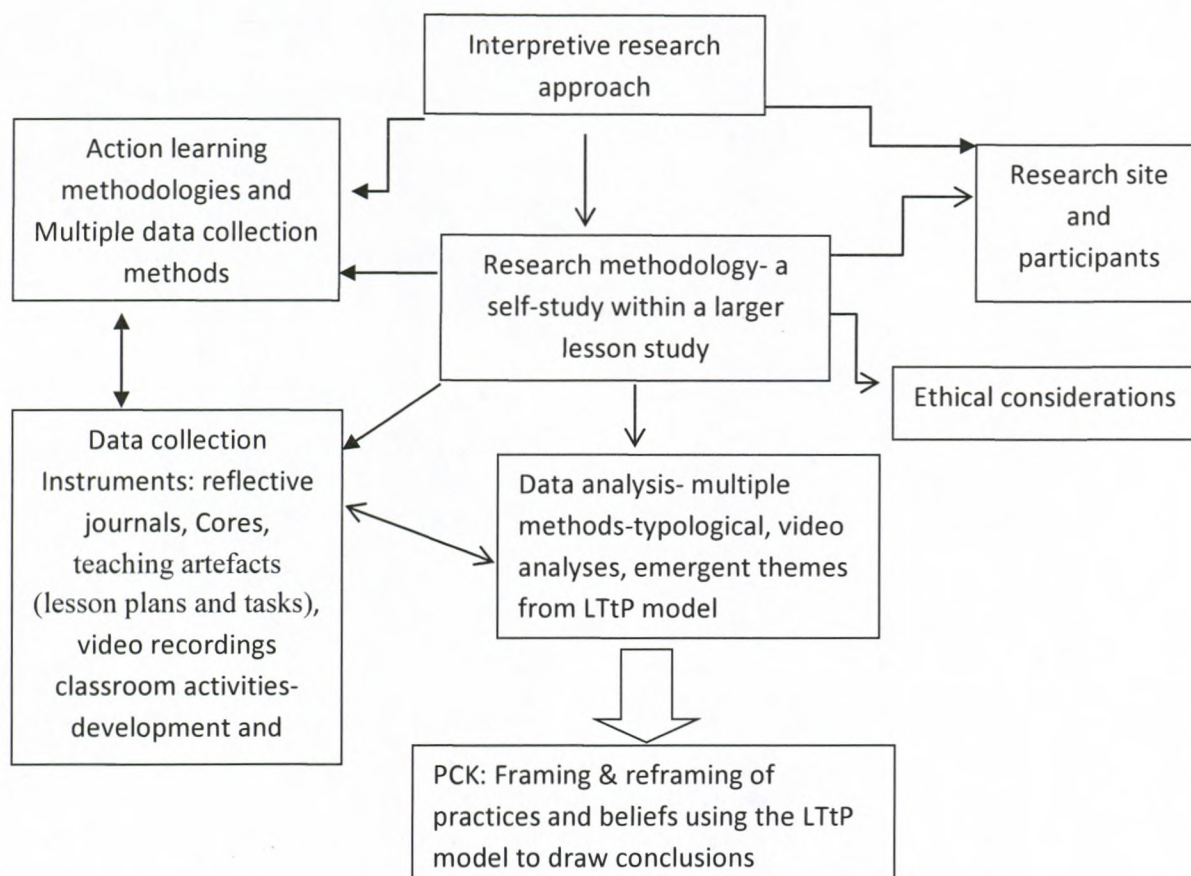


Figure 4.1: The research process that I followed

The research methodology adopted in this study is qualitative in nature. Qualitative research describes the depth, richness, and complexity inherent in the phenomena and involves putting pieces together to understand the whole (Burns & Grove, 2003). The qualitative approaches are based on the world view that there is no single reality, perceptions differ from person and over time and what is known has meaning only within a given context (Burns & Grove, 2003).

In this study I adopted a person-centered and holistic perspective to understand my own experiences and the impact thereof on the learning environment within the real classroom setting. Holloway (2005) notes that the original context of the experience is unique, and rich knowledge and insight can be generated in depth to present a lively picture of the participants' reality and social context. In essence the study used action learning methodologies which have their roots in action research design. Action research is a form of applied research where the researcher attempts to develop results or a solution that is of practical value to the people with whom the research is working, and at the same time developing theoretical knowledge (Elden & Chilson, 1993). Elden & Chisholm (1993) go on to note that action research is change oriented, seeking to introduce changes with positive

social values, the key focus of the practice being on a problem and its solution. This is quite relevant in this context as I sought to explore how my practices, design and implementation of activities within the classroom impact on learners' understanding of concepts and the general learning environment and in the process try to trace the development of my PCK within stoichiometry topic. An attempt was made to generate the knowledge in situ with regards to how activities were structured and how the content was articulated during enactment of the lesson.

A research approach has to do with ones' set of beliefs, about the way in which data about phenomena should be gathered, analyzed, used and nature of reality (Henning et al, 2010). In other words, it refers to the procedural framework within which the research should be conducted (Remenyi, Williams, Money & Swartz, 1998). It encompasses all the procedures that the researcher has to follow in the research study.

As already mentioned above literature presents two main approaches to doing research which are, qualitative and quantitative (Firestone, 1987). The quantitative approach emanates from the positivists' thinking of reality as stable and can be observed and described from an objective view point (Greenwood and Levin, 1998). This implies that observation is done without interfering with the phenomena being studied and that the observations about the phenomena should be repeatable. In my case it was difficult if not impossible to avoid interference with the happenings during my study. This interference was necessitated by nature of the study such as my desire to learn and possibly improve my practices for the benefit of myself and ultimately learners. At the same time the actions that I took were in response to the stimuli that emanated from the interactions or the context that obtained. By the same token it could be difficult to assume pre-set rules or goals or actions during discursive practices.

In contrast, the qualitative approach, here in this study referred to as interpretive embrace subjective interpretation of reality which leads to multiple realities (Galliers, 1992). The study of phenomena in their natural environment or setting is key to the interpretive approach (Rowlands, 2005). This is because the researcher wants to explore the phenomena and how it relates to the participants. The interpretive approach was adopted in this study based on the reason that I was studying a social phenomenon of learning which is subject to multiple interpretations. An interpretive approach was required for the purpose of the understanding of how I used the knowledge that I gathered during the study to enhance the development of my

PCK within stoichiometry concepts and ultimately the learning trajectory that I took as a science educator.

According to Afzal (2006) qualitative studies which have adopted participant observation (obtrusively or unobtrusively) result in deeper understanding of issues involved. Such methods tend to also explore various aspects that could be presented by the context in which the research is carried out in addition to information obtained from the participants. In terms of methodology interpretive research does not pre define dependent and independent variables, does not set out to test hypothesis, but aims to produce understanding of the phenomena and the process whereby the context and the phenomena influence each other (Rowlands, 2005). This applied to this study as I sought to explore my beliefs, teaching practices and learners' conceptions and then tailor made lesson activities to address the conceptions. I was the key participant in this study as such any obtrusions were as a result of my experience and augmented my professional growth and developmental learning.

In terms of methodology LaBoskey (2004) outlines five elements of self-study: it is self-initiated and focused; it is improvement-aimed; it is interactive; it includes multiple, mainly qualitative methods; and it defines validity as a process based on trustworthiness. With the focus on practice, the action of self in relation to other(s) reveals the professional identity and knowledge of the researcher (Hamilton et al, 2008). Perhaps this describes the "not one's self that is part or the description of self-study as given by LaBoskey (1998) in that there are significant others that may contribute to one's practices such as students and other educators. In this regard identity is viewed as a person's sense of self, as socially constructed within social settings (Spillane, 2010). Hamilton et al, (2008) note that the interaction may be the most important element to self-study because it incorporates reflection. The reflection element is dealt with later in section 4.2.

Some researchers have identified other features of self-study and collaboration is one of them. Collaboration is much similar to Laboskey's (1998) interactive element of self-study. In self-study research, collaboration has been emphasized as an important and integral component (Sandretto, 2009). To incorporate this aspect, I decided to participate in lesson study with other educators and experienced subject specialists. The aim was to get exposed to different perspectives that would help augment my beliefs and practices as an educator. One of the main challenges of self-study is to go beyond one's own perspectives and taken-for-granted assumptions to look at and understand practice in new ways (Loughran, 2007). At the

same time, Sandretto (2009) notes that, collaboration does not guarantee that this will occur, although the potential for it may increase.

Henceforth self-study approaches have not been without controversies. Despite the best intentions of those involved in self-study, one apparent difficulty is implicit in the terminology self-study. The term self-study carries a tacit message that suggests the involvement of only an individual and hence the exclusion of others in the study of one's self. However, Loughran and Northfield (1998) asserted that self-study inevitably requires involvement of others so that the learning outcomes are much more than personal constructions of meaning and that self-study must go beyond personal reflections of practice. In this study, experienced educators and experts in the chemistry education field were the 'critical friends' who helped shape my PCK through collaborative discussions as I reflected on my personal practices.

4.2 Reflection as a disposition of self-study

Reflection is one of the critical dispositions of self-study. During reflection teachers systematically and critically examine their actions and the context of those actions as a way of developing a more consciously-driven mode of professional activity (Samaras, 2002). The implication is that teachers deliberately engage in well thought out practices and reflect on their actions in order to improve the teaching and learning environment. This is in sharp contrast to practices that are based on habit or tradition that characterize most teaching and learning environments. Thus reflection will take place when individuals study their own practices or during discursive meetings with other colleagues. One aspect of contestation that has emerged is the definition of reflection. One issue that may be the cause of the contestation could be the authenticity of what is reflected upon and the processes of this reflection such as the need for training or probing in order to develop reflective thinking. Other authors have suggested *reflecting on* and *reflecting in* practice.

Van Manem (1977) defines reflection as the process by which teachers engage in aspects of critical thinking such as careful deliberation and analysis, making choices, and reaching decisions about a course of action related to teaching. On the other hand Ross (1989) defines reflection as a way of thinking about educational matter that involves the ability to make rational choices and to assume responsibility for their choices. It can be gleaned from these definitions that reflection is a complex phenomenon that involves thinking about some educational practices and taking action in order to improve the situation. I believe the merits

of the reflective practice outweigh the complex nature of reflection as actions taken are more likely to lead to improvement.

In this study reflection formed a key component in the design, implementation and analysis of the data. A study conducted in Egypt showed that more than 50% of prospective teachers who participated in their project fell at either low or medium level of reflection (El-Dib, 2007). The results suggest that prospective teachers in Egypt were unaware of neither multiple reasons for problems nor their motives for performing certain actions and not others, unaware of the consequences of their actions (El-Dib, 2007). However, I believe that the situation could be different to practicing experienced teachers who may have deeper understanding of the subject matter and their learners. Thus the importance of reflection cannot be over emphasized if educational goals are to be met. The reflection allowed for a deeper understanding of teaching, learning and of learners themselves.

My reflective capability was bolstered by the ideas that came from the colleagues and subject specialists during colloquial meetings of the lesson study group. This reflection happened in a variety of ways including journaling, conversations with colleagues, and thinking deeply about a teaching problem to search for solutions and even using experiences that I had gained from my professional development courses. This reflection can be shared with other members in social settings for the improvement of practice.

At the same time video analysis of one's teaching should add value to reflecting ability. A study conducted by Rosaen et al. (2008) confirmed that video is an effective medium for learning from teaching. The experience of viewing video recordings of their own teaching practice seemed to enhance mentees' self-reflection, confirming Kong's (2010) research that concluded that teachers made a greater quantity of reflective comments when they viewed video of their teaching practice. More recent research included in Schneider and Plasman's (2011) review echoes the trajectory in that overall, teacher thinking appears to progress first to thinking about learners, then to thinking about teaching, and finally to building (McNally, 2014). To sum up (Kleinsasser, 2000) points out that reflection plays a vital role in both practice and research process and has improvement of practice as its goal.

To engage in the process of learning I sought to use the LTtP model to help guide the process. The sampling method and reasons for the choice of the specific method of sampling are discussed in the next section.

4.3 Participant and Sampling Technique

This project being a self-study, I was the main participant in that I intended to focus on the development of my PCK and henceforth my practices and the reflections thereof became paramount. As already mentioned in the motivation behind pursuing this study that I had observed discrepancy between my beliefs about science teaching and learning and my actual practice inside my classrooms it meant that I engage in introspection and study my own practices in an attempt to bridge the existing gap. The need to interrogate my practices occasioned the involvement of learners in this project within a classroom set up. In order to capture learners' ideas and be in a position to trace my PCK it meant that I should teach those learners stoichiometry topics within a classroom context.

In order to enrich my learning environment in terms of knowledge I had to be part of a lesson study group comprising four experts in the chemistry education field at Wits University and two other peer educators. The inclusion of these peers and experts provided an opportunity to subject my practices (lesson) for critique within a collaborative forum during lesson study meetings. The presence of other peer educators allowed me an opportunity to learn from their practices and also share experiences such as how to approach or teach stoichiometry concepts. Self-study methodology demands that collected data be subjected to public scrutiny for validation purposes; hence the critical friends in the lesson study meetings had a significant role in this regard.

The convenience sampling, also called opportunity sampling method was used in this research project. In this type of sampling the researcher targets individuals who are easily accessible and requests these individuals to serve as participants. Invitation to participate in the study was extended to all grade 11 learners in an attempt to avoid exclusion and to attract diverse learners for a rich classroom environment. However, only 20 learners drawn across all the grade 11 classes in the school availed themselves to participate in the study. Working with a smaller group enabled effective interaction amongst the participants and the data analysis was effectively done. I taught only one grade 11 class out of the four classes in the school. The research was conducted towards the end of the third term when most learners were preparing for their end of term examinations. This was determined by some factors beyond my control such as the project being a self-study integrated with the broader lesson study and that some of the planning and preparation were done collectively within the lesson study group.

4.4 Data collection process

Even though limited in scope, my study aimed at tracing the shifts I made in my practice through mediating processes of action, reflection to frame and re-frame my practice within a collaborative process of learning study (Nakedi, 2014). To capture the limited shifts that I made in my practice during the research process, I used the LTtP framework, to organize present and analyze my data into three cyclic phases which are the pre-intervention, the planning and the classroom implementation phases. The LTtP *knowledge and beliefs* domain talked to the pre-intervention phase of the study while the challenge and stimulation domain, represented all the activities and interactions with peers and experts during lesson study preparations, planning and reflection phases and the third phase which represented the action and practice domain of the LTtP comprised the classroom implementation phase.

The general outline of this process and a description of the process indicate that data was collected at various stages during the study. Pre-intervention phase included tools such as lesson plan (LsP1), learners' written text and reflective journal (RFJ1). From these artifacts my knowledge and beliefs about how science knowledge should be made accessible to learners were captured. The planning and reflection phases included the development of CoRes, lesson plan (LsP2) and completion of a TSPCK tool as an individual and in collaborative meetings within the lesson study group that afforded me with the *stimulation and challenge domain* in the LTtP model. The third phase was the classroom implementation stage which focused on the *action and practice domain* in the LTtP model. In this stage video recording was done to capture utterances and behaviors during the lesson. The framing and reframing of beliefs and practices was done between stages and within a particular stage such as during the enactment of the lesson. In collecting my data, I had to engage with the research questions that enabled me to gather and make sense of the data that I had collected.

4.5 Data collection methods and tools

This study employed a variety of qualitative data collection techniques such as reflective journaling, videotape recordings, teaching and learning artifacts such as CoRes, the TSPCK tool and lesson plans. The table that follows shows the stages at which the data was collected and the tools that were used at the specific stage.

Stage	Data collection tool
Pre-intervention phase	• Reflective journal RFJ1, Lesson plan LsP1, Learners' written text LWT1
Planning and reflection	• CoRe, Lesson plan Lsp2, Lesson study meeting transcription LsM1, TSPCK tool, Reflective journal RFJ2, Learners written text LWT2
Classroom implementation	• Video lesson transcriptions VLT and Video analysis template VAS

Table 4.1: Stages and tools used to collect the data.

It has to be noted that some of the tools overlapped between stages depending on the context and type of the data that was collected for instance reframing of ideas during the planning and implementation action stage or lesson enactment and the interactions were later captured in the reflective journal in the post stage hence the video tape recordings were used to collect data at the two stages. The following table shows the sources that were used to collect data to address specific research questions.

Research Question	Research Sources
Main research question: How is my content knowledge for teaching stoichiometry to my grade 11 learners evolving as I engage in a self-study within the learning study?	CoRe, the reflective journal, video recordings ; teaching artefacts (lesson plans and tasks) and the TSPCK tool
Research question 1: How is my knowledge of learners and how they learn, specific to the topic of stoichiometry shifting, as I participate in self-study?	CoRe, the reflective journal, video recordings; teaching artefacts (lesson plans and tasks).
Research question 2: How was my knowledge of creating effective learning environments shifting as I participated in this study?	the reflective journals, video lesson transcriptions, teaching artefacts (lesson plans and tasks)
Research question 3: How were my metacognitive skills of planning, reflecting and enacting in my own and my learners' learning affected as I participated in the self study process?	CoRe, the reflective journal, video recordings of lessons; teaching artefacts (lesson plans and tasks) and the TSPCK tool

Table 4.2: Data sources and research questions

The table shows that data was collected across all my sources to address my research questions. In the following section I describe how to document PCK and the design of the data collection tools and how data analysis was done to address the research questions of the study.

4.6 Documenting PCK

There are several ways to document PCK (Baxter & Lederman, 1999 and Loughran, Mulhall, & Berry, 2004). One of such ways is that propounded by Loughran, Mulhall, and Berry (2004). This Loughran et al.'s (2004) scheme of CoRe (content representation) has been used in many studies due to successful previous experiences (Garritz, Porro, Rembado, & Trinidad, 2007; Padilla; Garritz & Velázquez, 2009). Loughran et al. (2004) used the term “central concepts or ideas” to mean those concepts that are at the core of understanding and teaching the topic; those that belong to the disciplinary knowledge which are usually used by the teacher to split the teaching topic. In this study the CoRe was used as a planning and data collection tool. In the following section I deal with the design of the data collection tools and later I focus on the analysis of data that was done in respect of each tool.

4.6.1 CoRe as planning and data collection tool

CoRes have been used in a variety of ways in the education field such as their adoption by teachers as an approach to curriculum planning, both as data collection tool as well as a developmental activity within a department when planning a unit of work. The CoRe has also proved to be a powerful tool in introducing pre-service teachers to PCK to begin to develop their PCK (Cooper, Loughran & Berry, 2015). In this study the CoRe was used as a data collection tool and also to some extent as a tool for lesson planning and a representational product (Cooper et al, 2015). The value of the CoRes as data collection tool has been noted to assist better access and exploration of teachers' thinking about their practices as well as a vehicle for concretizing issues, ideas and reasoning in action.

The structure of the CoRe is varied, depending on the role for which the CoRe is designed. However, in whatever form, CoRes should highlight the importance of thinking about science topic through Big Ideas, attention on the role of content in a new and different way for teachers (Cooper, et al, 2015). The structure of the CoRe used in this study included the following as subheadings: big idea, curriculum saliency, what makes the topic easy or difficult to understand and teaching strategies among others. The CoRe highlights that the development of PCK is not about content knowledge as information but about conceptual understanding of the content for teaching (Cooper, et al, 2015). This implies that the CoRe should show how a particular concept can be taught to the learners through appropriate concept sequencing and design of strategies that could address the content as well as the conceptions that learners may have about a specific concept. There is need to shift from the

perspective of seeing teaching as the simple delivery of content to thinking about teaching that uses CoRes, to unpack the topics for the benefit of the learners. It causes the teachers to think differently about what they are doing, how, and why, in teaching a specific science topic. It allows the teachers to consider their learners and their context when planning and teaching a specific topic.

As already stated earlier, the CoRe has varied uses in research studies but in whatever use, it has been found that the process of developing a CoRe challenges teachers' thinking (Cooper, et al, 2015). Studies consistently reveal that individually, teachers often struggle to construct big ideas and to answer the prompts of the CoRe (Cooper, et al, 2015). This could be due to various factors such as lack of exposure to the PCK construct during teacher training and professional development programs or failure to support teachers once they have been introduced to this concept. This situation could be worsened by the isolated environments where science teachers find themselves working. In this study CoRe development was done with the help of other researchers and colleagues in the lesson study group meeting.

PCK is described as a tacit form of teacher professional knowledge that is often topic specific, personal and content specific (Cooper, et al, 2015). The implication is that PCK is a highly complex construct that is difficult to document and assess. In order to "capture" PCK, it requires a combination of approaches which can invariably portray a teacher's beliefs about what they know, what beliefs they hold, what they do together with their justification for doing what they do (Baxter & Lederman, 1999). In spite of these challenges, Kind (2009) believes that the CoRe as a tool offers the most useful technique devised to date in science education research for eliciting and recording the PCK from teachers directly. In order to augment the CoRe instrument in the capture of PCK, Loughran et al (2006) designed another instrument called Pedagogical and Professional-experiences Repertoires (PaP-eRs). However, this instrument was not used in this study because I did not use narrative analysis as a method.

This study sought to explore how my PCK was evolving, hence I chose to use the CoRe to explore my knowledge base for teaching the mole concept and how that shifted as I participated in this study, as this tool is the most widely used instrument for PCK related purposes (Lehanea & Bertramb, 2015). The use of this tool exposes the study design to validation and rigor. The CoRe not only helps capture the teachers' PCK but can also be seen as a way of portraying this knowledge to others (Lehanea & Bertramb, 2015). This becomes

relevant in this study where I was involved in actual practice. The tool offers a topic specific orientation as opposed to a general PCK representation (Lee & Luft, 2008). In this study topic specific PCK related to the stoichiometry topics was explored. The teachers' PCK can be detected through such things as content specific teaching procedures, e.g. laboratory work, observations, questionnaires and discussions. At the same time the CoRe is a research tool that I used for accessing science my understanding of the content as well as a way of representing this knowledge (Loughran et al, 2006) during practice and reflection. All these attributes about the CoRe make the instrument to be relevant and therefore justifiable to be used in this study. Teaching strategies such as demonstrations, practical work, discussions, conceptual changes strategies, consideration of the learners' needs and how subject matter knowledge was represented were critical in this study as they indicated the extent to which PCK was articulated.

4.7 Teaching and learning artefacts: Lesson plans and learners' written texts

Lesson plans are documents that provide teachers with an instructional sequence that guides a learning experience for students (Bybee, Taylor, Gardner, Scotter, Powell, Westbrook, & Landes, 2006). According to Fourie (1991) a lesson plan outlines what the teacher wants to achieve with learners in a given period; how he or she wishes to do this (teaching method); how he or she plans to involve the learners and which teaching and learning media he proposes to use in the lesson. Fourie (1991) further explains that a lesson plan indicates what has already been done and also in what direction the learners should be guided as well as what work is to be taken up immediately. In essence it indicates the activities in which the participants become actively engaged in an attempt to learn specific concepts. The unit of analysis in the study was my learning as an individual from the planning stage, during the lesson enactment and in lesson study meetings.

Even though a single lesson was used in the study, Hiebert & Grouws (2007) argue that a lesson has the advantage of being large enough to include key interactions among teaching features and small enough to be thoroughly analyzable. The learning environment was extended to include the lesson study group context. I saw it fit to conflate the data obtained from the different sources so as to address specific issues. This implied that data from the multiple sources are then converged in the analysis process rather than handled individually.

This convergence adds strength to the findings as the various strands of data are braided together to promote a greater understanding of the case.

The CoRes was not only useful in the planning but also in the implementation of the lesson and reflection stages. Hence there was need in this study to consider teaching and learning artifacts such as lesson plans and learners written texts. In fact, when lesson plans are designed they should inevitably reflect the CoRes for the specific topic and in turn the learners' written text should give an indication of the planning that was done. In other words key concepts of teaching topic should be reflected across all these artifacts. At the same time the learners' procedural knowledge can be reflected in the learners' written text. Based on the focus of the study I saw it imperative to consider my planning before and after enactment of the lesson in order to identify any possible changes. Hence I had to engage the use of lesson plans and learner written texts. This study used multiple data analysis to corroborate and triangulate data sources in order to enhance and ensure proper response to issues of credibility and trustworthiness of the findings.

4.7.1 Design of Lesson plans

Two lesson plans were used in this study. The first lesson is the one that I used in my previous lesson when I taught the mole concept prior to engaging in self study project. I intended to use this lesson plan as a reference from which comparisons on various aspects such as content depth and meta-cognitive skills could be drawn. The lesson plan addressed the key concepts as prescribed in the physical sciences work schedule as demanded by the district. It resembled the lesson plans that I have used in my previous lessons.

The other lesson plan was designed collectively as a lesson study group but I re-worked it and included those aspects that I thought facilitated learning and catered for the context not only for my study but also for my learners. In re-working this lesson plan I used the CoRe as the guideline. At the same time the design of the lesson plan was subjected to lesson study group deliberations before enactment.

4.7.2 Learners' written texts

I extracted the texts from the activities that I had given to the learners prior to engagement with this study. The inclusion of this was to capture the knowledge or content that my learners had been exposed to before my engagement with the study and therefore try to get a picture of the kind of teaching practices and learning environment that obtained at that stage.

I also included a concept map that was presented by some learners during lesson enactment. In addition I focused on the written class activity that my learners wrote during the lesson enactment. In particular I focused on the content of the activities.

4.8 The TSPCK tool

Before engaging in the project I completed a stoichiometry topic specific pedagogical content knowledge (TSPCK) tool that was designed by one of the experts in the lesson study group who was also conducting his research on the lesson study towards his PhD studies.

The TSPCK tool consisted of two items based on learners' prior knowledge and misconceptions, three items based on curriculum saliency, and one item each for what makes the topic difficult to teach, representations and teaching strategies. I responded to these test items within a specified period of time and used knowledge gained from my teaching experience and interactions within the lesson study group.

Although the TSPCK tool is beyond the scope of the LTtP model, it comprises some of the aspects that are inherent in the LTtP model such as curriculum saliency and representations among others. This data collection tool was useful as a means on how to measure and document the development of my TSPCK as such it had a direct bearing on myself study as an indicator for the shifts or development of my PCK within stoichiometry topic. The pre and post stages allowed any possible shifts to take place as a result of the peer engagements in the *stimulation and challenge domain*. In addition it helped in the triangulation of my data with other data sources. The fact that another person was involved in the assessment of my performance it ensured that the aspect of validity of findings was catered for to some extent.

4.9 Reflective Journal

Journal writing can be done for many purposes such as personal reflection, facilitating collaboration and discussion as in lesson study meetings. In this study I used journal writing for personal reflection as I was faced with a challenge of understanding PCK to reflect on my teaching beyond the re-call of classroom activities. I needed to have a deeper understanding into my own priorities for student learning and how I would facilitate or support these priorities. I compiled two reflective journals. One journal (appendix 3, RFJ1) was compiled before engaging in the self-study project while the other journal (appendix 4, RFJ2) was compiled after the lesson study meeting when the lesson that I had taught had been subjected to comments and critique by the lesson study group members. The journal comprised varied

topics ranging from what happened, what I learnt from the experiences and reflections based on student learning and my teaching.

Baxter & Jack (2008) note that the problem of bias in qualitative research particularly is still debated in methodology texts and there is a lack of agreement on how much researcher influence is acceptable, whether or not it needs to be "controlled", and how it might be accounted for. This is what Denzin (1994) refers to as the interpretive crisis. In this study I chose to make my experiences, thoughts, and feelings visible (an action that most people would not wish to do). In doing this, my attempt was to make these an acknowledged part of the research process through keeping reflective journals and using them as data collection tools to write up my project. The main aim of this project was to study the development of my PCK as I taught the mole concept. To be able to identify any shifts there was need for critical reflection. Hence there was need to use reflective journals in order to capture the PCK attributes and the kind of learning environment that obtained at appropriate stages of my learning.

4.10 Video-tape recordings

Video has become a widely used tool in teacher education and teacher learning (Brophy, 2004). Teachers may observe video recordings of either their own teaching (Roth, 2009); or the teaching of others (Seago, 2004). The video material may consist of "edited" selections of classroom sequences (van Es, 2009) or "raw" data from classroom lessons and units (Stigler & Staley, 2002). In this study the enacted lesson and lesson study meetings were video recorded. However during analysis I used the two differently. For the enacted lesson I made transcriptions of the selected video sections while for the meetings I used transcriptions that had been done by experts. In the following section I deal to a greater with how video recordings were done in this study.

4.10.1 Video-tape recordings of the lesson

I needed to study my practices and make reflections on my teaching. In order to achieve this, the lesson on the mole concept had to be video recorded. I wanted to produce reliable data that could be used by other researchers in the lesson study group so I had to choose video recording. The analysis could also be done repeatedly thus allowing for deeper thinking of the practices. It was necessary to capture the different episodes of the lesson such as the demonstrations and the explanations that I made including contributions and presentations

from the learners as a way of getting feedback on my practices. I had planned that the lesson would comprise two sessions of one hour each. However, due to a number of activities such as practical activities, demonstration, group presentations and the fact that the learners were not used to manipulating materials themselves the lesson took much longer than initially planned. However, I turned this to my advantage so that I could capture as much data as possible in order to cater for the needs of my study.

As I could not teach and record at the same time, one of the experts in the lesson study group had to video tape the lesson while I taught. At the same time this expert had an interest in the lesson as it was relevant to his research thesis. He operated a camera to record the lesson and most of the time it was directed towards me as I was the main focus of the study. The use of a camera and the presence of another researcher could be obtrusive. However, using the experience that I have in the classroom and my open relationship with learners I tried to minimize the effect of the presence of the camera by encouraging them to behave normally and not deviate from the norms and expectations of teaching and learning process. At the same time the camera man being an expert in chemistry offered some help to learners when they were engaged in group activity and this could have benefited the learners themselves. Based on the video I produced two accompanying secondary data sources, the video analysis tool (appendix 13, VAS) and video transcription of the lesson (appendix 12, VLT).

4.10.2 Video tape recordings of lesson study group meetings

This study being a self-study located within a larger lesson study project it implied that I attend lesson study meetings in order to share and gain ideas on the various aspects of teaching and learning stoichiometry. The choice of this method is based on the fact that the nature of my study required that my methods be subjected to public scrutiny for rigor and validation purposes. At the same time I noted that the lesson study offered another rich environment where learning took place in addition to the classroom. As I was involved in self-study I took it upon myself to explore each and every opportunity to learning that presented itself. Thus I got feedback on my enacted lesson and at the same time I learnt some key aspects from this group.

As such these meetings had to be video recorded in order to capture my interactions and the trajectory of my learning that took place. A camera was placed in front of the whole group so that every member was focused. At the end of each session the video recordings were transcribed verbatim by experts. I selected videos and the corresponding transcriptions that

were based on the meetings before enacting the lesson and a few after I had implemented the lesson. By comparing and contrasting the two I anticipated that any shifts or none of them in terms of my learning would be evident.

Having described the data collection methods and design of tools, I now describe how the data was analyzed in the following section. One danger associated with the analysis phase is that each data source would be treated independently and the findings reported separately. In this study most of the categories cut across most of the data sources and therefore I sought to gain a holistic picture from all the sources by engaging firstly in analysis of each instrument independently and then focused on the emergence of these aspects across all the data sources. It however has to be noted that each tool had its limitations in this study in the sense that not all aspects were evident in a particular tool. For instance, the TSPCK tool could not capture directly the extent to which the communication in the classroom was to be addressed. In fact, inputs from learners could not be captured hence learner understanding of concepts could not be assessed including their procedural knowledge. In addition learners' written texts did not indicate the kind of the learning environment that obtained unlike the video tape recordings that showed the kind of the learning environment.

4.11 Data Analysis

This study involved qualitative data analysis as already highlighted in section 4.1 of the research methodology. Qualitative data analysis is a search for general statements and about relationship of categories of data (Marshall & Rossman, 1999). In addition, De Vos (2002) defines data analysis as a process of bringing order, structure and meaning to the mass of collected data. According to Patton (2005), qualitative analysis transforms data into findings. The analysis involves reducing the volume of raw information, sifting significance from seemingly unimportant details, identifying significant patterns and constructing a framework for communicating the essence of what the data reveal.

Typological data analysis was used in this study. Typological data analysis is a strategy for descriptive qualitative (or quantitative) data analysis whose goal is the development of a set of related but distinct categories within phenomena (Sewada, Piburn, Judson, Turley, Falconer, Benford, & Bloom, 2002). All my data sources were subjected to the categories that I identified from the LTtP analytical framework. These categories included Learners' Prior Conceptions/Misconceptions (LPC), Learners' Procedural Knowledge (LPK), Curriculum Saliency (CS), Representations, Models and Analogies (RM&A) and Science Oriented

Instruction Sequencing (SOIS). This study therefore used pre- determined categories. I adopted the same abbreviations of the categories in the LTtP model (Figure 3.1) as my codes. According to Marshall & Rossman (1999), coding data is the formal representation of analytic thinking.

Coding is used to select and emphasize the information that is important enough to record, enabling the researcher to weed out extremes of information and focus on the type of information needed for the study (Demunck & Sobo, 1998). Abbreviation of keywords was also used as a form of codes. I shared these categories with my supervisor before engaging with in depth analysis for validation purposes. The categories were color coded when they emerged from the data sources as shown in Table 4.3.

Category	Code	Color
Learners' Prior Conceptions/Misconceptions	LPC	green
Learners' Procedural Knowledge	LPK	yellow
Curriculum Saliency	CS	black
Representations, Models and Analogies	RMA	red
Science Oriented Instruction Sequencing	SOIS	Purple

Table 4.3: Categories and assigned codes for PCK aspects

In addition I saw it fit to identify the domains in which the categories were reflected in the LTtP model. The design of my data collection tools was varied in the same way as the number of the sources that I employed in this study. It therefore meant that I subject any of the sections on my tools to these categories. Before I could subject my sources to these categories I needed to ensure that I transcribe video recordings of the enacted lesson and have them in print form in order to allow for identification of the categories during analysis.

With regards to video recorded lessons I watched and listened to my video recorded lesson several times before engaging formally with the process of data analysis. Although at this stage I had not begun the formal process of data analysis I had keen interest in observing my actions and language in practice as this was my first lesson in which I saw myself in practice in the many years that I have been an educator. This then gave me the drive to move on to the real stage of data analysis. I chose to, then watch and listen to the video of the lesson in three segments to begin the process of data analysis. In the first segment I watched and listened for

the first time in order to gain a general sense of how the lesson had progressed with regards to the interactions and my practices.

In the second phase I watched and listened to the video in an attempt to identify some episodes that had some relevance to the categories that I had identified from the LTtP model. In this way I was starting the process of data reduction in order to focus on the key aspects that this project meant to address. At this stage I completed the video analysis template (VAS, appendix 13) that I obtained from the lesson study meeting thus to some extent contributing to some research rigor. In the third segment I watched the video for the third time, at this stage I selected parts of the video lesson in which the different categories in which the PCK surfaced. I then transcribed these parts of the video of the lesson (VLT, appendix 12) in order to capture the communication and interactions during the lesson and to augment the video analysis template.

I decided to organize my data collection in three phases namely: pre-intervention, planning and reflection and classroom implementation stages. This allowed me to synchronise data analysis with the three domains of *knowledge and beliefs*, *stimulation and challenge* and *action and practice* that make up the LTtP model. I then subjected these video analysis templates and the lesson transcriptions to the categories that I identified from the LTtP model, in the same way that I treated my other data sources. I systematically analyzed my data sources namely; teaching and learning artefacts i.e. learner written texts and lesson plans, the TSPCK tool, the CoRes, Reflective Journals, lesson study meetings and lesson transcriptions of my teaching using the five PCK aspects that were drawn from the LTtP model. I focused on key sections of each data tool in which engagement with these aspects was evident.

This study had a focus on the development of my PCK within the lesson study; it therefore became apparent that I consider the shifts that occurred at different stages. The teaching and learning environment is characterised by engagement with such PCK aspects it therefore implies that these aspects had a direct bearing on learning environment and metacognitive skills.

The manner in which these aspects were interrogated had strong bearing on the learning environment in the classroom that obtained while enacting the lesson in terms of interactions that took place. At the same time the manner in which I planned, implemented and reflected on my practices indicated how my metacognitive skills evolved as I participated in this self-

study. In essence the creation of learning environments and utilization of metacognitive skills are subsumed within the PCK aspects.

The structure and orientations towards teacher or learner centeredness, and the content thereof were exhibited in the teaching and learning artifacts. This was reflective of the *knowledge and beliefs* domain in the LTtP model. At the same time ideas surfaced during the enactment of the lesson which is located in the *action and practice domain*. Learners' utterances such as comments and answers made it possible to gauge their level of understanding and how best ideas could have been explained to them including what appropriate actions could have been undertaken to help them access the science concepts during my reflections. Collaborative sessions during lesson study meetings provided insights into how I had fared during the lesson enactment and this bolstered my knowledge about the key aspects of PCK. These aspects are embedded in the *stimulation and challenge* domain of the LTtP model.

Some data sources enabled me to compare my pre and post engagement with the PCK aspects. Using the constant comparison method of data analysis (Glaser & Straus, 1967) incidents or data are compared to other incidents or data during the process of coding. This was done on the two reflective journals that had been compiled prior and post engagement with the study, learners' written texts, and lesson plans. This approach enabled me to compare my engagement with the aspects before and after partaking in the self-study. This served to identify any development of my PCK that took place.

In addition to these aspects I also identified the context or the stage in which they were evident I analyzed these aspects and their relationship to my learning and learner understanding of concepts.

After having subjected my data sources to the categories of the LTtP model I then sought to come up with a holistic narrative of the development of my PCK with regards to stoichiometry teaching. I then traced each PCK aspects that I selected through the three stages at which the data was collected such as pre-intervention, planning and reflection and classroom implementation stages. I considered each PCK aspect at a time and subjected each of my data source to this category and colour coded accordingly. I systematically analyzed each data sources for the each category to identify any shifts in the way I engaged with the specific PCK aspect between stages. I then selected those sources that showed significant changes and reported my findings based on those sources. Findings were then drawn from the

results across a range of sources in an attempt to indicate any shifts that occurred during the self-study. The schematic representation that follows shows an example of how I traced learners' prior conceptions during the analysis using the LTtP analytical framework.

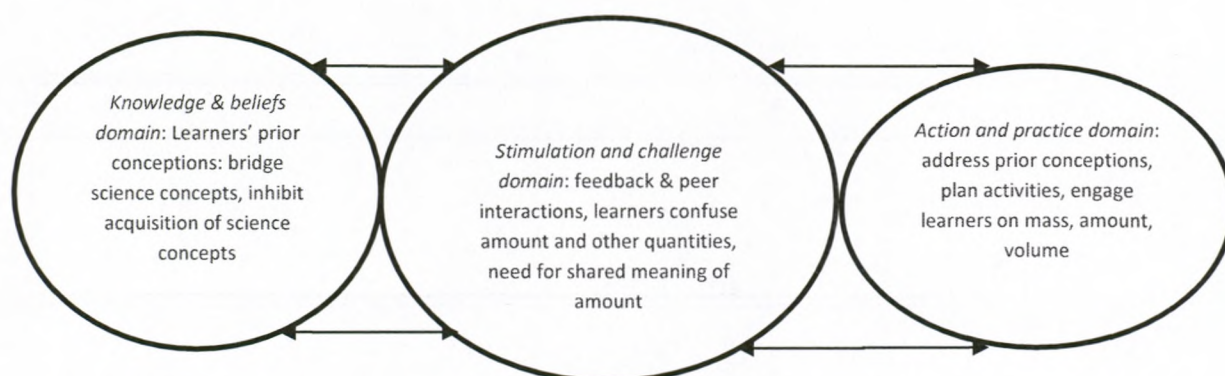


Figure 4.3: Analysis of learners' prior conception using the LTtP analytical model

The arrows indicate the links between the various sections in order to show that one domain informs the other as well as the need to reframe some thoughts or actions.

Since these categories were also indicators to my metacognitive skills and the attempt to create positive learning environments I had to broaden the scope of the analysis by not just focusing on the presence of these but also on how I engaged with them. In essence I had to make some inferences from the categories that played out in the data source. In making these inferences I focused on the structure of the tool and the content thereof. In this way I was able to identify not only the PCK aspects that played out but also how I utilized these for my own learning and that of my students. An extract (data analysis template, appendix 14) of the descriptions of these categories and the findings is shown in the following table.

PCK categories	Data Collection Tool	Descriptions	Findings
Learners' Prior Conceptions/misconceptions (LPC)	• CoRes • Lesson plan (LP2) • Lesson plan (LP1) • TSPCK tool • Video analysis and transcriptions • Reflective journal (RFJ1 and RFJ2)	• Engaged/non engagement with LPCs reflected in the tool • Learners engaged in activities that illustrate engagement with LPCs	• Learners had their own understanding of the science terms i.e. amount • Learners hold a variety of misconceptions but these can only be revealed when they are allowed to talk. • Interactions generally increased substantially during the enacted lesson.

Table 4.4: Findings based on the analysis of data

These categories were indicators representing the different elements of PCK within stoichiometry topic based on the LTtP model which informed this study. At the same time they were indicators to my knowledge of my learners, learning environment that obtained and the skills of metacognition that were employed during the study. The structure of this data analysis template is much akin to the analysis instrument developed by Barendsen & Henze (2012) in a study to explore the relationship between PCK and practice in the classroom. The findings that were reported were drawn from my entire data sources in general not just from a single tool.

4.12 Rigor

This project involved tracing the development of my PCK using the integrated methodologies of self-study and lesson study and PCK as theoretical framework. Qualitative research requires one to report accurate data. Self-study is a personal journey and for validation purposes, its nature requires one to open their work for public scrutiny. The process of gathering data by videotaping was subjected to critique in the public domain by colleagues and supervisors in the lesson study group. Members of the group watched the video of the lesson and made comments about what transpired and other possible ways of improving the lesson. The use of multiple data collection tools such as CoRes, lesson plans, TSPCK tool, learners' written work, personal reflective journals, and transcribed data from video/audio recordings allowed for triangulation.

4.13 Validity, Reliability and Credibility

Questions can be raised in terms of the quality of the research about the validity, reliability and credibility. According to Maxwell (2002) a method or procedure for conducting research is never valid in itself. Validity is not a commodity to be purchased with techniques (Brinberg & Mc Grath, 1985). Rather validity is like integrity, character and quality, to be assessed relative to purpose and circumstances (Kullberg, 2010). This makes validity as research aspect to be subjective. The research questions raised in this study required that the choice of method and the manner in which the study was carried out to be employed for them to be answered. To be able to carry out research on teaching it is necessary to analyze teaching as it occurs in the classrooms. I sought to explore my PCK as I taught the mole concepts in this study. Teaching involves a number of stages starting from beliefs and views about the nature of science planning, enactment, evaluation and assessment. Hence data outside the enactment stage was also needed in this study as the contexts were relevant to my self-study.

With regard to reliability I aimed to be as thorough as possible in the collection of data: designing CoRes, lesson plans, reflective journals analysis, written text analysis, video recordings and transcriptions analyses. The different sources of data contributed to deeper descriptions and analyses. It was also important to analyze both the lesson as a whole and the details of the parts of the lesson to provide reliable analysis.

A method of teaching in one setting may not necessarily fit in another setting due to the many different contextual factors that come to play during the lesson such as teacher beliefs and the kind of learners amongst others. Therefore, issues of credibility are context dependent and relative. In this study I did not seek to produce new theories or attempt to make prescriptions of some sort. The study was about me in practice and attempting to learn about my practices in order to improve my PCK for better understanding of concepts by learners. A lot can be learnt from such an approach for instance that knowledge is contextual and therefore the need for any concerned teacher to engage in such approaches in their own working environments.

4.14 Ethical considerations

In the field of educational research, ethical issues need to be taken seriously to protect participants against violation of their rights to freedom, their self-determination to consider all possible options in participating and to make voluntarily decisions regarding whether they would like to participate or not (Cohen, Manion & Morrison, 2011). I had to engage in the following steps to cater for ethical issues.

An ethical clearance certificate was sought from the University Of Witwatersrand, School Of Education (Appendix 17). An application to conduct research at the school was forwarded to the Gauteng Department of Education under whose jurisdiction the school lies and to the principal of the school. Permission was granted by the Gauteng Department of Education (Appendix 18). A discussion meeting involving the Principal, HOD of Science and the researcher was held in which the researcher explained the objectives of the research, its value to the science department and the school as a whole and that a pseudo name will be assigned to the school for the purposes of anonymity and that confidentiality would be upheld. The principal then signed a copy of the consent letter (Appendix 19). A copy of the consent letter from Gauteng Department of Education was then submitted to the District Education offices.

Informed consent ensures the full knowledge and cooperation of subjects, while also resolving or at least relieving, any possible tension, aggression, resistance or insecurity of the

subjects (Babbie, 2001). Consent was then sought from the learners and their parents. The researcher explained to the learners the purpose of the study and their rights to participation before signing the consent form (Appendix 21). Learners needed to participate willingly and their parents were supposed to agree to their participation and also sign the parents' consent form (Appendix 20). Learners were then assigned pseudo names and were informed not to write their real names on the scripts and that their scripts would be kept safely under lock and key.

It should be noted that the original title chosen for the research project and for which ethics approval was obtained was **“Exploring the effect of my development of Topic Specific PCK on learner achievement in stoichiometry concepts through self-study within a learning study group”**. While the planned research methodology as outlined in the ethics proposal was used in this research project, it became necessary after consultation with my supervisor and advice obtained from specialists including the nature of the data gathered from my sources that the main thrust of the study was on the self and therefore it was suggested that the title of project be changed so that it covers a broader scope that would address the research questions. Thus the title of the research project **“A self-study on the Development of my Topic Specific PCK while teaching stoichiometry within a lesson study”** was opted.

4.15 Summary

In this chapter I described how my research was designed and the methodological tools that were adopted. In essence I tried to show that PCK that relates to stoichiometry can be documented and traced. I also outlined the various steps that were followed in the handling and organization and the data collection process. I used typological data analysis in this study after some categories were identified from the LTtP analytical framework. My data sources were subjected to the categories. It was possible for a data tool to address some aspects and not others. The manner in which I engaged with the PCK aspects related strongly to my metacognitive skills of planning, enacting and reflecting. At the same time these aspects of PCK enabled the creation of a positive learning environment as the planning considered the knowledge of learners in the context of the study. Issues relating to validity, reliability, rigor and ethical considerations were discussed. Chapter 5 focuses on findings that emerged during the processes I have dealt with in this chapter.

CHAPTER 5

FINDINGS

Introduction

In this chapter the findings of the study are discussed to a greater detail. These findings are drawn from multiple data sources that were employed in the study. I present the findings pertaining to how my PCK evolved as I participated in this study. The findings are presented under the specific aspect of the PCK that the study sought to address. It has to be noted that metacognitive skills, the learning environment and the knowledge of learners are subsumed within these aspects of PCK. The interrogation of these PCK aspects greatly impacts the learning environment, metacognitive skills and the knowledge of learners. From these findings I will draw conclusions that will address my research questions in chapter 6.

5.1 The evolution of my topic specific PCK.

The aspects of PCK that are related to the mole concepts which were traced during data analysis included Learners' Prior Conceptions/misconceptions (LPC), Learners' Procedural Knowledge (LPK), Curriculum Saliency (CS), Representations, Models and Analogies (RM&A) and Science Oriented Instructional Sequencing (SOIS), as already mentioned in the previous sections. The manner in which these were interrogated had a bearing on not only my metacognitive skills but also on the learning environment in the classroom.

In the following section I deal with how I engaged with the various PCK aspects based on the LTtP model and then a discussion on the implications on my learning experience is presented under each aspect. Within each aspect of PCK I make an attempt identify how metacognitive skills of planning and reflection were utilized, including how the knowledge of my learners helped to shape the learning environment.

5.1.1 Learners' Prior Conceptions/Misconceptions

Contrasting my two lesson plans (LsP1, appendix 1 and LsP2, appendix 2) indicates a marked difference in the nature and the manner in which I engaged with LPCs in my planning which ultimately impacted the implementation in the classroom. In the pre enactment stage the learners' prior instruction conceptions were presented as previously learnt knowledge or assumed knowledge. This is the knowledge based on the topics that had been covered in the work schedule or lower grades as can be seen in the lesson plan extract (LsP1, appendix 1) in the pre intervention stage. Such conceptions may however still be too abstract to learners as

they may still be decontextualized from learners' everyday life experiences. The following section of the lesson plan shows the concepts that were regarded as prior conceptions in my everyday lesson plans.

Lesson preparation grid
Lesson Plan - 1

Lesson preparation			
Teacher: <i>S. B. B. B. B.</i>	Grade: <i>10</i>	School: <i>[redacted]</i>	
Topic: <i>Knowledge of prior beliefs</i>	<i>balancing equations, chemical change, atoms, molecules, mass</i>		
Knowledge area	<i>CHEMICAL CHANGE</i>		
Knowledge/prior beliefs	<i>10/08/2015 - 14/08/2015</i>		
Core knowledge and concepts	<i>Quantitative aspects - The mole</i>		
Teacher activities	Learner activities	Resources	Assessment methods
<i>Define the terms mole, molar mass, Avogadro's number. Describe the mole as the amount of substance...</i>	<i>Perform calculations using $n = \frac{m}{M}$ $n = \frac{N}{N_A}$ $n = \frac{V}{V_m}$</i>	<i>Self study, Master Physics, Text book</i>	<i>Class activity, Assignment</i>

Figure 5.1: A section of a lesson plan prior to intervention showing prior knowledge (LsP1)

However, I believe that engagement with learners' conceptions drawn from learner's immediate environment may help learners to grasp the scientific concepts as they may find such conceptions plausible and therefore more likely to accommodate the science concepts. The collectively planned lesson showed LPCs that were derived from the learners' real life experiences. As an addition to the collectively designed lesson plan on the possible responses that learners may have I included responses that may relate amount to the size of something as shown in the following lesson plan.

Duration	Teacher activities	Learner activities	Assessment (what, when and how)
Introduction 5 minutes	1. Begin the lesson by giving the overall purpose or objective of the lesson. 2. Start off by asking learners what they understand when you use the term amount? Give an example – e.g. 'What do you think of when I say I have an amount of oranges?' Keep the question open-ended to generate from learners' own experience, do not restrict responses.	Learners generate responses relating to their understanding of amount. Possible responses could be • A certain mass of oranges • A certain number of oranges • A certain volume of oranges • Amount is about size of something	Informal: Based on learner responses you can gauge their understanding of the term 'amount' and work towards a shared understanding of 'amount of substance' to be used for teaching stoichiometry. Also establish the need for scientists to devise a suitable way for measuring amount based on the

Figure 5.2: A section of a lesson plan showing learners prior instruction conceptions in the lesson plan used during intervention (LsP2, appendix 2)

The video analysis template (VAS, appendix 13) indicates the engagement with the learners' prior instruction conceptions during the introduction. A closer look at this part indicates that the inclusion of the learners' prior instruction conceptions was a part of the collectively planned lesson. However I had to include those conceptions that I thought were relevant and closer to my learners' everyday experiences.

Video segment and time.	Description of segment.	Was this part of the planned lesson? Did it work? If it was not why did you deviate from the plan?	What components of TSPCK are in this segment? Explain.	What within your actions can help or constrain learning. Why?
First clip				
00-03:46 VAS1	Introduction on lesson objectives. Drawing from learners' everyday life experiences with regards to the term 'amount' and the way of counting/measuring objects. Attempts to elucidate the differences between mass, volume and amount. Leading to summary on the need to have a universal way of measuring by scientists	This was part of the planned lesson but I had to use examples that I thought were closer to learners' everyday experiences. The strategy worked as learners could identify the different ways of measuring and hence I used this to emphasise the need for a universal way of measuring /counting amongst a community of scientists.	Learners' prior instruction conceptions were covered in this segment as learners used their experiences about amount referring to mass/numbers and how price of tomatoes is determined by street vendors by counting while supermarkets will weigh and price according to the mass.	Directing learners to the objectives of the lesson help learners to keep in mind what it is that they are expected to know at the end of the lesson. Focusing much on the use of the word amount in everyday life could validate and legitimise the use of this word and learners may fail to relate it to its scientific context.

Figure 5.3: A video analysis template showing what can help or constrain learning segment (VAS1, appendix 13)

In this segment of the video analysis template I not only showed the need for scientists to find a common way of measuring amount more so in that scientists deal with very small invisible particles but also highlighted the risks associated with dealing with the conceptions for disproportionate amount of time during the lesson. The implication is that in addition to identifying the possible conceptions I was able to figure out some challenges that may be faced when attempting to engage with these conceptions.

The learners' ideas seemed to be at variance with what I intended to teach them and as such they acted as a barrier to accommodation of new conceptions. The unexpected responses that seemed to be out of context with the topic of discussion surfaced when learners were required to give explanations to their responses. Attempting to gain access to learners' prior instruction conceptions necessitated some kind of communication during the lesson and this implied that I invoke classroom management and organizational skills in order afford a learning environment that fostered acquisition of science concepts. In such circumstances there was need to redirect learners to the topic of the discussion. At the same time, there was need to guard against spending a disproportionate amount of time on such issues that were not the main concepts of the lesson. This indicates the transformation in the manner in which I viewed the use of these conceptions in the teaching and learning processes. This experience

for me point to a marked shift not only in the way I interrogated the various possible conceptions that relate to learners' immediate environment but also the need to ensure that learners understand how such conceptions relate to the scientific concepts. This clearly indicates that I gave a serious thought about how the kinds of conceptions that my learners may have and how these could be used as bridging science concepts. The CoRe also indicated the typical students' misconceptions that teachers may encounter when learning the mole concepts such as the mole being same as mass, and volume and also the mole as referring to molecules. Some of these misconceptions are shown in the extract of the CoRe that follows.

C. Learner Prior Knowledge	
C1. What are typical students' misconceptions when teaching this idea?	The amount of substance is misunderstood to mean the mass of a substance – possibly also volume of a substance. The mole only refers to molecules. Molar volume applies to all substances and not only gases.

Figure 5.4: A part of the CoRe showing students possible prior conceptions (CoRe, appendix 5)

It can be gleaned that even though I espoused the value of these conceptions during lessons I never considered these conceptions beyond what students had learnt in their previous lessons as can be confirmed in the pre intervention lesson described earlier. However, engagement with such conceptions during collaborative meetings gave me a broader perspective on these aspects. Over and above, I personally learnt a lot about the experience of using learners' prior instruction and trying to link them to the science conceptions. In a nutshell, it is very difficult to access these conceptions during lessons unless thorough ground work is done during the preparation stage. During this stage it is important to focus on students' anticipated difficulties and possible ways of accessing these conceptions and how to address them. There is also need to have sound subject matter knowledge in addition to the subtle PCK that is crucial to help learners internalize and accommodate the science conceptions. Of noteworthy is the fact the learners' conceptions are very difficult to change and that there is no guarantee that any instructional strategy designed to address these would result in the desired change. In this regard I have come to greatly appreciate the value of engaging learners' prior instruction conceptions when planning for lessons. Of critical importance and challenge too is the

inclusion of these conceptions not only in introductions to lesson or before a science concept but also during the main body of the lesson. This is drawn from the excerpt below of the reflections on how I can do things differently in future.

What happened (what I saw/heard)	How I felt?(what this might mean)	What did I learn?(what is my opinion about the experience)	How can I do things differently next time?
1. Pre planning • Lesson discussion was done collectively as a lesson study group. The final draft of the lesson	This was a critical stage in myself study research as it exposed the content and strategies to	Discussion of the lesson enabled the 'big ideas' to be uncovered. The content knowledge for teaching the mole concept was exposed during the discussions as I was engaged in	Design activities or questions that would probe learners' conceptions during the entire stages of the lesson rather than on the introduction only and have strategies that would enable

Figure 5.5: How I anticipated dealing with LPCs in the future in the reflective journal (RFJ2)

However, it has to be noted that it is not easy to elicit these conceptions from the learners unless there is thorough preparation during the planning stage. The situation is worsened when a teacher works in an isolationist environment with no colleagues to share ideas. Fortunately for me, in this project possible conceptions and confusion that learners have were discussed with members of the lesson study group. This means that as an educator I have to expose myself to collaborative discussions with my colleagues at my work place or other educators in forums such as “teach a teacher” sessions at cluster level in order to share and gain ideas for my own professional learning experience and for the ultimate benefit of my learners. At the same time learners must clearly understand their conceptions and how they relate to the science concepts if they are to benefit from the inclusion of their conceptions in the lesson. When reflecting on the engagement with LPCs I commented on these aspects as shown in figure 5.6.

The lesson study meetings emphasised the role of learners' prior instruction conceptions and designing teaching approaches that value such conceptions on the mole. Including these conceptions allows learners to talk and this can help the educator to gain insight into their thinking and then give the necessary explanation or design relevant teaching strategies to address these. While I have a

Figure 5.6: An extract on the general reflections of the reflective journal (RFJ2, appendix 4)

The recognition of the need to broaden the scope of learners' prior conceptions instead of restricting to assumed knowledge and the desire to include these conceptions in the main

body of the lesson indicates a positive shift in the knowledge and beliefs about how to engage this critical aspect of PCK.

It has to be noted that these contexts offered a rich environment with regards to my learning. The deliberations about these conceptions provided the opportunity to afford learners a learning environment that was not divorced from their everyday world but one that had a direct link to their immediate environment. The role of these conceptions was to try and help learners gain a better understanding of science concepts. In general learners were motivated and engaged in conversation about their everyday understanding of the terms. This is captured during the conversation held in the post discussion of the enacted lesson in the lesson study group meeting. The excerpt that follows shows this conversation within a lesson study meeting.

Expert 1	<i>I don't think we can take more than five in a group. Because those (?11:47) are quite small. But I was just thinking, if we have...if half the groups do the three grams, and half the groups do the one spoon, and then you have the samples on (?12:07), and you actually record the results, and you put them up. I mean, that thing about writing from the overhead worked very well, don't you think so?</i>
Expert 2	<i>Mm.</i>
Expert 1	<i>Ja, and they enjoyed that.</i>
Expert 2	<i>The variety of (?) and engagement (?). And I also found that the context of the (?12:39).</i>
Expert 1	<i>Ja.</i>
Expert 2	<i>What their everyday encounters, that was very good.</i>
Expert 3	<i>Ja.</i>
Expert 1	<i>Ja, I thought that was nice too.</i>
Expert 2	<i>But you know, from the beginning I was convinced that you could have...the way they dealt with that context from the beginning, I felt...I was feeling that way, if you could have asked them what is a mole, they would have responded the way they responded halfway in the lesson. So with that I felt there was a lot of clarity, for instance, you were asking about...what was the question? When you were introducing the context, (?) it was (?).</i>

Figure 5.7: Comments about prior conceptions in the post lesson meeting (post LSMT2)

However whether this approach enabled learners to grasp the science concept was not ascertained but at least learners showed much interest during engagement with the activities. One other finding that can be drawn from the engagement with learner' prior conceptions is that more often times than not misconceptions are not usually addressed during lesson possibly as a result of teacher factors such as the tendency to direct learners to model

answers, attempting to avoid diverting from the objectives of the lesson and inability to follow learners' thinking or failure to pay particular attention to students utterances. This could be at variance with the VNOS about how science should be taught especially with regards to conceptions that students may hold. This could compromise the acquisition of correct scientific knowledge. Matthews (1994) argued that aspects of the nature of science (NOS) are critical in teacher training programs because understanding of the NOS could facilitate the implementation of conceptual change models in their instructional approaches. In the following excerpt the learner (*Richard*) had a conception that the type of bonding determines the mass of substances, for instance that ionic substances have greater mass than covalent molecules. This can be gleaned from the excerpt that follows.

Teacher	So the mass of sulphur is different from the mass of sodium chloride, which is different from the mass of iron and different from the mass of water. What could be the reason? Yes (points to learners, Richard).
Richard	It has to do with the type of bonding, which is the particle type of bonding for instance H_2O is covalent bond. This one (pointing to sodium chloride) it's like the bonding is ionic. May be ionic has higher mass than others.
Teacher	So you are saying type of bonding affects the mass and then you are saying covalent molecules have a smaller mass than ionic substances. That's what you are saying.
Teacher	Now what is it that contributes to the mass of atoms? If you think about you did in grade 11. Which particles are present in an atom?

Figure 5.8: LPC about bonding in the video recorded transcriptions (VLT, appendix 12)

In this regard I did not affirm or disapprove of the learner's ideas possibly because I was trapped in a dilemma of validating the idea and linking it to the lesson concept. As Brodie (2006) notes teachers who attempt to take learners' ideas seriously are faced with a key dilemma between validating learners' knowledge and transforming it. Another way of expressing this dilemma is when and how the teacher might intervene when learners go off track or make mistakes Brodie (2006).

At the same time if such errors are missed the misconceptions may remain entrenched in the minds of the learners and this can affect their understanding of science concepts which may ultimately result in poor performance in science in general. The major finding in this aspect is that instruction that considers learners' prior conceptions improves interactions between the teacher and learners and this can lead to better understanding of concepts. It means that as a science teacher I should have in mind the children's possible difficulties with regards to stoichiometry. This is confirmed by Schmidt (1990) who asserts that it is very helpful for any chemistry teacher to know beforehand the difficulties of the students in doing stoichiometry

calculations and this helps to develop specific activities prior to the teaching situations. What is critical at this point is that I was able to reflect after lesson enactment on my inability to exhaustively deal with some misconceptions.

The major observation with regards to learners' prior instruction conceptions is that they were generally often ignored in my day to day lessons regardless of having a strong belief that these are a learning resource onto which science concepts should be built. However as a result of engagement with peers in collaborative meetings my perceptions about the value of these during the teaching and learning evolved. I did not only gain an understanding of the value of these conceptions in learner understanding but also how to craft strategies that would address these conceptions.

From this experience I have come to appreciate that lessons should be anchored on what learners bring into the classroom. Learners may have some naïve ideas about some science phenomena; however, these ideas may be explored to fully understand how such concepts arise and therefore craft strategies that would allow for formulation of proper scientific concepts. At the same time using learners' experiences creates an environment that allows social interactions to take place from which ideas get exposed as evidence by the emergence of typical misconceptions in the previous conversation.

5.1.2 Learners' Procedural Knowledge

Indications are that in the pre enactment of the lesson, learners' procedural knowledge was rarely depicted; when it emerged it was largely in the form symbolic representations in problem solving. The planning of the tasks that offer opportunities for learners' procedural knowledge was therefore lacking as evidenced by the lesson plan (LsP1, appendix 1) and reflective teaching journal (RFJ1, appendix 3). The learning environment was designed in such a way that the activities of the lesson were dominated by the teacher.

Engagement of learners to talk to their work was generally minimal, although I indicated acknowledgement of the importance of this talk by having a learner perform a solution to a task usually given as homework on the chalkboard in the reflective journal (RFJ1, appendix 3). The implication could be that it was difficult to access learners' procedural knowledge through communication. A closer look at the learners' written text (LWT1, appendix 6) that was written before intervention shows engagement with such procedural knowledge when solving mathematical problems.

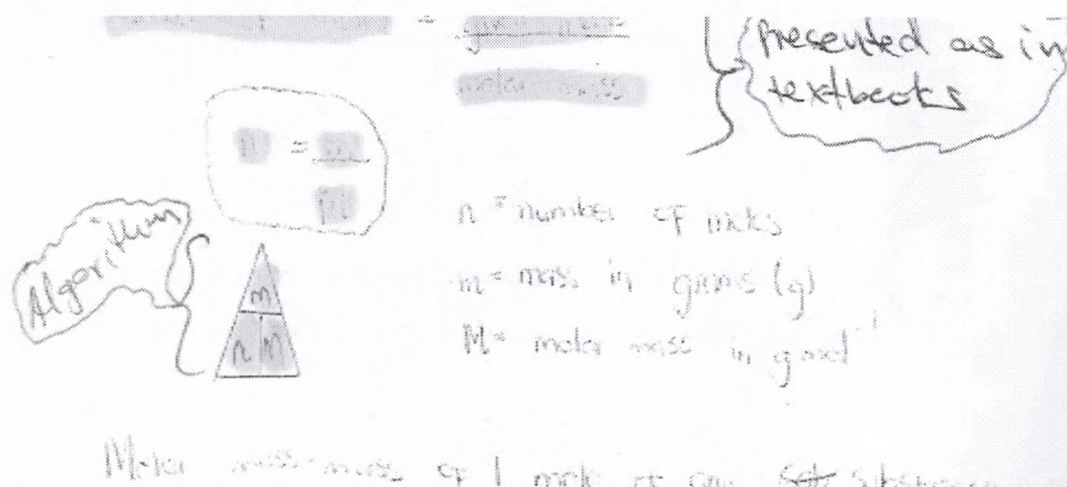


Figure 5.9: An extract of learners' procedural knowledge taken from learners' written text before engagement with this study (LWT1, appendix 6)

In my everyday lessons learners are afforded a chance to present solutions to problems to the whole class due to my belief that teaching is an interactive process. However they rarely had the opportunity to present their ideas in other forms such as mind maps and illustrations. As a result I did not pay attention to their language used during their presentations. This implied that some ideas that learners held were not interrogated.

In this context an interactive process is one in which learners were not only engaged with the learning tasks but also amongst themselves and the teacher. This is opposed to the practice where teachers dominate the lesson while learners become passive recipients of information. When learners engage or interact with artifacts such as mind maps, language issues arise and these can be probed so as to gain a deeper understanding of underlying concepts. This would then allow the educator to devise means to address the misconceptions or provide relevant scientific explanations. The interactive process enabled me to gain an understanding into how learners reasoned and formulated their conceptions as they explained or gave responses to questions.

As an improvement in my future lessons I suggested that I have to include my learners in the teaching and learning process. This is indicated in the section of how I can do things differently in my lesson in the reflective journal (appendix 3, RFJ1) as shown in figure 5.10 that follows. Probing students and assessing them during the teaching and learning draws learners into the discussion and may help to uncover some concepts that may not be clearly understood by learners in addition to improving the interactions.

6. Lesson conclusion was done by giving learners homework and highlighting the next topic.	The home work reinforces the concepts that were covered during the lesson while mentioning the new topics help learners to read ahead so that they come prepared to the lesson.	I did not assess the learners understanding of concepts. This could result in learners not understanding the concepts and therefore not doing their	I need to probe students understanding of concepts during the lesson so that I gain understanding of their learning
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Figure 5.10: An extract of my pre reflective journal (RFJ1)

However the planning and reflective practice that I engaged in towards the enactment of the lesson showed a consideration of these processes to a greater extent during this study. The CoRe (appendix 5) indicates that besides being a collectively constructed tool I individually thought of how to utilize learners' procedural knowledge in my context. This is shown in the extract of the CoRe that follows.

CoRe D. Representations	
D1. What representations would you use in your teaching strategy?	Demonstrations of mass of a tablespoonful of different elements and compounds. Submicroscopic pictures of atoms of different elements, molecules of substances and ions of ionic substances. Demonstrations of the mass of a fixed number of different objects. Symbolic representation of the number of particles represented by the counting unit a dozen. Demonstrations of mass of a fixed amount of different substances. Macroscopic pictures of volume gases collected during experiments. Balanced chemical equations of the reactions with gases. Symbolic – mathematical relationships between amount of substance, mass of substance, volume of gas & number of particles through the proportionality constants of molar mass, molar volume & Avogadro's number.
What ways would you use to assess students' understanding? (original: Specific Ways of ascertaining understanding)	Learners work in groups and present their answers to the class for discussion, allow learners to talk so as to gain insights into their thinking and how they approach problems. Learners present mind/concept maps on how to summarise what they think they learnt from the lessons. Encourage learners to write as much as possible on their mind maps. Encourage learner to learner interactions for sharing and interrogation of ideas.
What aspects of teaching and planning for this big idea would you like to reflect on?	The kind of the learning culture that would take place Concept sequencing: on whether concepts were logically sequenced. The effect of activities on learners' understanding of the concepts.
KEY: group contributions: black My own contributions red	

Figure 5.11: An extract of a CoRe showing my contributions on the collectively designed CoRe (appendix 5)

Learners' procedural knowledge was demonstrated in my learners' written tasks and when they engaged in conversation either during group discussions or presentations to the class in different episodes of the lesson. Learners' procedural knowledge was depicted as the use of formulaic approaches to problem solving not only in the pre intervention phase but also in the intervention stage. Teacher activities that should reflect teachers' knowledge and beliefs domain indicate that I was the dominant figure in the pre intervention stage in the lesson activities (LsP1, appendix 1). The learners' procedural knowledge was not precisely included in the structure of the constructed CoRe (appendix 5). In this section I anticipated that learners would work in groups and make presentations to class in order to allow various kinds

of interactions and creation of a positive learning environment. Over and above to encourage learners to talk would not only help to assess their level of understanding but also gain insight into their thought process. It has to be noted that such varied opportunities were not afforded to learners during the pre intervention stage of the study. Presentation of concepts in form of mind maps helps to identify the key aspects of a topic and hence learner understanding of ideas as shown by the interconnectedness of concepts. One such mind map is shown in the figure that follows.

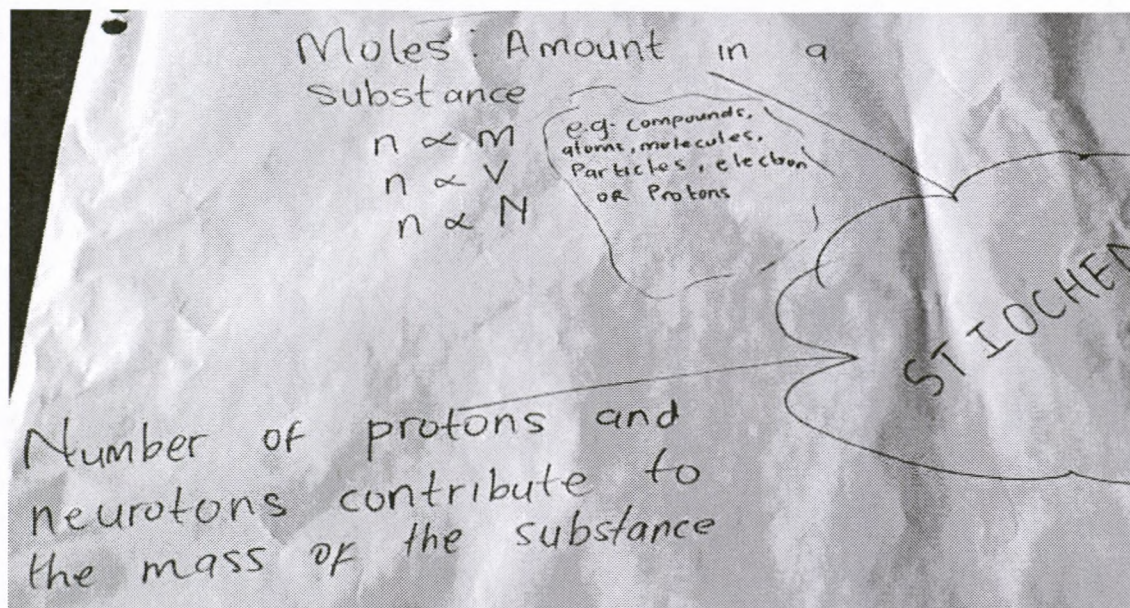


Figure 5.12: A mind map (appendix 9) designed and presented by a learner during the enacted lesson

While the mind map showed a few ideas related to stoichiometry, the learner talked extensively about the relationships of the mole to other physical quantities that are indicated implying a better understanding of the concepts and this showed a better understanding of the concepts. The learners gave some thought on the mind maps in coming up with what they had learnt during the lesson. This could be indicative of learners' understanding of concepts. The incorporation of such approaches during lessons should be drawn from the planning stage. Such approaches are used to cater for and engage with the development of the procedural skills which are foundational in the process of generation of science knowledge (Nakedi, 2014). Part of the learners' verbal presentation is shown in the figure that follows. The mole was identified as a central concept that links to other concepts covered during the lesson. The learner described in her own understanding the meaning of the mole and showed its link to mass, number of particles and volume of gases. In the response that I offered I reflected on my actions of not telling learners the type of the particles represented. This is because I

wanted to highlight the aspect of isotopes but this dawned to my mind as a peripheral concept and I had to shelve it during the lesson.

Banele: So it's sort of like a mind, mind map. So there (pointing to the mind map) there is imole ukuthi yini (there is a description of what a mole is) and then we described ukuthi (what) it was, amount of substance (substance) and then we made ama (the) examples of ama (the) substances like ama (the) compound, atoms, molecules, particles like electrons, protons. We also learnt that ama (the) moles have a relationship to... there is a relationship to imass ne (and) number of particles. So we have I relationship e directly proportional. And then we learnt ama (the) formulas which is $n=m/M$ which we know and there na lena (and this) constant le esiyazi vele (we know) and also we learnt that the number of protons and neutrons contribute to the mass of a substance since ma siyenza into leziya (when we doing that)... (referring to activity on counting the number of protons and neutrons). Ma siyenza (when counting) sulphur ama (the) protons were 16 and then the neutrons were also 16. So we added the numbers so that we get the atomic mass.

Teacher: You see the time when were counting those particles I did not say which ones were protons and which ones were neutrons because their numbers were the same but many times neutrons are more than protons. so let us say we had counted red and found 16 and blue 17, 17 will be the number of neutrons, and remember how we calculate the number of neutrons it's the mass number minus the atomic number, that stuff in grade 10.

Figure 5.13: Learner talk during presentation of mind map (appendix 9, VLT)

By tracing movement of my practice in the pre intervention stage to the enactment stage with to regards to how I planned and implemented strategies that promoted the use of the learners' procedural knowledge I shifted from teacher-centred approaches to learner-centred approaches.

I devised a mind map as shown below during pre intervention phase when I completed the TSPCK tool prior to lesson enactment.

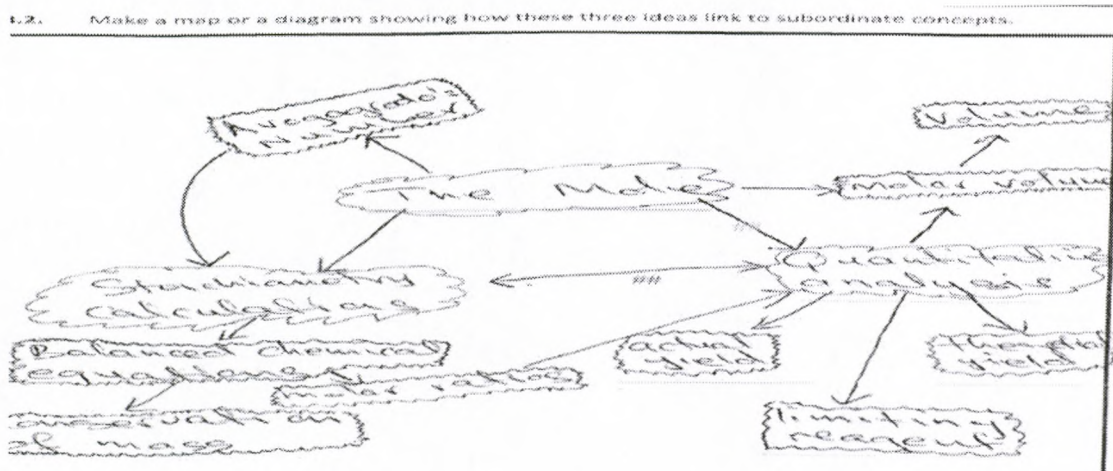


Figure 5.14: A mind map that I designed when completing a TSPCK tool (pre TSPCK, appendix 15)

While the mind map shows other concepts that were related to the mole that were not necessarily part of the study, it clearly shows some relations between the various concepts

and more importantly that the mole is central to all other ideas. This is not to suggest that the above mind map is the best that I could design but rather that it shows my development in as far identifying the interconnectedness of the ideas within stoichiometry. At the same time recognition of these ways of accessing and processing knowledge were captured during the planning and reflection stages as noted in the segments of the video analysis (VAS, appendix 13) and in the reflective journal (RFJ2, appendix 4). The last column of this extract shows that learners were given an opportunity to deal with concepts at different levels of representations.

27:30-35:38 VAS11	Determining the amount of substances that they measured-spoonfuls and same mass-3g. Calculations done with each group assigned one substance. Presentations of solutions to the task by learners. Learners engaged by responding to what has been presented by their colleagues.	Yes but brought it forward yet the plan required this activity to be done after the mole as a counting unit activity.	Learners procedural skills	Calculations were based on what they actually measured mass (macroscopic), the amount (microscopic) and the symbolic (formula) this illustrates the link amongst the three levels- strategy that is rarely used during the day to day normal teaching.
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Figure 5.15: My comments in the last column of the segment VAS 11(appendix 13)

Well documented learners' procedural knowledge procedures such as using algorithms or formulaic approaches were evident during the learners' presentations. When learners are given the opportunity, they can engage their procedural knowledge to solve problems. Learners may solve problems by just following some formula without necessarily understanding what the terms in the formulas represent. This was evident in the utterances made by the one of the students when presenting answers as shown in the following extract when interactions amongst learners were evident.

<i>Trom: What is the next question?</i> <i>Vuyo (reads question): What volume does this amount of hydrogen occupy at standard temperature and pressure occupy?</i> <i>Trom: Okay as you can see this is the formula... which use Avogadro's number (pointing to the formula $v=n.V_m$). (Teacher interjects: that's molar gas volume not avogadro's constant)</i> <i>Trom: Yes we used the ... what oh sorry as you can see we used that, what do we call it again?...</i> <i>Class: At STP</i> <i>Trom: We used that (pointing to 22.4dm³) which is ...</i> <i>Class: Molar volume.</i> <i>Trom: Molecular volume volume, thank you very much. We used that molecular volume multiplied by the moles which is 5, we got in the first question. This is the answer that it gave us 112 dm³. Next question?</i> <i>Vuyo: (reading the next question): how many hydrogen molecules are present in 10g of hydrogen?</i> <i>Trom: We use the same formula but in a different form, $n=N/N_A$. As you can see so we have got molecules (pointing to 5 mols), this is the first answer we got. So we substituted it here ka 5 (by 5) and is equal to... because we are looking for how many molecules so as you can see we substituted and we got $n=5$, that constant number jah of Avogadro. This is the answer that we got.</i> <i>Teacher: It's fine. Language is very very important. So let us not just memorize formulas. Let us know what those things stand for: small letter n stands for the number of moles, the amount of substance, capital letter N- the number of particles, N_A the Avogadro's constant. Let's keep in mind that there is a relationship between volume and... there is a relationship between mass and amount instead of just memorizing these formulas.</i> [VLT]

Figure 5.16: LPK when presenting solutions to the class (VLT, appendix 12)

The implication could be that such a learner did not have an understanding of the underlying concepts and that he could have been following formulaic approach to solving problems. This showed the value of learner talk over the written text. Thus in a way according to Lewis (2002) I was beginning to develop '*eyes to see*' children. However I made an attempt to encourage conceptual understanding by encouraging learners to mention the science terms during presentations which in essence is the language of science. As an educator I have a key role to play in helping learners to use conceptual understanding approaches to solving problems. Mentioning of symbols in given formulas by learners may not indicate understanding of concepts by learners. Conceptual change approaches are not formulaic, instead of encouraging learners to simply substitute into given formula; learners should be encouraged to demonstrate their understanding of concepts through reasoning by using ratios and identifying quantities that are related to each other in a formula. The implication is that an educator should therefore pay more attention to the language that learners use and try to probe learners' understanding through follow-up questions.

As part of my knowledge and beliefs domain, with regards to everyday teaching I rarely gave a deep thought on some critical aspects of how to teach the mole concept and what it is that can make it difficult for students to learn stoichiometry concepts and even to think deeply about how learners solve stoichiometry problems or how the various ideas are linked. The implication is that the value of learners' contributions during lessons was not catered for. By engaging in such practices it implied that the type of skills and knowledge inherent in how scientific knowledge is generated (Nakedi, 2014) was lacking in my lessons.

In order to create a learning environment that was organized in such a way as to encourage interactions amongst learners and with the learning resources learners were put into groups of mixed abilities. I discovered that when given such opportunities to talk and share ideas in social settings such as groups, learners are capable of representing their ideas in such different forms that may shed light into their thought processes and possibly understanding of science concepts especially when encouraged to talk.

Tapping into learners' procedural knowledge allows the various modes of interactions to take place in the classroom and this enriches the learning environment in that a variety of issues or ideas may come to the fore and some conflicting ideas may need to be resolved through particular strategies. Various kinds of interactions included teacher to learner, learner to learner and learner to resource materials. The presentations by learners for whole class

discussions allowed for interactions amongst learners to unfold. The interactions help to indicate the extent to which communication is done between students, the teacher, and the whole class, and the extent to which the teacher play the role of a guide and a listener, as opposed to a director (Sawada et al., 2002). The interactions helped to create a learning environment in which ideas were shared and knowledge generated collectively within the class. Learners were therefore afforded an opportunity express their ideas amongst themselves and to the class as a whole.

“Learners talked to their task, talked amongst themselves while I facilitated the interactions by way of redirecting the question posed by one learner to other learners or by asking some learners to respond to the answer given by another learner. In a way I expected learners to engage in discourse that allowed learners to provide reasoned explanations for their responses.”

[Lesson reflections LsP2]

Figure 5.17: Reflections on learning environment after lesson enactment (LsP2, appendix 2)

Language issues surface when learners are allowed to talk; some learners prefer to use their mother tongue when conversing. At the same time the conversation indicates the resistance of some learners’ conception to change in spite of prior engagement with the misconception. The conversation below illustrates the interactions that took place in which I was given an opportunity to tap into the students’ ways of knowing and how they learn. Knowledge of students and how they learn is critical in helping to capitalize on personal and community asserts to enrich instruction (Gees-Newsome, 2015). This knowledge helps learners to engage not only in cognitive processes but also social interactions during the teaching and learning.

Teacher (me): Right. Who said no? Let’s go back to the first answer. Yes (pointing to a learner Ml). What’s the explanation? Why are you saying that they do not have the same amount?

*Learner (Mlamleli): Sir I think I made a mistake (learners laugh). Ngithe ma mbona zingalingani ngathi azina amount efanayo. **(When I looked at them I saw them being unequal then I concluded that they have different amounts).***

*Teacher (me): Ok. So you just looked at them. What is it that you were looking at there? You were looking at volume, space occupied and then you say because space occupied is not the same it follows that amount is not the same. **[VLT]***

Figure 5.18: An extract of video lesson transcriptions showing learners’ ways of knowing (VLT)

The implication could be that the learner (*Mlamleli*) seemed to focus on size or volume of substance to decide whether amount was the same or not. Stavy (1991) observed that student misconceptions are often quite resistant to common classroom instruction. There could have been underlying issues such as reasoning out in vernacular language and then translating ideas to the English language as the cause for this resistance to change. However because I was not the only source of information and I needed to create a culture of learning where ideas were shared in class I then asked one learner who had responded correctly that all the samples of substances contained the same amount to explain her response. The learner (*Mpho*) provided the following response.

Teacher (me): Yes. Help us (pointing to learner Mpho).
Learner Mpho: Sir it's the same amount because re berekesitse Sir 0.1 go tse tsotlhe, the only thing e rei kereleng idiferente ke mass, yes. (Sir it's the same amount because we used 0.1 in all substances and the only thing that we found different is the mass, yes)

Figure 5.19: A response to an answer that amounts of samples were different (VLT, appendix 12)

This response served the situation as most of the learners then generally agreed that the 'amounts' were the same. I then explained presumably, profoundly what amount was and what determined mass. However I felt I did not explain the term amount convincingly even though I dealt on the misconception for a long period of time. I did not emphasize a precise meaning of the term amount at this stage of the lesson in order to remind learners about its meaning with particular reference to science. The following excerpt shows how I responded.

Teacher (me:): So in science, amount has a specific meaning. And what amount is present in this one (pointing to first test tube)?
Learners: 0.1 mole.
Teacher (me): In the second one?
Learners: 0.1mole.
Teacher (me): So in science, amount has a specific meaning and the mole is the amount of a substance. So of course we have used the same number of moles in each test tube, container. It means that amount is the same. Even though we are getting different masses and different mass it's because we have different substances which are made of different types of atoms. Different types of atoms have different masses because of different number of protons and . . . (neutron, learners follow up). So when you look at them you may think that amount is different but remember that in science amount has a specific meaning, it's the mole. So because we are using the same number of moles there, it means that the number of particles that are present in sulphur (pointing to the test tubes,) iron, water and sodium chloride are the same, which is what we are going to look at in the next activity. [VLT]

Figure 5.20: An excerpt showing interactions about amounts of samples (VLT, appendix 12)

This can be taken as a rhetoric statement that did not offer a precise meaning of the mole and therefore could have done little to help learners grasp the mole concept. However it has to be noted that these opportunities availed themselves because of the kind of the learning environment that I sought to create, in which ideas were to be unearthed from the context within the classroom situation. From these experiences I have learnt that I need to pay particular attention to what learners say, and probe them to explain their understanding in order to promote learner talk and gain an understanding into their conceptions. At the same time it implies that learners do not usually transcend beyond what they can perceive with their eyes, they tend to focus on the concrete aspects of the concepts and leave out the cognitive aspects that could be related to the understanding of science ideas. This confirms the general finding that students prior instructions are difficult to change. At the same time learners' contributions during a lesson are a valuable resource not only in helping gauge their understanding but also to create positive learning environments.

At times activities that are meant for conceptual change could end up been taken as basic practical activities by learners in which they develop some skill building without due thought being given to the underlying concepts. This could be partly extended to the activities that learners wrote as class exercises. This could have led to one of the experts in the lesson study group meeting to suggest that parts of the lesson were activity based as can be seen in the excerpt taken from the lesson study meeting based on the lesson that I had taught. Various reasons could be responsible for these assertions such as that learners' ways of understanding the mole concepts were not articulated to some extent during my lesson, or that I did not assess properly the extent of their understanding of the mole before moving on to next activities. The conversation below illustrates the assertion.

Expert 3: You know, it shouldn't be like if you're going to, you know...when I say it's driven by activities, you're going to sort of ignore what they already have (?44:58). We should, if it was introduced previously.
Expert 1: But you (?)
Expert 2: They don't have an understanding of amount. It's not used in the sense that...I mean...
Expert 1: Even if they've been told the definition.
Expert 2: Ja, even if they've been told the definition because teachers and textbooks say, (in?) number of moles or (in?) moles.
Expert 3: No, you see, they might have the (algorithmic?) rote learning maybe, and maybe the activities are there to (?) each the conceptual understanding, but if they are able to (?) the word mole, and then you have some conceptual (?), you can't not work with it, yes. So it would be, what do they know? And it might come from maybe rote learning, and you sort of use the activities maybe to challenge, and trying to make that, a conceptual understanding. [LsM2]

Figure 5.21: Experts views on how activities had progressed during the lesson (postLSTM2, appendix 11)

What can be learnt from such an experience is that as an educator I should be wary of the kind of activities that I plan for my learners. Activities become useful if they encourage conceptual understanding by the learners. Nevertheless, in order to learn and understand my practices I had to learn from my mistakes and reflect on these to avoid their recurrence in future after all *learning from mistakes* is not a bad thing either. A shift in the way I incorporated the learners' procedural knowledge in terms of designing ways of accessing this knowledge through written activities and verbal pronouncements indicated the developmental process that I was undergoing in as far as utilizing the content knowledge for teaching the mole concept.

Code switching that occurred during the lesson could have been an indicator of a positive learning environment that obtained at the time as can be seen in this excerpt taken from the post lesson study meeting.

Expert 1	<i>By the way I enjoyed the (?7:08). I thought that was quite interesting. But both you guys are not in the position that Thabo is in, do you understand Zulu?.</i>
?	(?)
Expert 1	<i>Do you understand? Because at some point (?) code switching. There were some kids who were very comfortable in English, and there were some kids who were switching in and out. But, I sort of noticed there were specific kids who felt more comfortable talking Zulu, when other kids who felt more comfortable in English, did you notice that? But...and actually, ja, I've got a note here, file two, eighteen minutes, they seemed to know (?8:01) like you said. There's a question I asked Thabo in keeping all the artefacts from the lesson, all the stuff the kids wrote down.</i> [LSMT2]

Figure 5.22: An expert's comment on code switching that took place in the lesson enactment (postLTSM2, appendix 11)

I could not have figured that learners focused on size or volume to determine amount had one of the learners as shown in the previous interactions (of the VLT, appendix 12) not expressed himself in his home language (isiZulu). This then puts into focus the issues of linguistic backgrounds of the educator and the learners that he or she teaches. It implies that if there is a huge linguistic difference between the teacher and the learners some learning opportunities could be overlooked and this could negatively affect the learning environment. Hence, as a

science educator I have to acknowledge such contributions as they could have some valuable ideas embedded in them.

Knowing my learners enabled me to afford them with an environment that was ideal for them to engage in conversation using their language and thought process at the same time I was to some extent in a position to figure out their reasoning abilities. This could have enabled me to figure out their anticipated difficulties and therefore come up with ways of trying to explicate issues to them. As in regular classroom contexts, student-student interactions are seen as a central contributor to the lesson outcome (Loughran et al, 2006). The interactions between learners enabled the learners to share ideas and come to a consensus about some concepts and how to solve or perform tasks. My task during such interactions was to reflect and reframe on my practice and student' ideas and orient them towards constructing science knowledge. At the same time my role was to initiate and orchestrate this kind of discourse that encouraged learner talk and hence try to move learners to a consensus on the knowledge produced. This indicated a marked shift from my traditional teacher dominated practices to one where learners were the focus of the teaching and learning process.

5.1.3 Representations, Models and Analogies (RM&A)

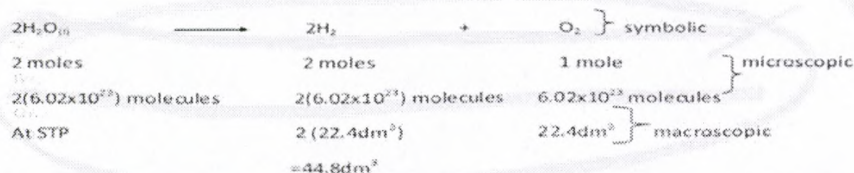
Representations, Models and analogies are used for variety of purposes in science teaching. They help learners to gain an understanding of the complex abstract science concepts in that they bridge the gap between learners' everyday life experiences and science concepts. Hence their value in science learning is critical. Prior to engagement with the self study I rarely invoked these artefacts during my normal teaching even though I had an understanding of their value in science. The situation changed as a result of exposure to some ideas with collaborative meetings of the lesson study. Evidence in learners' written text (LWT1, appendix 6) implied that I should rethink, frame and reframe and reflect on the way I used these representations to explain scientific concepts.

A variety of representations were evident in the teaching and learning artifacts that were used during the lesson enactment stage. This had been made possible as a result of the collaborative meetings that took place in the lesson study group. The representations ranged from physical activities of weighing or counting, to diagrams and illustrations. Different representation modes such as analogies and illustrations (coin activity, atomic models, electrolysis of water, microscopic and symbolic representations) were used to teach the mole

concept. The following extract of the lesson reflections shows my consideration of using the symbolic and microscopic representation to indicate the relationship between these.

2. Representations

On the results for the electrolysis experiment learners noticed that the volumes of the two gases were different but could not identify which test tube contained a particular gas and why the other gas (H_2) had a volume that was twice that of the other (O_2) until I had to direct the learners to the equation and formula of water. I made an attempt to link the microscopic, symbolic and macroscopic representations using the electrolysis of water. I made the following representations on the chalkboard with the help of learners:



(I forgot to put the state symbol for the gases in the equation). I could have used the opportunity to make learners to be aware of the differences between molecule and atom by highlighting that a water molecule has 2 moles of H atoms and 1 mole of O atoms.

Figure 5.23: An extract from the reflections of the enacted lesson plan (LSP2, appendix 2)

By contrast prior to intervention stage, my practices were characterized by the use of symbolic levels of representations, where formulas were used when teaching the mole concept. The artifacts should be clearly understood by learners as well as how they are useful in explaining the science concepts to avoid the buildup of misconceptions. During lesson enactment I considered the shortcomings or gaps that could lead to wrong conceptions at the end of the lesson that could suggest that the H_2O as represented in the decomposition reaction was a gas based on the representation. At the same time I made suggestions about how I could improve my practice in the reflections of lesson plan (LP2) by stating that:

In order to reinforce the mole as a counting unit I could have linked this to an analogy that I had used earlier such as a pair or dozen or may be the one shown below.'

1 bicycle $\rightarrow$ 2 wheels + 1 chain

[RJ2]

Figure 5.24: My suggestion on the mole as a counting unit in lesson reflections (LSP2, appendix 2)

This indicates a shift towards my reflecting ability by way of acknowledging the weakness of these representations and also providing alternative examples. Of critical importance is the rather different approach to the use of the symbolic representation, prior and during enactment of the lesson and also an understanding on the implications of these to learning. The three levels of representation have been noted to cause problems with regards to understanding concepts (Russell et al, 1997) as indicated in section 2.11 of stoichiometry and stoichiometry teaching. The problems manifest to both teachers and learners. Teachers tend to migrate between the three levels unaware while learners may not understand the

representational levels. The following representation is common in many text books used often in stoichiometry calculations.

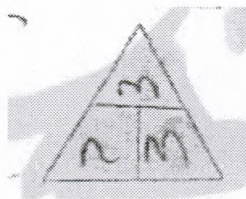


Figure 5.25: A symbolic representation common text books, used in LTWT1 and as representation number 2 in the pre TSPCK tool (appendix 15)

In section 1.5 of the TSPCK tool I commented on the usefulness of the above representation, which was presented as representation number 2. This is indicated in the following extract of the TSPCK tool.

Complete the table below by providing as many details as possible about each representation.

Representation No.	What I like	What I do not like
1	Shows change in size of objects counted. Effective to introduce mole as a counting unit	Could have represented numbers in standard form. Assumes that atoms can be seen
2	Shows how to determine each quantity quicker	encourages rote learning - no reasoning conceptual understanding suffers at the expense of mathematical manipulation

Figure 5.26: An extract of comments on use of symbolic representation number 2 (pre TSPCK, appendix 15)

Learners tended to use this representation in a formulaic approach in their procedural knowledge as already highlighted section 5.1.2 of the Learners' Procedural knowledge.

To sum up the major finding is that the representations were generally missing in my planning and practice prior to this study. The only representation that featured mostly at that stage was the symbolic representations that learners used to solve stoichiometry problems. However as a result of peer engagements in collaborative lesson study meetings these learning tools were employed in my planning and enactment of the lesson. Not only were they included in the teaching and learning process but also reflected upon in order to make them more useful in helping learners grasp the rather abstract stoichiometry concepts and for my learning. However the findings about these representations indicate that learners tend to use algorithmic approaches to solve problems without conceptual understanding. Hence there is need to explain these representations and explain to learners how they relate to science concepts. At the same time care should be taken to avoid reinforcement of misconceptions or formulation of wrong conceptions. However judging from the way I engaged with these representations I am convinced that I was able to use these to package subject matter knowledge in ways that were comprehensible to the learners more so with concrete objects such as the coin activity to help learners visualize sub atomic particles.

5.1.4 Science Oriented Instructional Sequencing (SOIS)

This study employed demonstrations and exploratory practical activities including explanations to teach the different ideas of the mole concept. It is important to note that each of these strategies was chosen in order to address specific concerns. In this study the instructional strategies aimed at dispelling some common misconceptions which may hinder the understanding of science conceptions. The fact that the mole concept is an abstract concept there was a need to design activities that would concretize this concept. Since science phenomena can be represented at different levels that are connected I had to design activities and use strategies that help to bridge the gap between microscopic, macroscopic and symbolic levels of representing phenomena. These levels also pose some challenges to both teachers and learners. Learners were supposed to gain a better understanding of the mole concept and appreciate its role in chemical reactions. However due to the wider scope of the project the effectiveness of these strategies were not fully assessed. Instruments that address these misconceptions could have been designed to assess learners' understanding. The

following table shows the strategies that I employed to address some mis/conceptions during the enacted lesson.

Mis/conception	SOIS	What informed the choice of the strategy	Effectiveness of the strategy
Mass and amount are the same	Measure mass and determine amount. Learners predict, observe and explain	The purpose of this activity was to enable learners to gain an idea that mass is not the same as amount in science and to some greater extent to gain in depth understanding of what mass is and relate mass to amount. Learners need to be aware of the relationship between the macroscopic and microscopic levels of representing stoichiometry concepts.	Through measurement of mass on scale learners were able to differentiate the two physical quantities. The strategy was useful when learners had to engage in calculations after having measured the masses of different substances. At the same time some of the predictions were at total variance with the expected responses such as iron having a smaller mass compared to sulphur.
Volume and amount are the same.	Measure the same amount of substance and display samples to gauge whether they have the same volume.	The need to have clear understanding that amount and volume are different. If learners have a clear concept of volume then they would appreciate that substances of the same amount may have different volume, thus making a distinction between volume and amount. Volume is concept that can be demonstrated clearly compared to amount.	The strategy was effective in that it helped learners to concretize and visualize the concept of volume. However due to the abstract nature of amount of substances some learners may fail to link the mole to amount. An example of such dilemma was when learners were asked to say whether or not 0.1 mole of substances had the same amount. The most common response was that they had different amounts. However it was clear in the displays that all the 0.1 mole samples had different volumes.
Molar volume applies to gases only.	Demonstration of the difficult encountered when trying to measure mass by trying to weigh mass of air enclosed in a balloon.	This strategy was used as a transition from the relationship of amount to number of particles to the relationship between amount and volume. This strategy was meant to help learners to appreciate that in general for gases, volume is used to determine amount instead of mass.	I anticipated that learners would appreciate that it was convenient to measure the volume of a gas rather than its mass and that the molar volume only applies to gases only. However, such an approach may imply that mass is not used for gases yet a gas is also matter.
All sub-atomic particles contribute to the mass of an atom and that one can tell the mass of a substance by looking at the size of particles.	Learners count the number of protons and neutrons in particles and record these next to the mass of the substances.	Learners needed to appreciate that different substances had different masses due to having different types of atoms as a result of different number of nucleons. Electrons do not contribute to the mass of the atom due to their small relative mass.	Learners used the microscopic models of particles to count the number of protons and neutrons and concluded that different substances have different numbers of nucleons and therefore even though they have the same amount substances would have different masses. During discussions other misconceptions may surface such as that the type of bonding may contribute to the mass of the substance.

Table 5.1: Mis/conceptions and strategies employed

Science being a practical subject it implies that the teaching and learning of science should be done through engaging learners in some kind of activities to solve problems. My initial planning and execution of the lesson including the learners' activities fell far short in as far as indicating the consideration these strategies in my teaching approaches (appendix 1, LsP1). However because of being accustomed to traditional practices I tended not to engage learners regularly on practical activities let alone when teaching stoichiometry concepts.

As a result conceptual change strategies, argumentation, open enquiry, demonstration, experimentation or practical activity, case studies and role playing amongst others were never

employed in my lessons. However, I attempted to employ some of these strategies in the enacted lesson. With regards to practical activity I adopted **Bybee's 5Es** instruction strategy during the lesson enactment. This instructional strategy value learners' prior conceptions and allows for connections between the learners' prior conceptions to the science conceptions. This was evidenced by the engagement of my learners with everyday life experiences about some terms and how such terms were related for instance the relations of the term amount with volume and size. Learners then moved on to engage in activities and later gave explanations or discussions on their findings during the enacted lesson. These are the initial stages of Engagement, Exploration and Explanations in Bybee's 5Es instructional strategies.

Some learners, after figuring out how to measure the required moles by first performing a calculation, they then later weighed the mass on a scale. The following learners' written text shows the calculations that the learners performed using measurements that they obtained from the practical activities.

Handwritten calculations on a piece of paper:

For 1 SPATULA LOAD

$$n = \frac{m}{M}$$

$$= \frac{0,43}{23 + 35,5}$$

$$= 0,01 \text{ mol}$$

For 3g:

$$n = \frac{m}{M}$$

$$= \frac{3}{23 + 35,5}$$

$$= 0,05 \text{ mol}$$

NaCl

Figure 5.27: LPK on the calculations based on results obtained from the SOIS (LWT2a, appendix 7)

By engaging in such a strategy learners own the learning process and the product of the process in that they use what they obtain and then transform it into conceptions that they can deal with in problem solving. This again illustrated the learners' abilities in employing their procedural skills in solving problems being enhanced by creation of enabling environment with the help of the science oriented instruction strategies that I used in which the various components of PCK were integrated. This strategy is of importance when trying to bridge the gap between macroscopic and microscopic as attested to by one of the comments made by a

member of the lesson study group as seen in the following excerpt of the transcriptions of the lesson study meeting.

Expert 2 Ja. And then straight after the activity there were some calculations, weren't there? Ja, they had to actually calculate the amount of each of the substances from the mass they got. And in the previous lesson, the calculations were only left to the end. But I think what is going to make this more powerful, that continual link between macro and micro. [post LSTM]

Figure 5.28: An extract highlighting the value of linking the levels of representation (post LTSM2, appendix 11)

Such actions indicate a positive shift in the development of my PCK with regards to the use of science oriented strategies to learning. I have learnt that different strategies can be used within a single lesson in order to approach different concepts and that bridging the gap between various levels of phenomena through practical activity is critical in helping learners understand stoichiometry concepts at the different levels. Collaboration within the lesson study group enriches learning environments by way of providing and sharing ideas about how to approach some concepts.

At the same time thinking beyond the ordinary could help one to shift from traditional teaching practices to strategies that may foster learner understanding of science concepts. By performing a practical activity and then engage in mental activity based on the results of a practical activity helps learners to understand the underlying science concepts. This became a wakeup call for me to try and consider ways of making the science concepts accessible to learners before teaching a lesson by considering a broader range of Science Oriented Instructional Sequencing strategies. This would demand that I look at possible strategies that can be used to teach the topics in the planning stage and engage in reflection on approaches that I employed in my previous lesson.

Explanation of concepts and guiding learners when they engage in activities is an important teaching strategy in that the language use by the teacher may help learners construct science ideas. Language issues do not only emerge from the learners as described in section 5.1.2 of the **learners' procedural knowledge** but also on teachers. The careless use of language can hinder the learning process. This occurs when language or words are used without due consideration to their impact on learners' understanding of science concepts and the learning

process. Such lesson episodes in which language issues surfaced enabled me to reflect on actions and reframe the ideas during and after the lesson enactment.

On the other hand the conversations could be indicative of the learning process that was taking place. According to Gee & Green (1999) one may think of (genuine) conversation as a building process in which the participants may be engaged in various social building tasks. This entails assembling situated meanings about reality, present and absent, concrete and abstract (Hafpor, 2007). In a way in this conversation I was involved in a kind of situated learning about my practices in real classroom set up. At the same time the findings from such interactions shows that language employed during lessons has direct impact on the outcomes of the lessons especially on how learners would tend to think; reason and model their ideas alongside those of the teacher.

When practical activities are involved in the lesson implementation, they enable learners to use cultural tools such as language as they interact with one another. It has to be noted that for effective formulation of concepts learners had to appropriate the relevant language to describe phenomena. This meant that I pay particular attention to the language that I employed during the lesson, albeit with lack of consciousness in some cases. The language comprised words that are were not necessarily mine but those that I had appropriated from my interactions with subject matter and experts within the chemistry education field in the lesson study meetings.

The appropriation of such words by me was much akin to learning. I was extremely elated to observe my learners engage with the tasks and when they used science terms to explain their ideas, an indication of the creation of a positive learning environment. From the views about the Nature of Science it can be gleaned that science is not just investigation but also entails sharing of results, concerns and questions among a community of scientists (Edelson, 2001).

By providing my learners with the means to engage in science activities I was enabling them to acquire a body of scientific knowledge that was integrated with an understanding of science, tools, techniques and social interaction. In a way I was attempting to put into the hands of learners the tools and techniques of scientists with their context of learning stoichiometry concepts. This is indicative of a culture of learning that was shifting from one in which I was the dominant figure to one in which learners also expressed and shared their ideas. I have learnt that paying particular attention to language use is of critical importance as learners would tend to arrive at answers based on what has been said in the lesson especially

if the statements emanate direct come from the teacher. This lesson and participation in the lesson study and self study served as an eye opener to the way I should plan for my future lessons. Through the interactions with my learners and peers I was able to gain some deeper understanding of how my learners reason especially on formulation of science concepts the kind of language that can be employed to prevent the formulation of wrong conceptions how the particle size contributes to mass of an atom, these are attributes that are difficult to acquire in isolationist working environment but those that can be acquired through colloquial discussions such as in lesson study groups.

However there is no guarantee that such instructional strategies would always lead to desired results. For instance, failure to move to higher levels of Bybee's 5Es strategy could have been necessitated by my practices. After analyzing my talk and questioning skills in the video (VLT, appendix 12), I noticed that in some instances learners were not given chances to give explanations to their responses. Instead I tended to direct learners to model answers. These findings show that failure to give learners the opportunity to explain their ideas may actually stifle learning as they may not get a deeper understanding of science concepts. By not giving serious thought to learners utterances and not allowing them to explain further their reasoning could mean that I stifled the learners' argumentation abilities and possible conceptual change as further probing could have unearthed students' difficulties. At the same time failure for such strategies to meet the desired outcomes indicates that some of the traditional approaches are resilient and therefore very difficult to change. In the post lesson meeting one of the experts in the lesson study group suggested further probing on the learners so that they give explanations to their responses so as to tap into their ways of thinking. This is seen in the following excerpt in one of the lesson study meeting that was meant to give feedback on how the enacted lesson had progressed and a suggestion was made on what can be done to encourage conversation.

Thabo(me): Ja, it was relatively easy. Except (?) when they're presenting (?). To emphasise that, instead of just saying (?12:48) they should actually state what they think (?)

Expert 1 Maybe what the teacher must do then is to...if the kids don't ask questions is to say, explain what do you mean by this? Explain what you mean by that? Because that then models it for the class. And that's like what is difficult (component?13:11). With the conceptual teaching strategy, which.... is... [LsM2]

Figure 5.29: An extract showing contributions on what can be done to probe learners understanding (LsTM2, appendix 11)

In addition to helping learners gravitate towards higher levels of **Bybee's 5Es** instruction strategy, this approach of engaging learners with follow up questions could help transform traditionally teacher dominated classroom to one where learners participate actively in the lesson in which their ideas are catered for in the teaching and learning process. The strategy that was used to concretize the abstract ideas through practical work had a positive impact on students' learning. Learners were able count the protons and neutrons in given pictures and then made conclusions about the mass of the atoms. The previous excerpt indicates the importance of exposing one's practices to the critical friends for scrutiny. While I could have been satisfied about my practices, constructive criticism from the members of the lesson study group helped me to be aware of my weaknesses. Posing a range of questions and rephrasing of questions helps to probe and capture learners' views.

5.1.5 Curriculum saliency (CS)

From my own understanding curriculum saliency is wide ranging and includes having in mind the structure of concept sequencing, knowing which concept are critical and which ones are peripheral and how these concepts build upon each other. Signposting of lesson ideas is one key aspect of curriculum saliency. The contextual factors drawn from the enveloping change environment such as resource availability in terms of the expertise provided me with the opportunity to interact with the mole concept with some degree of confidence. I was enabled to identify the key concepts and to suit my situation and ability. I managed to structure these for the benefit of my learners in the classroom. This lies within the action and practice domain of the LTtP model. This framing and reframing of concept sequencing allowed me to have a better understanding of how to sequence ideas and also help learners to grasp the mole concepts during lesson enactment.

Lesson plans should inherently indicate the topics or concepts that learners should understand at the end of a teaching and learning process. Failure to precisely state the key aspects of the topic may result in the omission of these during teaching. While the lesson plan (LsP1, appendix 1) that was used prior to intervention shows the content that learners were supposed to know, it however is not specific about what exactly students should know.

When contrasting this lesson plan with the one (LsP2, appendix 2 that was used during the implementation stage marked differences are visible. The specific content that students were expected to know at the end of the teaching and learning process were explicitly stated. The CoRe (appendix 5) also augments this observation. These specific concepts of the curriculum

saliency were articulated during lesson presentation. The extract below shows the specific content that was planned in the enacted lesson.

Core knowledge	
•	The amount of substance is one of the seven fundamental quantities measured in science. The symbol n is used to represent the quantity amount of substance and the mole is the SI unit for the amount of substance.
•	In chemistry when we refer to the amount of substance we are referring to a measurement of the size of a sample in terms of the number of elementary particles in the sample. Amount of substance does not refer to the mass of the sample, or the volume of a sample.
•	The same amount of any substance has different masses because they are made up of different kinds of atoms.
•	The mass of one mole of any substance has a mass that is equivalent to its relative atomic/molecular/formula mass and this mass is called the molar mass. The molar mass of any substance can be determined by using the relative atomic masses on the period table due to the equivalence of the mass of one elementary particle (measured in atomic mass units) and the mass of one mole of the substance measured in grams per mole.
•	One mole of any gas occupies a volume of $22,4 \text{ dm}^3$ at standard temperature and pressure. Standard temperature is 0°C and standard pressure is $101,3 \text{ kPa}$. If the temperature or pressure changes the volume occupied by the gas also changes. Molar volume only applies to gases.

Figure 5.30: An extract of the enacted lesson plan showing specific content taught during the lesson (LSP2, appendix 2)

At the same time curriculum saliency deals with shelving some concepts while exposing others at specific stages of the lesson. This played out during the implementation of the lesson when I shelved the definition of the mole until specific activities had been done. In addition, in order to enable learners to own the learning process I requested them to describe the mole concept, and this was followed by an attempt to come up with the definition of the mole using learners' ideas. This was captured in the video analysis template (VAS9, appendix, 13).

17:51-20:45 VAS9	Teacher asks learners to define the mole from their previous knowledge. Use of the prepared transparency to define the mole. The mole as a counting unit shelved for the later part of the lesson.	No. The plan was to expose definition to the learners, but I thought it was important to work from the students ideas as this was part revision of the concept.	Science oriented instructional strategy and Curriculum saliency	Discussion on the mole was based on the definition given by learners. They referred the mole as the amount that contains the same number of elementary particles. Particles that they referred to were then identified. The discussion focused more on the mole as the amount than as a counting unit, an aspect that was
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Figure 5.31: An extract of video analysis demonstrating curriculum saliency (VAS9, appendix 13)

In addition the activities that were designed for the learners show the need to include conceptual problems in lessons as shown in one of the activities written during the lesson enactment (LWT2b, appendix 8). To be able to include such knowledge there must be sound understanding of the subject matter knowledge. In the lesson study meetings, prior to lesson enactment I sought to improve my subject matter knowledge as shown by my contributions in the form of questions or comments (LsTM1, appendix 10). At the same time the sequencing of concepts within the lesson plan (LsP2, appendix 2) shows a greater consideration of the curriculum saliency, a feature that is nonexistent in the teaching artifacts that were used before the intervention stage (LsP1, appendix 1). The following extract of lesson plan indicating areas that are marked in red and blue in the lesson plan was used during the implementation stage.

0.1 mole of compound and relative formula/molecular mass of compounds. Ask learners do 0.1 mole of different substances contain the same amount? Will they have the same mass? I added these questions at this stage. (Predict, observe and explain) Learners keep their samples for display at the end of the lesson. Learners calculate the number of particles using the relationship $n = N/N_A$ Learners respond that the number of particles for each substance is the same.	0.1 mole of compound and relative formula/molecular mass of compounds. Ask learners do 0.1 mole of different substances contain the same amount? Will they have the same mass? I added these questions at this stage. (Predict, observe and explain) Learners keep their samples for display at the end of the lesson. Learners calculate the number of particles using the relationship $n = N/N_A$ Learners respond that the number of particles for each substance is the same.	Transparency: with the number of particles is relationship between of substance, it helps (transparency) the amount of substance and mass relationship (done at end of lesson) Refer to Silber (textbook) for relationship between mole, amu and Ar or M	Teacher activities	Learner activities	Assessment (what, when and how)	Resources (LSTM)
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Figure 5.32: A part of the enacted lesson plan indicating the re-arrangement of concepts (LsP2, appendix 2)

In order to plan for meaningful teaching and learning process, it meant that I use my knowledge of the subject so that the concepts can be presented in a logical sequence. The concepts were arranged in such a manner as to allow concept progression during the lesson. This is evidenced by the re-arrangement of concepts in the collectively drafted lesson plan. This is one aspect that is evidently missing prior to enactment of lesson. As a science educator I have the requisite knowledge on stoichiometry concepts and strongly believe that during teaching there must be a logical flow of concepts during lessons for the understanding of science ideas. This knowledge, belief and attitude domain with regards to curriculum

saliency was never explored in my day to day lessons. However, through engagement with myself in reflecting on my practice and with peers and researchers in the lesson study-group (*the stimulation and challenge domain of the LTtP model*) I was empowered to engage with the concepts and how they can be presented during a lesson.

Ideas on what makes the mole concept difficult to teach and how to sequence ideas and strategies to use are clearly evident in my teaching resources. When engaging with aspects of curriculum saliency one encounters cognitive challenges on how to sequence the ideas and ‘stick’ to the lesson plan. Sign posting the ideas during the lesson helps to direct and focus learners on the objectives of the lesson and helps to present a logical sequencing of ideas. However this has its attendant challenge of keeping in mind the concepts that are being taught at the same time trying to ascertain understanding of concepts by learners. This helped me to think and reflect on various issues that were unfolding during the lesson. Put simply I was engaged in *reflecting in practice*. The comments that I made show the extent of the challenges that I faced while I was engrossed in teaching the lesson. I commented on this part during collaborative sessions as indicated in the following extract.

Expert 2: *Stop, let's look and consolidate (?). And for me it's something that we have not seen them because we haven't really explored our TSPCK in practice. And I think one of those would be when you stop and summarise. (?) learning issues, general learning issues on (?7:10).*

Expert 1: *From what?*

Expert 2: *From a learning point of perspective, from a learning perspective, right? From the learner's point of view. If you look at that the issue of time is an element that comes irrespective of what theoretical concept (?7:33).*

Expert1: *Learning takes time.*

Me: *Ja, I also think it was a (?12:30), especially the implementation of the lessons. It's not easy to implement a lesson that is (?) that will allow (?). We have to keep in mind the issues that we discussed, something comes to the fore, other things (?12:52) you have to get yourself to the destination. But I think (?) is the implementation part, where do I (?), got here, how am I (?). [postLsMT2]*

Figure 5.33: An excerpt showing how I reflected on aspects of curriculum saliency (post LsMT2, appendix 11)

In this instance I was reflecting on the challenge that I encountered when implementing a collectively planned lesson in which I was expected to meet the objectives of the lesson study group which was that of an improved engagement with ideas discussed in the meetings and also the objectives that I had set for myself. Curriculum saliency in this regard concerned signposting the next ideas at the same time pausing and summarizing the learnt concepts

during lesson enactment. Hence I had this challenge of dealing with issues that came to the fore and those that receded to the background.

Anticipating student difficulties and designing activities to address such difficulties was missing prior to the enactment of the lesson but this aspect was not only planned but also enacted during the lesson as indicated in the stimulated recall sessions within the lesson study meeting. With regards to dealing with gases I had to show learners that amount of gases is related to the volume and that volume is usually preferred instead of mass. I therefore sought to create a discrepant event by trying to weigh the mass of a gas in a balloon on scale which I could not. I had anticipated that learners may have questions on why gases may be treated differently and also for them to appreciate that the amount of gases can also be determined thereby attempt to link the various levels of representations. After this stage I had to introduce and discuss the relationship $n=V/V_m$. This aspect of curriculum saliency shows that I had to think and rethink about the ways in which I could make the concepts easily accessible to learners which in a way is part of the *practice and action* domain of the LTtP model. The conversation that follows was based on the observation made by an expert regarding the demonstration that I had employed during lesson enactment.

Expert 2: Thabo was that balloon planned, or did you plan to do that? Or did you just see the balloon and...

Thabo (me): I did plan it. I was hoping to show that its difficult to measure the mass of a gas, instead for gases volume is preferred. (?21:18)

Expert 1: But it worked very well.

Expert 2: I think that was a moment of unplanned...

Expert 1: It worked. It was convincing as well...

Expert 2: Ja.

Expert 1: The jar. Because especially they don't really know what (?19:28). I also...we talked about the coins, so you're going to fix up the coins with Willard. And I like the difficulty on weighing the gas. I thought that...

Expert 2: Yes, that was brilliant.

Expert 1: That was brilliant.

[post LsTM2]

Figure 5.34: An excerpt showing demonstration of my understanding of anticipated students' difficulties in relation to gases (postLsTM2, appendix 11)

This activity was meant to address the possible misconception that learners may assume the molar volume applies to all substance instead of gasses only. In an attempt to dispel this notion by using this analogy learners may therefore think that the mass for gases cannot be used to determine the amount of a substance presumably because gases are mass less. However I managed to pick this up during the lesson and highlighted that it was possible to determine amount when given the mass of a gas and that over and above a gas is also matter.

This indicates the shift that I was undertaking in as far as devising some ways of making learners appreciate why some concepts are preferred to others when dealing with gases.

After partaking in this study I have a strong conviction that curriculum saliency is a result of the knowledge gained from actual classroom practice and from the knowledge gained formally through professional development programs and that this PCK aspect improves with experience. It however needs to be given due recognition in practice if it is to be effectively exploited. The ability to engage with this aspect during planning, reflection and enactment of the lesson points to a positive shift. One critical issue that comes to the picture when dealing with curriculum saliency is the subject matter knowledge. It became clear to me that an understanding of the discipline one teaches is crucial not only in explanation of concepts to learners but also in allowing the educator to structure the science concepts, identify which concepts are central and those that are peripheral. This would allow logical concept sequencing and prevent premature exposure of ideas which may lead to misunderstanding of some concepts.

5.5 Summary

The findings highlighted in this section are drawn from the analysis that was done using the LTtP framework. The varied nature of data sources and the wide scope of the LTtP framework open the doors for unlimited possibilities that can be explored through this model. I showed how the aspects of the research questions were addressed by the multiple data sources. Some considerable shifts were evident in some PCK aspects such as Learners' Prior Conceptions/misconceptions (LPC), Learners' Procedural Knowledge (LPK), Curriculum Saliency (CS), Representations, Models and Analogies (RM&A), Science Oriented Instructional Sequencing (SOIS) strategies between the pre, during and post lesson enactment. These were evident in a number of data collection tools. The learning environment was impacted by the PCK development as it changed from that of teacher dominated talk to that of active engagement of learners in activity as indicated during group work and presentations. Engagement with these tasks was a challenging experience. Eliciting and tracing the development of these PCK aspects was a huge task and this illustrated the subtle nature of PCK. Over and above these improvements were a result of the thorough planning and reflections within the enveloping change environment. The conclusion of the study is presented in the following chapter.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

Introduction

The main aim of the project was to explore the development of my PCK as I taught stoichiometry concepts in grade 11. Stoichiometry concepts that are related to the mole, as physical quantity, counting unit and its relationships to other physical quantities such as mass, volume and number of particles were taught to the learners. These concepts are fundamental to the general understanding of chemistry topics and therefore critical for high performance in Chemistry.

This study involved the use of a variety of data collection tools. The data were analyzed using an analytical framework that draws from constructivism perspectives. Some critical issues and ideas emerged from the analysis of the data. These related to the aspects of PCK and how shifts were identified using the LTtP model as an analytical framework. The way the planning, design and implementation of plans were affected during this study is discussed. I also discuss findings about how the knowledge about my learners and how they learn changed when I taught the mole concept as I engaged in self study. I bring to the fore the research questions that this study was meant to address. In essence, I present the conclusions that I drew from the findings of the study and shed light on further areas of research including limitations of the study.

6.1 Addressing the research questions

This project was a self-study on my PCK while teaching stoichiometry topics in particular the mole concept. As such it had a huge significance to me as an individual in that it involved the study of my own practices on a specific topic in Chemistry within a collaborative forum. In particular the study sought to address the following research questions.

Main research question: How is my content knowledge for teaching stoichiometry to my grade 11 learners evolving as I engage in a self-study within the learning study?

- 1: How is my knowledge of learners and how they learn, specific to the topic of stoichiometry shifting, as I engage in self-study?
- 2: How is my knowledge of creating effective learning environments shifting as I participate in this study?

3: How are my metacognitive skills of planning, reflecting and enacting in my own and my learners' learning affected as I participate in the self study process?

To answer these questions I had to use the LTtP model of PCK as the analytical framework. Using this model I was able to trace the various aspects of PCK using data collected from multiple sources. By tracing how the different aspects of PCK played out at different stages of the study I was able to identify the shifts that took place as I participated in self study.

The use of multiple methods is one of the disposition features of self-study. It has to be noted however that no single method could capture data to address a specific question. Instead there was an overlap of issues across research questions and data collection tools. For instance the knowledge gained in the aspects of PCK had an impact on my metacognitive skills and ultimately this impacted on the knowledge that I gained about how my learners were engaged in the learning process. During the lesson there were also indicators to the manner in which my practices impacted on the learning environment. At the same time it was possible for a data collection tool to address two or more research questions. Triangulation has been noted as ensuring trustworthiness in self-studies, hence the need to have a variety of tools. In chapter 5, I described findings that were drawn from the data sources and how these findings pointed to any possible shifts in PCK aspect and how these shifts impacted on learner understanding of the mole concept and my metacognitive skills.

The main research question sought for the changes in the development of my content knowledge for teaching with respect to stoichiometry concepts. When addressing this question I was in a position to identify some shifts in my practices with regards to the content knowledge for teaching the stoichiometry concepts. I not only made an attempt to show how the various aspects of PCK emerged while I undertook this study but also how these aspects changed to some extent throughout my course of engagement with the study.

The subject matter knowledge (SMK) is a key factor in the LTtP theoretical framework and I would argue that it impacts all other PCK aspects to a greater extent. For instance without this knowledge it may be difficult to structure the content and to explain the content for ease of understanding by learners. The way my subject matter knowledge evolved between the pre and post engagement stages had a positive impact not only on learners' understanding of concepts but also my learning. Hence this evolution of subject matter was not only beneficial to my learners but to me as a *learner* teacher as well. This is evidenced by the products of the process that I was part of namely content rich lesson plan and the CoRe and my actions of

attempting to make the mole concept easily understood by learners during the lesson enactment. The use of the prior instruction conceptions helped learners to appreciate the differences between the mole and other physical quantities that are not only associated with the mole but also confused to mean the same thing as the mole by learners. My overall impression is that the concepts were generally packaged into forms that were accessible to learners. This was manifested in the learners' procedural knowledge when they solved conceptual problems and during presentations of summaries of the stages of the lesson using mind maps and solutions to classroom activities. All these are indicators to a marked shift in the way I presented the concepts for the benefit of the learners.

Being able to rearrange the concepts for my learners and engagement with concepts during the lesson and in lesson study meetings are some of the noteworthy changes that occurred in me as an educator. The implication is that I managed to take decisions during my practice about how to approach some ideas, how to gauge learners' understanding and the kind of knowledge that the learners were taught. In this way I was beginning not only to be aware of my actions but also to understand and justify some practices and ultimately to be responsible for my learning process. In this way I think lesson study in general and self study in particular much like a learning study responds to the teachers' professional needs and concerns with regards to teachers' engagement, ownership and decision-making within their classroom (Nilsson, 2014).

Collaboration has been identified to be critical in self-studies and as such, this project provided some insights emanating from different perspectives within a lesson study group into the conceptions that students have about stoichiometry concepts and how a teacher can respond to these. Critical analysis and reflections on the video of the lesson by me and collectively as lesson study group and other data sources were used to identify and trace any shifts in my PCK that occurred in helping learners grasp the scientific concepts within stoichiometry topic. By participating in lesson study, I gained ideas from colleagues and experts in the Chemistry field on how to approach some concepts during teaching and deeper understanding of stoichiometry concepts. Over and above, my interpersonal relations within a community of shared practice improved and this had a positive impact on my confidence when dealing with the stoichiometry topic. The shift would allow me to share some virtues, values and insights gained from project with other colleagues at my work place.

The first sub research question sought to establish how my knowledge of learners and how they learn, specific to the topic of stoichiometry was shifting as I participated in this study. In order to create an environment in which effective learning took place it meant that I seek to use the knowledge of my learners and craft teaching strategies that utilize this kind of knowledge. In particular I focused on how this knowledge evolved over time as I participated in the study.

My experience while partaking in the study was that of learning. Right from the onset I was concerned about the mismatch between my beliefs' and practice in particular with regards to the use of 'constructivism as referent' as put by (Lobasch & Tobin, 1992). I therefore tended not to effectively apply the tenets of constructivism such as use learners' everyday life experiences and engaging learner centered approaches to learning, even though I acknowledged their importance in the teaching and learning process. This therefore compromised my VONS during actual practice. These beliefs and practices did not even translate to be good indicators of my learners' understanding of concepts as observed when my learners engaged in discussion of science concepts or even in performance. This had been the situation prior to engagement with the study. During the enacted lesson, I sought to use my knowledge of learners to engage them in more meaningful learning of science concepts to some extent through discussions and presentation of mind maps.

On the part of learning by my students I agree to the assertion by Chickering and Gamson (1987) that learning is not a spectator sport, students do not learn much just by sitting in classes listening to teachers, memorizing pre-packaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences, and apply it to their daily lives. When they talked I was able to gain insight into the way they reasoned and solved the problems. These insights could not have been achieved by analysis of written text hence the video analysis came in handy in as far as getting to understand the thinking processes that learners engage in when solving problems. The finding that learners solve problems mechanically confirmed results found in other studies that learners tend to solve problems algorithmically without conceptual understanding (Stamovlasis, et al 2004).

I believe the same view made by Chickering and Gamson (1987) can be extended to the teacher's learning. In other words I have to be concerned about my practices with regards to how they affect the learners that I teach and how best I can improve them for the ultimate benefit of my learners. In this way I would be engaging in reflecting teaching practices. As I

participated in this study I had my own expectations and interests as an individual at the same time other members in the lesson study group had certain expectations from me. In other words I expected to gain some insights into the PCK construct from the members, at the same time my colleagues expected to gain some ideas from me. Hence to be a participant entailed getting to reflect deeply about issues of discussion during meetings so that I gravitate to the same level as my colleagues and subject specialists. Thus I had to engage in learning and in particular *learning to teach* the mole concept.

For me each session that I attended was invaluable and an eye opener to the other possible avenues of my professional growth and self-directed learning. The information that I got from the sessions about the concepts, how to decipher the big ideas of the topic, the need to tap knowledge from context, the need to think about my learners and the different ways of approaching the same concepts impacted positively on the way I view learning. These factors are highlighted in the multiple data tools that I have dealt with in the previous chapters.

The second sub research question sought to address how my knowledge of creating effective learning environments was changing as I participated in this study. Effective classrooms begin by physical arrangement of the resources in the classroom. Although these were not captured in my data sources prior to engagement with this study, the sitting arrangement during the lesson enactment was appealing and ideal for the teaching and learning process. Learners were organized into groups of mixed abilities during the lesson enactment. This was done so as to allow for the various kinds of interactions to take place and also for the manipulation of apparatus and materials and to allow for differential roles to be assigned amongst the members of the group.

Science Oriented Instructional Strategies that were employed during the lesson enactment allowed the various kinds of interactions to take place either during the hands on practical activities or discussion sessions. I was in a position to allow for learner to learner interactions by way of directing questions posed by a learners' to other learners for their response. During the process I took a stand back position to listen to their utterances. Such an action not only allowed me to listen to their ideas and ways of reasoning but also to get a chance to frame and rephrase my response because ultimately I was supposed to respond to their concerns. At the same time when learners were allowed to talk in their home language the interactions and general contributions increased during the lesson enactment. At the same time as the more

capable peer I was supposed to guide the learners in their thinking processes. However not all my actions promoted the kind of the learning environment that I sought to create. For instance directing learners to model answers did not allow learners to engage in procedural knowledge skills such as argumentation and possibly higher levels of Bybee's 5Es instructional strategies. The implication could be that their potential to emulate the practices of scientists using science cultural tools could have been curtailed to some extent. Contributions from the learners verbally, and in written form provided guide lines on how to structure subsequent stages of the lesson. In this way learners made a contribution to the lesson and could have developed a sense of ownership of not only the process but also the product which was the knowledge about the mole concept. Nevertheless the planning and the enactment of the lesson indicates that I valued the contributions that learners made and this helped to stimulate various modes of interaction such as learner-learner and teacher-learner interactions.

The metacognitive skills were addressed by the third research question. This question sought to establish how my metacognitive skills of planning, reflecting and enacting in my own and my learners' learning were affected as I participated in this self study. In this study metacognitive skills had to do with how the lesson plans were designed, how I engaged learners with the activity within a context, how and why I sequenced the concepts in a particular order during the implementation stage. In essence they encompass my planning, reflecting and enacting of the lesson including an understanding of how this impacts on the learning by my learners.

As already highlighted in chapter 5 there was a significant change in the manner in which planning was done from prior to enactment of the lesson. This difference is not only found in planning but also depicted in the manner in which I reflected on various issues which suggest significant impact on the implementation stage. Lesson planning was not a product of textbook but rather born out of meaningful and thoughtful engagement with not only the concepts but also the context in which the learning was taking place with the help of the stimulation and challenge domain of the LTtP model as provided by the lesson study group. By using tools such as the CoRe to plan for the lesson it implied that big ideas of the topic were identified and that learners' possible conceptions were clarified. As a result it meant that the lesson planned was focused and tailor made for the kind of learners that were in my

classroom during the lesson enactment. This suggests that development was realized in as far as my planning skills were concerned.

It has to be noted that planning and teaching any subject are complex cognitive activities and, in these processes, teachers must apply knowledge from various domains (Resnick, 1987). The domains may include considering the context in which the teaching and learning process takes place such as learners' background, possible conceptions on a topic, available resources and possible teaching approaches and teacher attributes such as experience and professional qualifications. Such factors to be considered in the design and planning of instruction can be drawn from the enveloping change environment of the LTtP model. In this regard I considered learners' everyday experiences on terms such as amount and counting systems to relate these to science ideas. I considered their cultural linguistic background and social settings such as group work to allow learners to express themselves and engage in some form of interactions. I was able gauge their level of understanding, how they thought and ultimately formulated some science concepts such as tending to focus on the concrete and attempt to link to the abstract science ideas during enactment of the lesson. I listened to the learners' responses during presentations and paid particular attention to the language they used in explaining or describing their conceptions.

At the same time, teachers' inadequate understanding of the knowledge structure of mathematics and science is problematic to the teaching and learning of these subjects (Taylor & Vinjevold, 1999). This situation is worsened when teachers work in isolated environments where collaboration with other colleagues is not possible and where professional development programs are not part of the actual teaching practice in classrooms. In this study I structured the ideas in a sequence that allowed progression of concepts during the lesson by dealing with each of the relationships of the mole to the other physical quantities at a time. This ability was bolstered by the collaborative environment of the lesson study group as opposed to an isolationist environment that is normally the situation that most of the teachers find themselves in. On the other hand Magnusson, Krajcik & Borko (1999) suggest that effective science teachers know how to best design and guide learning experiences under particular conditions and constraints to help diverse groups of students develop scientific knowledge and an understanding of the scientific enterprise. The enacted lesson was structured in such a way as to allow learners to engage in activity and make presentations at

various stages. This in a way showed a better improvement in the way I organised the structure of the lesson in an attempt to create an ideal learning environment.

Such a strategy was drawn from my knowledge of the subject and beliefs that I hold about how physical science should be taught and learnt a part of the *knowledge and beliefs* domain of the LTtP model. The implication is that science teachers' knowledge and beliefs have a direct effect on all aspects of their teaching (Carlsen, 1999) as well as how and what their students learn (Magnusson *et al.*, 1994). Teachers' personal views about content influence what goals they set for their students as well as how they implement curriculum (Gess-Newsome, 1999).

The success of the design and planning of the lesson was to a greater extent attributed to the collective effort of the lesson study group that provided the enabling change environment on my part. I intend to use knowledge that I gained from this study to improve the planning for every lesson that I would teach through reflection as I now believe that effective learning occurs in situations where this learning is taking place, and for me it is the classroom as well as in discursive collaborative meetings with colleagues or more able peers.

The reflecting ability is critical, as previous studies have shown that teachers generally experience challenges when they attempt to engage in reflective teaching as highlighted in section 4.2. I was able to use the tools that I appropriated from the *stimulation and challenge* domain as a result of peer collaborations such as ideas drawn from group to effectively engage in reflection not only during the enactment of the lesson but also after this stage. The enveloping change environment with regards to learner factors such as willingness to talk using whatever language and sharing ideas, their prior instruction conceptions was also helpful in as far as helping me to reflect *in* and *on* my practice. At the same time teacher factors in the enveloping change such as my experience and the basic knowledge that I gained from undertaking some professional development courses and confidence in practical work ensured that some materials were utilized effectively for the benefit of learners and myself.

It has to be noted that even though some of my abilities were not a product of engaging in this self study these were rather dormant during my practices before engaging in this study but were rekindled by partaking in this study. Lesson study meetings and observation of video recorded lessons were in effect ways of generating collective PCK with other members, although I did not really recognize it that way at the time. I have come to understand and

appreciate that reflecting on this experience overtime is equally valuable in terms of my understanding and development of PCK as I partook in this self study. In other ways grasping the notion of PCK has been, and continues to be an ongoing process shaped by the context and experiences as I teach my learners. At first I did not share a common language for talking about teaching in the lesson study meetings, but as time went on I began to grasp and internalize the language used by the experts in the lesson study group with regards to the PCK construct which in essence bolstered my reflecting ability.

The CoRe as a tool that can help to decipher the teachers' PCK was one of the terminology or language that dominated the discussions during lesson study meetings. The ability to develop a CoRe helped me to be aware and gain some deeper understanding of the language used in stoichiometry concepts such as the various levels such as sub-microscopic, macroscopic and symbolic levels in which they can be represented. During practice teachers tend to transition between these levels unknowingly and this may confuse learners when concepts are not clearly well articulated to the learners. Having appropriated such language from the study I was able to differentiate the different levels at which I dealt with the stoichiometry concepts, as evidenced when learners engaged on practical measurement of the mass followed by calculations based on what they had obtained from the activity. In such situations it was possible to gauge the learners' understanding of the concepts at both macroscopic and symbolic levels. Thus in a way my reflecting ability was bolstered by the language that I had acquired from the lesson study group meetings.

However it can be gleaned from the findings that the ability by a teacher to develop 'eyes' to see children is not a simple task (Lewis, 2002). Nevertheless making efforts to think about learners' talk can help to gain insight into the way they reason as was noted in the chapter 5 when a learner looked at the size or volume of the samples of the substances and then concluded that the amounts were different without thinking about the meaning of amount in science.

In general, the study had a huge significance to me as an individual in that it involved the study of my own practices on a specific topic in Chemistry within a collaborative forum. It helped to expose my strengths and weaknesses specifically within the stoichiometry concepts and in teaching science in general to myself and to the public domain in the form of the lesson study group. Knowing one's self is a painstaking experience and very few people would be bold enough to know their weaknesses but I believe getting to know one's self

could help to achieve self-efficacy within one's profession. The study gave me the opportunity to learn more about my students, on how and why they think or reason the way they do, the content, and how to specifically teach stoichiometry concepts and science in general.

6.2 Significance of the findings of the study

The findings of this project may be important to practicing teachers in that they provide guidelines on how they can restructure their knowledge within a particular topic for the benefit of their learners by engaging in the various aspects of PCK as depicted in the LTtP model. An important aspect of self-study that is crucial in understanding this methodology is embedded in the desire of teacher educators to better align their teaching intents with their teaching actions (Loughran, 2004). Teacher educators who engage in self-study of their practices in order to achieve their teaching efficacies may be interested in knowing and understanding why I had to engage in some actions and not others in this study. Hence the findings from this project may be useful to these stakeholders in education who are critical in educating, professionally developing and providing support to educators.

In addition the model can be an invaluable tool in providing support to teacher learning through the framing and reframing of practices and beliefs between the various domains. Over and above it encourages educators to take stock of their teaching practices and possibly engage in reflective practices in an attempt to address the gaps that may exist between their practices and what they hope to achieve, in essence self-efficacy. The enveloping change environment can be exploited through identifying the enabling and constraining factors to learning. Once these are identified critical reflection is required in order to frame and reframe practices during implementation. This framing and reframing can also relate to one's set of values and views about the nature of science. As can be seen in findings I had the correct beliefs about how science should be learnt but I rarely put what I believed into practice. Henceforth I had to find a platform in the form of self-study to critically focus on PCK that is related to stoichiometry topic and engage in some kind of learning within a particular context.

A number of strategies are used as vehicles to promote professional growth and development of practicing teachers as already highlighted in Chapter 1. Self-studies and lesson studies are more often times ignored in the professional development of educators. Such research methodologies can contribute a lot towards professional development of practicing teachers. Addressing self can help in the understanding of teaching and ultimately learning which

could have significant role in learner performance. This project was a self-study of my practices within real educational contexts. By and large subject facilitators, subject specialists and teacher educators may be interested in structuring programs that are tailor made to meet the needs of professional growth and development of educators within their classroom settings. Inclusion of courses inclined towards reflective teaching for in-service programs could help practicing teachers and student teachers to develop skills that may be critical for their professional development.

At the same time learners are set to benefit as they would be in a position to identify common misconceptions and possibly learning strategies using their procedural knowledge which could then lead to better understanding of concepts and better performance. To improve this study and possibly broaden its scope I suggest some recommendations in the following section.

6.3 Recommendations

I recommend that further studies be instituted to investigate the extent to which self-study on stoichiometry PCK could impact on student achievement or performance. This is one aspect that the study initially sought to establish, but I had to change the focus to be more biased towards my learning due to certain circumstances beyond my control such as the time factor and structuring of the study. Hence more work can be done on the relationship between PCK development and learner achievement in science as this aspect was beyond the scope of this study.

There is a general understanding that learning is a lifelong process. It means that learning is a continuous process. This then raises the questions such as; after having developed through self-study how best can the teacher be supported throughout their careers as science educators. This then calls for the need for scaffolding and helping teachers achieve their optimal zones of development which could be emanating from the enveloping change environment in the LTtP model. Hence more avenues to utilize this model can be exploited.

To address the question of validity of findings to a greater extent structured TSPCK instrument tool can be drawn prior to the study and be availed to members of the lesson study so that they may comment and critique on specific aspects of PCK. Such instruments can also be adapted to include learners so that they can comment on some specific PCK aspects in order to evaluate the effectiveness of the teacher's practices. I also recommend that if a self-

study is to be carried out using the LTtP as conceptual and analytical framework, a much longer period of study is needed in order to allow for the reflection and implementation of the cyclical processes and to capture a wide range of issues for broader framing and reframing of practices within a specific topic. This then necessitates that a series of lessons be taught in order to be able to trace the development of PCK within a specific topic.

6.4 Limitations of the study

The study was affected by a lot of factors such as the time constraints and the timing of the study and its positioning within lesson study group (larger project). Only a limited time was available and this greatly affected the way I interrogated some aspects that are inherent in the LTtP analytical framework. One of the critical features of the LTtP model is the framing and reframing of practices based on reflections on prior experiences. This makes the model to be less ideal for studies that are based on a single lesson. After analyzing the model I decided to adapt the model so that the design of this study could fit into the model by using the pre engagement, planning and reflection and enactment stages. However the reflections allowed me to think and make adjustments at various stages of the lesson and also make suggestions on how things could have been done differently for the sake of my learning. I therefore, managed to make the best of it by adapting my study to fit into the framework considering the time constraints and integration of this study into lesson study.

The project was conducted during the third term when most topics had been covered and learners were preparing to write their exams. This then necessitated that the lesson be taught as revision as the topics had been covered during normal teaching time. However instead of seeing this as a disadvantage, I took this as an opportunity that allowed for at least some interaction as it was anticipated that the concepts would be familiar to learners and that learners would benefit out of this revision. Other data collection tools such as PaPer-s could have been used to augment the CoRes. These could have been used to gain insights into the reasons as to why I employed some strategies and not others during my practice.

The choice of certain sections of data and not others could have restricted this study. For instance instead of focusing on a few excerpts from the lesson study meeting transcriptions I could have collected data from all sessions in order to then identify any significant shifts on my PKC and other forms of knowledge that could have been taped by engaging in this study and to provide a holistic picture about my growth and development. The same could be said about the collection of data from other sources such as the TSPCK tool that had statistical

measurements on my performance for pre and post stages. Hence there could be some missing gaps in this study that can be explored further.

On the issue of validity of the findings that is more often times than not a cause for concern in self study methodology I sought to subject the data to the lesson study group so as to ensure that valid findings were reported upon. Members of the group deliberated on the lesson that I had conducted, comments and criticisms were given with regards to how the lesson had progressed. It has to be noted that I had no control over what these members had to comment on or critique and therefore I had to work with what I got from their deliberations. I could have designed some instruments for members to comment on and critique some aspects in order to improve the validity of findings as already suggested in the recommendations section above.

In self-study it is important to expose ones' perspectives and thoughts to critical friends so that any claims of reframing of practice are not idiosyncratic. Thus failure to expose some of the claims and reflections to the members of a lesson study group, the critical friends, was also a limitation to this study. However the validity concerns could have been catered for by the multiple data sources to some extent and the fact that I constantly engaged my supervisor, an expert in the education field on critical aspects of this project such as what categories to focus on and the data analysis process that I engaged in. On the other hand, the multiple data sources could have had negative impact on the findings of this study in that large volume of data could have been collected and this could have impacted on what kind of data was collected and therefore relevant to this study in as far as addressing my research questions. Some of the data could have been concealed in these sources due to the multiplicity of these sources and time constraints. In fact the ability to work with such enormous amount of data and to reduce it into meaningful themes became a challenge to me.

At the same time avenues to explore the transferability of my TSPCK to a different context could have been explored. This could have been done by teaching the same lesson to a different group of learners or teaching a concept that is different from the mole concept within the stoichiometry topic. There could also be need to restructure the lesson to fit within the average period of a normal lesson by reducing or restructuring the number of activities without necessarily diluting the concepts or sidelining key learning areas. I could also have integrated statistical analysis to determine the recurrence of some themes over the period of study.

The findings of this study, being a self study relied greatly upon my reflecting ability. As already highlighted in Chapter 4 in section 4.2 it is implied that reflection is a critical challenge for some teachers. According to Loughran et al, (2006) teaching as a reflective practice implies an active, persistent and careful examination of teaching actions and beliefs that underpin them, so as to continuously improve one's practice as a teacher. This (reflection) is one aspect whose importance I overlooked in the initial stages of the study. The importance of reflection became apparent later when I had engaged with literature and analyzed my data to draw out findings. Reflection seeks to challenge practices that are based on tradition and habits and give an account of how and why certain actions were taken during practice. This would involve critical thinking in order to *reflect on* and *reflect in* one's practice. The implication could be that based on my reflecting ability, I could have reflected on some aspects that I deemed important while others were left out or that some actions were not properly interpreted or that some key issues were not exposed due to my lack of experience on reflective practices. I therefore recommend encouraging, empowering and supporting teachers in reflective practices through engaging more able peers in formal professional development programs.

At the same time in this self-study I engaged in some aspects of action research as I was involved in a study within a specific setting to address issues that were particular to my practice within a specific setting. As with case studies, action research is usually restricted to a single organization making it difficult to generalize findings, while different researchers may interpret events differently (Elden & chilshom, 1993). This study involved grade 11 learners of a particular school within a specified period of time and this could make it difficult to claim that the findings may apply to another group due to different contextual factors.

6.5 Conclusion: My last word

This has been a difficult journey that was worth taking. At first I had this fear of the unknown especially the fact that the theoretical concepts of PCK and self-study methodology were relatively unfamiliar territory for me. This turned out to be the driving force behind my endeavor. As I engaged with literature and interacted with my supervisor and other experts in the lesson study group I began to see the light at the end of the tunnel. I have this compelling desire to explore the LTtP model during my practice as I believe that it is a tool that is relevant to individuals who are willing to engage in self-directed professional development

and could provide supportive framework to one's practice. At the same time Loughran et al (2006) referring to the messiness of teaching notes that being a good teacher requires lifelong learning, implying that one takes charge of one's own personal and professional development.

To this end, though a short journey, I have come to appreciate that learning to teach is not "a process of being but rather that of becoming" as I intend to seek to continue to '*learn how to teach*'.

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Appendices

Appendix 1: Pre lesson plan (LSP1)

Lesson preparation grid
Lesson Plan-1

Lesson preparation			
Teacher: S. P. M. S.	Grade: 10	School: ...	
Topic: Chemical change	Date: 10/08/2015 - 14/08/2015		
Knowledge area: CHEMICAL CHANGE			
Knowledge prior beliefs: ...			
Core knowledge and concepts: Quantitative aspects - The mole			
Teacher activities	Teacher activities	Resources	Assessment methods
Define the terms mole, molar mass, Avogadro's number. Describe the mole as the amount of substance. Relate amount of substance to relative atomic mass. Describe the relationship between the mole and Avogadro's number. Calculate mass, molar mass, number of particles and moles according to $n = \frac{m}{M}$, $m = nM$, $N = nN_A$.	Perform calculations using $n = \frac{m}{M}$, $m = nM$, $N = nN_A$. Relate the mole to the number of particles.	Student's Master Phy. Sc Text book	Class activity by assignment

LPC - solve mathematical problems.

LSP-1

COPY AND PASTED THIS PAGE FOR USE WITH THE PHYSICAL SCIENCE GRADE 10 LEARNER'S BOOK

Appendix 2: Lesson plan for enacted lesson (LSP2)

PHYSICAL SCIENCES: GRADE 11

Context: Grade 11 Revision Lesson planned for Lesson Study	Periods: Double period – 100 minutes
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Purpose of lesson
To revise the mole concept and show the relationships between mass, volume of gases and the number of particles in the amount of a substance.

Big Idea
The mole is the SI unit for amount of substance that is used to help chemists count elementary particles that make up a substance and provides a means to connect the macroscopic views of matter such as mass and volume (of gases) to the submicroscopic view and the number of elementary particles.

Process skills, embedded in the assessment standards you have chosen. (Tick)		
☒	Observing and comparing	☐ Hypothesising
☒	Measuring	☐ Planning science investigations
☒	Recording information	☐ Conducting investigations
☐	Sorting and classifying	☐ Communicating science information
☐	Interpreting information	☒ Calculations
☐	Predicting	

Conceptual links to previous and future lessons/learning	
Previous	Future
- All matter is made up of particles (atoms, molecules and ions) and different substances are made up of different atoms. - The different types of atoms that make up matter have different relative atomic masses because the different types of atoms have a different number of protons and neutrons in their nucleus.	- Molar concentration is the amount of solute per unit volume in a solution. - In reaction stoichiometry the mass or volume of gases is used to determine the amount of substance in order to use molar ratios in balanced chemical equations to determine the mass or volume of product formed / reactants used in stoichiometric calculations.

Core knowledge
- The amount of substance is one of the seven fundamental quantities measured in science. The symbol n is used to represent the quantity amount of substance and the mole is the SI unit for the amount of substance. - In chemistry when we refer to the amount of substance we are referring to a measurement of the size of a sample in terms of the number of elementary particles in the sample. Amount of substance does not refer to the mass of the sample, or the volume of a sample. - The same amount of any substance has different masses because they are made up of different kinds of atoms. - The mass of one mole of any substance has a mass that is equivalent to its relative atomic/molecular/formula mass and this mass is called the molar mass. The molar mass of any substance can be determined by using the relative atomic masses on the periodic table due to the equivalence of the mass of one elementary particle (measured in atomic mass units) and the mass of one mole of the substance measured in grams per mole. - One mole of any gas occupies a volume of 22.4 dm^3 at standard temperature and pressure. Standard temperature is 0°C and standard pressure is 101.3 kPa. If the temperature or pressure changes the volume occupied by the gas also changes. Molar volume only applies to gases. - One mole of any substance contains Avogadro's number of particles and is the number of particles contained in 12 grams of carbon. Avogadro's number is a huge number of particles and is given as 6.02×10^{23} particles. This value has been determined experimentally and the exact number of particles is unknown, but we know it represents a constant number of particles. - Avogadro's number allows us to count (although not the exact number) the number of elementary particles in a given mass of a substance, or the given volume of a gas. - If we know the mass of a substance, or the volume of a gas we can determine the amount of substance and the number of particles. These relationships are expressed mathematically.

	was the same. Learners to predict, observe and explain.				
	6. Ask learners to explain why mass of the same amount, a spoonful of each substance was different. Ask the learners if the same mass of each substance looked like they had the same amount.				
Duration Activity 1 (cont) Developing an understanding of the term amount	Teacher activities 7. Ask learners why the different atoms that make up substances have different masses? Ask the learners why, when they took the same mass, they did not have the same amount? 8. Give learners microscopic models of particles of six substances. Ask them to look at the models. Emphasise that the model only indicates the protons and neutrons in the atoms. Tell learners protons are in red and neutrons in blue. Reinforce that the atomic mass represents the total number of protons and neutrons in nucleus. Ask learners to determine the number of protons and neutrons in the particles. (Indicate to learners that atomic mass is approximately equal to the mass number) 9. Explain that due to the difference of atoms which make up substances, which have different masses, chemists need a way to measure the amount of substance. Define the term amount of substance; indicate that it is one of the seven fundamental quantities in science; the SI unit is the mole and that the amount of substance is	Learner activities	Assessment (what, when and how)	Resources (L.T.S.M)	
		Aim to draw on their previous knowledge about atomic structure, that different elements are composed of different atoms, compounds are made up of different atoms, that different atoms have different masses because they have different numbers of protons and neutrons in their nucleus. Different atoms have different relative atomic masses. Learners count the number of protons and neutrons in particles and record these next to the mass of the substances. Learners pay attention to this information input session of the activity.	Formal assessment in tests and exams – definition of amount of substance, definition of mole as SI unit for amount of substance, Avogadro's number of particles in one mole.	Cut-out models of the substances used in the first part of the activity. Atom of sulphur, atom of iron, molecule of water, formula unit of sodium chloride. Overhead projector and transparency with definition of amount of substance, its unit the mole.	

	12. Discuss the relationship between the number of particles n and M (e.g. $n = 10^{-23}$ particles in 1 mole). 13. Ask the number of the help learners get a sense of the amount of substance that is being measured. Explain that the amount of substance is not the same as the mass of the substance (included in the model as a counting unit).	Learners write out the number.		
Duration	Teacher activities	Learner activities	Assessment (what, when and how)	Resources (LIS M)
Activity 1 (cont) Developing an understanding of the term amount	11. Use transparency to introduce / review how to find the amount of substance from the mass (learners figured out themselves). Tell the learners to calculate the amount of each substance from the mass of the spoonful and from the equal masses examples (through forward to step 3 in activity 1). 12. Get feedback from learners and ask if the amounts were the same.	Learners calculate the amount of substance using the relationship $n = m/M$. Learners respond that the amounts calculated are different.	Formal assessment: Relationship between amount of substance and mass. Calculate using the formula $n = m/M$ (derived to step 3 in activity 1).	Transparency with the amount of substance and mass relationship. (not to be used at this stage instead it will be shown at the end of the lesson when learners have presented their answers).
Activity 2 The analogy of the model as a counting unit such as a dozen 25 minutes	13. Introduce the model as a way to represent the amount of substance. It is a counting unit such as a dozen. Introduce the notion of a counting unit. Tell the learners that the amount of substance is a counting unit such as a dozen. Ask learners what number of coins represent the mass of a dozen ten cent coins, half dozen ten cent coins, and a dozen ten cent coins. Explain that the mass of the model is 1 and the mass of the coins is 100 g. 14. Introduce a dozen ten cent coins. Ask learners to calculate the mass of a dozen ten cent coins. Explain that the mass of the model is 1 and the mass of the coins is 100 g. 15. Ask learners to calculate the mass of a dozen ten cent coins. Explain that the mass of the model is 1 and the mass of the coins is 100 g.	Learners respond – a dozen represents twelve, two dozen represent twenty four, half dozen represents six. Learners record the mass of a dozen five cent coins and a dozen ten cent coins. Groups work out from the mass how many dozen coins in each envelope.		Digital scale, a dozen five cent pieces, a dozen ten cent pieces, six envelopes with multiples of a dozen (e.g. two dozen, three dozen, three and a half dozen, four and two quarter dozen) in envelopes with the mass of the of the coins written on the envelopes.

Activity 4 Ways of finding the amount of substance 15 minutes	33. Begin activity by explaining that the amount of substance can be calculated in different ways. 34. Use transparency with overlays to show all the relationships used before relating to mass and volume of gases to amount of substance and amount of substance and number of particles. Emphasise the mathematical relationships and proportionality constants of molar mass, molar volume and Avogadro's number. 35. Hand out envelopes with work cards and problem. Facilitate problem-solving by moving to different groups. 36. Feedback – go through the problems by asking member of different groups how they determined the amount, volume and number of particles. Use transparency Learners write what they have learnt using mind maps.	Practice – in groups learners solve problems on work card. Members explain how they calculated the amount, volume of gas and number of molecules.	Formal: Use of mathematical relationships in solving stoichiometric problems.	Overlay transparency of all the mathematical relationships. Work cards with problems and transparency with answers.
Conclusion 5 minutes	Display the transparencies to learners on relationships between the mole and other physical quantities. Display samples measured by learners and pre prepared samples 37. Consolidate lesson by reminding learners that chemists use amount of substance, measured in moles to work with substances due to relationship between amount and mass and volume. 38. Show equal volumes, equal masses, equal amounts of elements to emphasise this.			Test tubes with equal volumes of three elements, equal masses of elements and one mole of elements.

Key additions by myself to original lesson: red ink

-rearranged original steps: green ink

-comment: blue ink

-unchanged steps: black

Appendix 3: Reflective teaching journal pre enactment (RFJ1)

11

RJ-1

TEACHING & LEARNING REFLECTIVE JOURNAL

Educator: Sibanda E.T. Date: 12/08/2015

Name: _____

Grade: 11

Teaching Agenda

Lesson Topic: Chemical Change - Quantitative aspects

Lesson Learning Outcomes:

Define the words, under words, ^{concentrations}
 Solve the problems using the formula $n = \frac{m}{M}$, $n = \frac{N}{N_A}$, $n = \frac{V}{V_m}$
 $c = \frac{n}{V}$

Research Agenda

Hypothesis (my assumptions): Learners should be able to solve given problems after I have taught them the relevant concepts

Problem Statement: Engaging learners in activities will help them understand science concepts.

RJ-1

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?
1. I posed questions on the type reactions that had been covered in the previous lesson. Learners responded by giving the type of reactions. A few learners raised their hands to give answer. Some gave chorus answers.	Learners re-call previous concepts. Helps them to remember some previously covered concepts.	Continuous recitation of the learned concepts help learners understand science concepts	I have to link the previous concepts to the concepts of the lesson. I need to probe learners' everyday understandings of ideas using short structured questions based on the topic to be taught.
2. I wrote the topic on the chalkboard and then introduced the	This directed the learners to the topic of the day.	This being a new topic, learners were general eager to learn the topic. Learners general quite and	Engage learners in structured activities to

IAS
To include
LPCs
in future
lessons

Attempt
to change
learning
environment.

Silence/quiet. → learning.
Environment → talks to learning
culture.

mole and explained the mole as amount of a substance and a unit for amount of a substance. <i>IAS - suggest transmissive mode.</i>		wrote what the mole is.	invite them to participate in the lesson.
3. Defined the molar mass and demonstrated how to use the formula $n = m/M$ in calculations. <i>SMK</i>	Learners need to know what the molar mass as they are supposed to use it in the calculations	I think learners generally understood how to handle the formula and changing the subject of the formula.	Give more examples of activities <i>engaging them in activity</i> <i>SMK/LPK</i>
4. An activity on calculations involving the formula $n = m/M$ given to learners and <i>LPK</i> learners engaged in the activity. Learners talked to each other during the activity. I	Activity quite relevant to the level of learners as it was taken from their textbook. Sharing of ideas by the learners. <i>aged of constructivism</i>	Learners had problems with determining the molar mass of the substance especially when the molecular formula was not given to the learners. At the same time it was difficult to ascertain the understanding of the learners based on the	Have to show learners how to work out the molar mass using the periodic table.

learning environment, talk - was it about text or social conversations.

Appendix 4: Reflective teaching journal post lesson engagement (RFJ2)

Reflective journal and reflections on the lesson RFJ-2

Lesson Topic: The mole concept

Lesson outcomes:

- Amount of substance as one of the seven fundamental quantities
- Amount of substance refers to the size of a sample in terms of the number of elementary particles present in the sample.
- Amount of substance is not the same as mass or volume
- 1 mole of substance has a mass that is equal to the molar mass of the substance.
- 1 mole of gas occupies a volume of 22.4 dm^3 at STP
- 1 mole of substance contains 6.02×10^{23} particles
- Use the relationships $n = m/M$, $n = N/N_A$ and $n = V/V_m$ to perform calculations.

Research Agenda: studying my practices as I teach the mole concept

Hypotheses (my assumptions):

- There is a link between the development of my TSPCK in stoichiometry and understanding of concepts by learners.
- Engaging in self study within a lesson study group will transform my content knowledge for teaching the mole concept.

Problem statement:

What kind of TSPCK is required to transform the culture of learning within my class?

What happened (what I saw/heard)	How I felt?(what this might mean)	What did I learn?(what is my opinion about the experience)	How can I do things differently next time?
i. Pre planning Lesson discussion was done collectively as a lesson study group. The final draft of the lesson	This was a critical stage in my self study research as it exposed the content and strategies to	Discussion of the lesson enabled the 'big ideas' to be uncovered. The content knowledge for teaching the mole concept was exposed during the discussions as I was engaged in	Design activities or questions that would probe learners' conceptions during the entire stages of the lesson rather than on the introduction only and have strategies that would enable

plan was adapted to address the needs of my research. • Apparatus work sheets assembled at each group.	teach the mole concept	discussions with subject specialists and peers. I discovered that some aspects that I normally ignore during my teaching are very important in the design of lesson plans. These include the anticipated difficulties that learners may have when learning the mole concept and the need for clarity in the three levels of teaching: stoichiometry such as microscopic, macroscopic and the symbolic.	transition from learners' everyday conceptions to science concepts in place.
2. Classroom organisation • The class was organised into groups.	Classroom organisation sets the tone for a conducive learning atmosphere. Groups allowed discussion and engagement of learners with learning activities which could enhance learning.	Properly organised classroom enhances classroom management skills and maximises the time spent on activities and hence on interrogating the concepts.	Involve learners in organisation of classroom and group the learners according to abilities.
3. Learner talk • Learners were encouraged to talk during the lesson and in group discussions.	Learners should be given a chance to talk during group discussions so that they share ideas and engage in co-operative learning.	Learners understand each other better when they are engaged in small group discussions. Even the reserved learners get a chance to share their ideas. Learners' experiences help to contextualise the learning process. This enabled learners to relate everyday life experiences to the science knowledge. E.g. counting in	I need to listen to the discussion and participate in small group discussion by way of probing and directing the discussion. I also need to encourage learner-learner interaction during the lesson. I could do this by asking other learners to respond to ideas posed by other learners.

		everyday life experiences was related to the measurement of amount of substance in science in science. I was able to pick out ideas that they held and assessed their understanding of concepts from their talk. This allowed me to tailor make the content and concept progression to suit their needs	
4. Presentation of solutions of activities by learners to the class.	The presentations allowed learners to participate in the learning process.	Learners may solve problems by using appropriate formulae without conceptual understanding of the underlying principles. Learners that mention the physical quantities as given in the formula stand a better chance of understanding the concepts than those that merely mention the symbols.	Allow the weak learners to make presentation to the class in order to involve them in the teaching and learning process.
5. Presentation of the mind maps by learners to summarise the main concepts covered during the lesson.	The presentations gave me the opportunity to assess my learners understanding of concepts and how the mole was related to other physical quantities	Learners showed an understanding of the mole concept and its relationship to mass, number of particles and volume. I was also able to pick out the possible misconception from one of the concept map that was presented by learners i.e. mole is same as the mass	Discuss the misconceptions and try to uncover why and how they arise and ascertain the accommodation of science concepts using relevant conceptual strategies.
6. My content knowledge for teaching • Introduction of a concept was followed by an activity. • Learners were supposed to	Concept sequencing and the teaching strategies were key to the achievement of lesson objectives. Elicitation.	I learnt that it is important as an educator to ensure that learners understand one concept at a time before progressing to the next concept. Having learners to find the mass and then calculate amount enables them to	Conduct an experiment that produce a gas and determine its amount to familiarise learners with experimental techniques of production of gases. Encourage learners to explain and evaluate their findings.

subsequent concepts link helps the building up of concepts in learners' minds. This was evident at each of the phases of the lesson when I asked learners about some concepts that had been covered and summarised those ideas before proceeding to the next concepts. I needed to give learners an opportunity to make predictions and give explanations before engagement with the task and help learners to compare what they already know with what school science offers. Allow learners to evaluate their explanations or findings. This then increases the chances of accommodation of the new science concept

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

They should be allowed to share ideas and make presentations for class discussion. Learners tended to manipulate mathematical calculations without conceptual understanding. This was evident in their presentations when utterances such as '*substituting this into this formula*' were made. Having learners talk helps not only to be aware of the conceptions that they already have but also to check whether they have understood the concepts taught during the various stages of the lesson.

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

I have to identify obstacles to learning in a particular topic prior to teaching a particular topic, with these in mind create discrepant events that will help learners accommodate the new concept. I have to go beyond what the textbooks prescribe. I have to let learners have ownership of the learning process by engaging them in inquiry activities and practical activities in topics where it may seem virtually impossible to have a practical activity. Personally I had never thought of doing a practical activity with the mole concept in 'mind' even though one of the concrete quantities i.e. mass can be measured using a balance. I have always approached it from the abstract perspective to the calculations.

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

CoRe D. Representations	D1. What representations would you use in your teaching strategy?	Demonstrations of mass of a tablespoonful of different elements and compounds. Submicroscopic pictures of atoms of different elements, molecules of substances and ions of ionic substances. Demonstrations of the mass of a fixed number of different objects. Symbolic representation of the number of particles represented by the counting unit a dozen. Demonstrations of mass of a fixed amount of different substances. Macroscopic pictures of volume gases collected during experiments. Balanced chemical equations of the reactions with gases. Symbolic -- mathematical relationships between amount of substance, mass of substance, volume of gas & number of particles through the proportionality constants of molar mass, molar volume & Avogadro's number. What ways would you use to assess students' understanding? (original: Specific Ways of ascertaining understanding) What aspects of teaching and planning for this big idea would you like to reflect on?
		Learners work in groups and present their answers to the class for discussion, allow learners to talk so as to gain insights into their thinking and how they approach problems. Learners present mind/concept maps on how to summarise what they think they learnt from the lessons. Encourage learners to write as much as possible on their mind maps Encourage learner to learner interactions for sharing and interrogation of ideas. The kind of the learning culture that would take place Concept sequencing: on whether concepts were logically sequenced. The effect of activities on learners' understanding of the concepts. KEY: group contributions: black my own contributions: red

E. Conceptual Teaching Strategies	Activity 1 Since learners often assume that the term amount refers to either mass or volume begin the lesson by doing a demonstration that aims at developing a shared meaning for the term amount. In the demonstration use elements (like charcoal/carbon, sulphur, magnesium, water, sodium chloride and calcium chloride). These various substances that include elements, compounds that are made up of molecules and ionic substances since learners often think the mole only applies to molecules. Begin the lesson by stating that we want to find the mass of the same amount of different substances. Clarify that a spoonful can represent the same 'amount'. Using the predict-observe-explain method ask learners if they think the mass will be the same or different (predict). Carefully take a spoonful of each substance and find the mass of each using a scale and record the mass of each substance (observe). Ask learners why the mass was different and use questioning to extract that substances are made up of different atoms, or combination of atoms. Use sub-microscopic pictures of atoms, molecules and ionic formula units, to highlight and explain why the different substances have different masses. Use this activity to highlight the language issue that the term amount has a specific meaning in science. Define the mole as the SI unit for the amount of substance. Activity 2 Since one of the difficulties with this section is the abstract nature of the Avogadro's number and the extremely large number of particles in 1 mole the use of an analogy such as a dozen is useful to introduce the mole as a counting unit and show that the mole is a single entity to count a large number of small units. Give each group an envelope with twelve objects (e.g. beans, pop-corn kernels, dried peas, 10c coins). Allow each group to predict which group has the envelope with the largest mass. Let each group find the mass of a dozen of these objects and write the results on the board. Ask groups to determine the mass of 2 dozen, 4 dozen, 0.5 dozen, 0.25 dozen and 0.75 dozen of their objects to highlight how the mole can be used as a counting unit. Emphasise that use of the mole as a counting unit is an analogy and that in 1 mole there is the same number of particles/Avogadro's number of particles. Scientists do not know the exact number.
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Write down a comparison of numbers on board for learners to get a sense of the magnitude of the number. As a demonstration take 0.1 mole of the substances used in Activity 1 and find the mass on the scale of this amount of substance. Use 0.1 mole since the mass of the substance will have the same numbers as one mole. For example, 0.1 mole of Carbon will have a mass of 1.2 g. Refer learners to the periodic table to determine the relationship between the amount of substance and the molar mass. Explain that if you divide the molar mass by Avogadro's number this gives you the relative atomic masses, or relative molecular masses or relative formula masses of the particles in atomic mass units. In all above activities incorporate Bybee's 5Es instruction strategy Activity 3 Learners often have the misconception that molar volume applies to all substances. Use the predict-observe-explain. Begin by gauging the learners' prior knowledge by asking if the same amount of the different substances has the same volume. Then lay out the samples of the 0.1 mole of different substances and ask the question again. Elicit explanations from the learners to explain why the volumes are different. Then move on to discussing gases asking learners to predict if the same amount of different gases has the same or different volumes. Use the pictures of different experiments conducted under the same conditions with the balanced chemical equations representing the different reactions. Through questioning extract from learners what they observe about the volume of gas produced and coefficients of the balanced chemical equations for the products that are gaseous. Through questioning get learners to explain the relationship between the volume of a gas and the amount of gas. Relate molar volume to amount of gas and the number of gas particles. Activity 4 One of the reasons learners find the mole concept difficult is that there are different ways the amount of substance can be determined. This activity brings together the previous activities that started off with macroscopic measurements of mass and pictures of volume of gases and the sub microscopic number of particles and brings these together as incorporated in the big idea – as a means to connect macroscopic properties to the sub microscopic using the appropriate symbolic representations or mathematical relationships. Use lecture-style interaction to explain that mass and volume can be measured, and from these we can find the amount of substance and that in a fixed amount of substance the number of particles can be determined. Draw this on the board and highlight the proportionality constants that are used to determine the amount of substance for a given mass, given volume of gas, the number of entities. Write down the mathematical relationships. Hand out work cards to groups of learners with one or two problems relating the finding the amount of substance when given mass, volume of gases, number of particles. Allow each group a few minutes to solve the problems and ask them to do the solutions on the board.	
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Appendix 6: Learner written text (LWT1)

LEARNER WRITTEN TEXT (LWT)

The mole concept

The mole is a unit for amount of a substance.

1 mole of any substance contains 6.02×10^{23} particles (atoms, molecules, ions) etc.

1 mole of H_2 = 2 g = 2 g/mol

1 mole of H_2O = 18 g = 18 g/mol = molecules

6.02×10^{23} is the Avogadro number (N_A)

no evidence of linking to counting systems - p.m.f., d.m.f., S.M.F., I.A.S.

presented as in textbooks

Algorithm

n = number of moles
 m = mass in grams (g)
 M = molar mass in g/mol

Molar mass = mass of 1 mole of any substance = g/mol

Q. How many moles are present in 75 g of potassium?

$m = 75 \text{ g}$
 $M = 39 \text{ g/mol}$
 $n = ?$

L.P.K.

(2)

For 1 SPATULA LOAD

$$n = \frac{m}{M}$$
$$= \frac{0,43}{23 + 35,5}$$
$$= 0,01 \text{ mol}$$

NaCl

For 2g:

$$n = \frac{m}{M}$$
$$= \frac{3}{23 + 35,5}$$
$$= 0,05 \text{ mol}$$

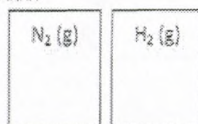
Appendix 8: Learner written text (LWT2b)

PRE-TEST

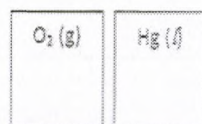
CODE: L199

Question 1

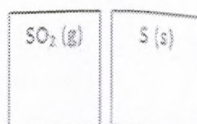
Each cube represents a volume of $22,4 \text{ dm}^3$ at STP. In which of the three pairs of cubes, Set A, Set B or Set C, is there 1 mole in each cube and in which of the three pairs cannot contain 1 mole in each cube?



Set A Cubes



Set B Cubes



Set C cubes

- (a) Each pair contains 1 mole of substance.
 (b) Set B and Set C contain 1 mole of substance. Set A does not.
 (c) Only Set A contains 1 mole. Set B and Set C do not.

My choice is: b

Explain the reasons for your choice.

Set A has both 2 moles of substances which is N_2 and H_2 . Set B has 2 moles on a cube and 1 mole on the other cube which is O_2 and Hg and Set C has also 2 moles on a cube SO_2 and 1 mole on the other 'S'.

Question 2

Which of these three sets in the diagram below contains 1 mole of tin, 1 mole of magnesium, and 1 mole of sulphur in each tube?

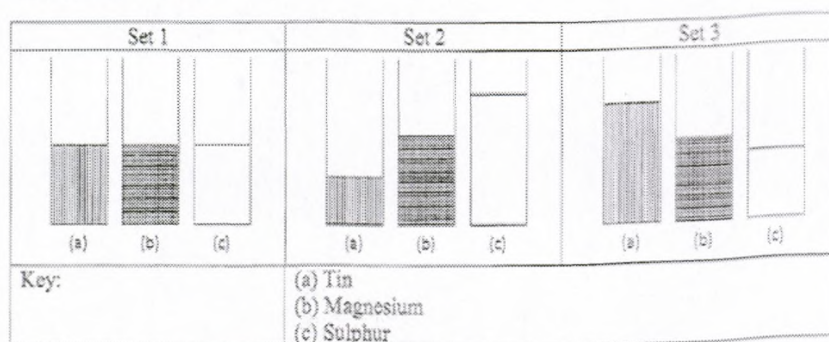


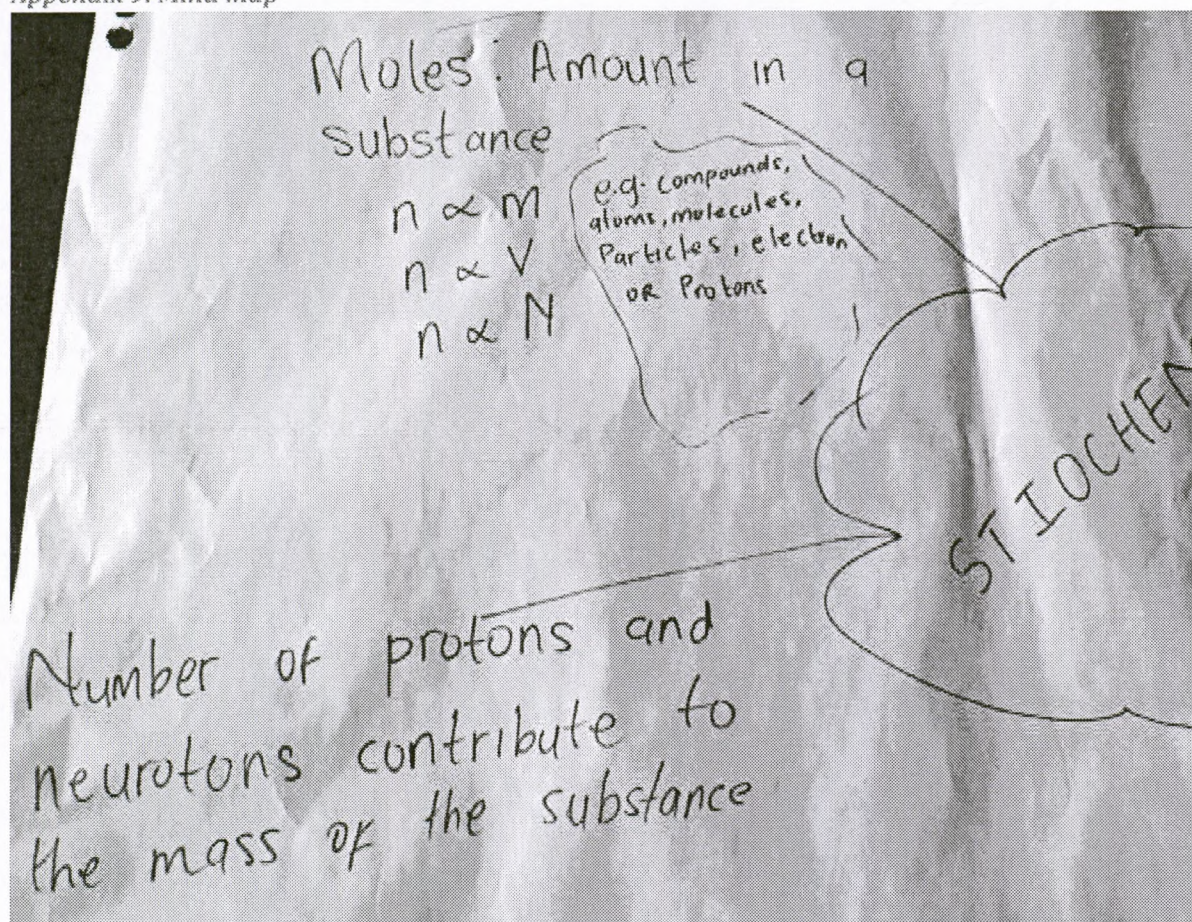
Figure 1.

- (a) Cannot tell by just looking at them as more information is needed.
 (b) Set 1 as they contain equal volumes.
 (c) Set 2 as they contain equal masses of substances.

My choice is: b

Give a reason for your choice.

This is because the substances inside the tubes are equal / they contain equal volumes / they contain equal moles.



Appendix 10: Lesson study meeting transcriptions-pre planning (preLTSM1)

LSMT-1

Pre-planning meetings:

Stephen Malcolm, Marissa Rollnick, Elizabeth, Mpunki, Willard, Thabo, Tarasai

Date: 29 May 2015 Duration: 1 hour hrs Transcribed by Stephen Malcolm

The first part of the meeting, which was not recorded centred around coming to a decision to plan the lesson for Grade eleven learners as a revision session, rather than Grade twelves. This was due to concerns about getting ethics approval from the Department of Basic Education, and concerns that any revision for Grade twelve should focus on exam preparation. As a result the first minute of so of the discussion of conceptual teaching strategies was not recorded.			
Stephen	Introduced the first activity and projected the CoRe onto the screen. Explained that the first activity was aimed at dealing with the confusion relating the word amount. In this activity learners would measure out a spoonful of five substances. An listed the substances. Sulphur, iron or zinc, water, calcium chloride and sodium chloride.		
Stephen 00:00 – 00:10	... sodium chloride, and that's five and it covers elements, and ionic substances. Print Full Screen Web Outline Draft Layout Reading Layout Navigation Pane Show Zoom: 100% Page Width Zoom New Window Arrange All Conceptual Teaching strategies <table> <tr> <td>What effective teaching strategies would you use to teach this big idea?</td><td> Activity 1 Since learners often assume that the term amount refers to either mass or volume begin the lesson by doing a demonstration that aims at developing a shared meaning for the term amount. In the demonstration use elements (like, sulphur, iron or zinc, water, sodium chloride and calcium chloride). These various substances that include elements and compounds. </td></tr> </table>	What effective teaching strategies would you use to teach this big idea?	Activity 1 Since learners often assume that the term amount refers to either mass or volume begin the lesson by doing a demonstration that aims at developing a shared meaning for the term amount. In the demonstration use elements (like, sulphur, iron or zinc, water, sodium chloride and calcium chloride). These various substances that include elements and compounds.
What effective teaching strategies would you use to teach this big idea?	Activity 1 Since learners often assume that the term amount refers to either mass or volume begin the lesson by doing a demonstration that aims at developing a shared meaning for the term amount. In the demonstration use elements (like, sulphur, iron or zinc, water, sodium chloride and calcium chloride). These various substances that include elements and compounds.		
Marissa 00:12 – 00:24	Elements... No, your mixing your macro and your micro. Elements, compounds ...		

	solid and that of a liquid.
Marissa	But I sense the way he measured it...there was one point near the end, only at the end, where he had the test tubes with the same...basically the volume was done by the same height in the test tube. So they were all powders. It was sulphur...
Thabo?	Sulphur, zinc...
Marissa	And then he just made sure they were at the same height in the test tube.
Thabo?	And then when you say, around the misconceptions that (?17:01) which I wasn't sure (?) in our lesson, that of the mole to say, they assume that the mole is the abbreviation for (?17:10).
Stephen	Mm. And I think that actually, in the one point in the diagnostic test, based on their responses I would say that it was clear that maybe some of the learners, (?), still confuse mole and molecule. So I think that does need to be emphasised.
Marissa	Can we put that to one side as something we need to discuss in more detail, is how we work that into the lesson. Mole versus molecule. Because that's not just a procedural thing, that's something we have to think about how we do it. So that's quite a big issue, which we need to think about. Do you have some more, Thabo?
Thabo	It seems there is a lot of preparation that is required, a lot of planning and preparation. Guessing from the number of activities that we've done. I think quite a number of activities were done and that means a lot of planning and preparation. But (?18:42).
Marissa	But now the advantage is now it's done? So, Stephen will be able to like make some boxes.
Marissa	Thabo, am I making sense? For you?
Stephen	Ja, the volume one.
Elizabeth	The volume one. So after the next...
Thabo	Isn't it you are saying we should now bring in...
Marissa	I think we should...
Thabo	...proportionality (constance?41:09).

Thabo	Ja, I think still on the same concern, like they each could measure the amount of stuff in terms of mass. Did they get any...were there any deviations in terms of the mass of the stuff that they weighed?
Stephen	Ja, I actually didn't allow any time, or ask in fact, which I think I should have done. I should have asked that.
Thabo	Ja, and I think that (?) they had to say, you have measured the same amount of the substance but then you are finding that the masses are different, and therefore they need to find something that is universal, and say, if you have the same amount of the stuff (?10:35) maybe to compare the masses.
Marissa	If you do away with the granulated zinc, I think you're going to have less variations as well. Okay, Thabo, your next point.
Thabo	Ja, (?) when you're measuring volume for different substances you have to show them that those volumes have equal number of particles. And there was the use of different substances there with the liquids and solids. You have to know that to measure the volume with the solid, you use a totally different method for measuring the volume of a liquid. So I thought maybe if we could use only liquids there, unlike we're using a (?15:24) to show that if they're the same volume but you weigh them, you find that you get different masses.
Stephen	Then also as you're measuring the volumes you're showing them if the vials are the same that this same amount in terms of zero point one ml of solid did not have the same volume. That's why solids you can't say if they've got the same volume you've got the same amount.
Marissa	It was more to prove something is not true than to prove something is true.
Stephen	Ja. It's more just a visual thing to say, look, we've got the same amount but you can see the volumes are not the same, just by kind of a visual gauging (?16:11). So I wasn't actually trying to measure the volume (?).
Thabo	Ja, because I thought that could also bring in some misconceptions about the measuring the volume of a

LTSM-2

Post lesson enactment transcriptions

LS Post lesson 2: Stephen, Marissa, Mpunki, Thabo, Willard, Tarasai

Date: ? 2015 Duration: 1 ½ hrs Transcribed by Cané Lake

Stephen	Okay, I've given everybody an agenda, so first of all thank you for coming. I've given everybody just a...this isn't as thorough an analysis as in last time but it's just an analysis, and only of three of the questions. To start with, question number four I made a mistake. Kept it as hydrogen so the learners didn't get it, but my concern is a lot of learners changed from the correct answer to the incorrect answer to question one. and then a lot of learners...more learners got question two right in the post test than they did in the pre test. A lot seemed to do...to get the question on calculating the mass, because of I think the practice with doing the calculations. And with the last question, two learners answered it correctly, who didn't answer it correctly before, but then two learners answered it incorrectly. So overall there wasn't a significant difference in the means of the pre and post test. So ja...
Marissa	They had a twenty minute break, but I think it becomes counterproductive after a while, if it takes too long. What did you think, Thabo, do you think they were tired?
Thabo	Ja, it took very long. And I think, especially the practical activities, they are not used to doing the prac. So they (?) to what to use (?) mass and remove (?).
Marissa	So I was just thinking that, we're sort of getting into the discussion of the lesson now, that maybe we should go to the lesson and just see what we think actually did work well, and what we think is actually just adding to the time and making them tired, you know what I mean? I think, I found personally that it lightened up considerably after the first (?3:21). After the first two activities. You know, it didn't feel (?3:32). It lightened up. Those first two activities, I thought...I don't know if that volume one is working. I thought the mass one was good. Because I know why we're doing it, but I got into thinking that the volume one...Stephen seems to think that one of the reasons why they're doing badly in question one is because we emphasised the volume.

Thabo	Ja, it was relatively easy. Except (?) when they're presenting (?). To emphasise that, instead of just saying (?12:48) they should actually state what they think (?)
Marissa	Maybe what the teacher must do then is to...if the kids don't ask questions is to say, explain what do you mean by this? Explain what you mean by that? Because that then models it for the class. And that's like what is difficult (component?13:11). With the conceptual teaching strategy, which is...
Stephen	I mean, I liked the fact that Thabo actually did that as a...we planned that (?) a demonstration (?13:25). But then (?) calculation beforehand (?)...
Marissa	No, my only concern is that maybe you need to pre-drill them to make sure they remember that it's very easy to divide by ten. And that point one is one over ten. Willard, do you think your kids would easily divide by ten without a calculator?
Willard	Ja, they would.
Marissa	So maybe one can just needs to pre-check that there are no (arithmetical?) obstacles, because you want this to be easy.
Mpunki	But then, why are we doing this? Can't it be (?14:12)?
Marissa	Now why we're doing this is because while you're trying to get a concept okay, you don't want the other half staring...you just want to get other obstacles out of the way while you're dealing with conceptions (?). That was Schmidt's...Schmidt's idea was, so if he was doing iron sulphur, he would do five grams and seven grams. Because that's the ratio in which they actually learnt.
Mpunki	(?14:44)
Marissa	Ja, exactly (?).
Mpunki	You know, another thing, in terms of practicalities of the activities, what maybe the learners were struggling with, is using the spoon or spatula, I think they have a need to sort of (getting it?) level, so that the issue of (?15:12) or (as you have helped with these ones?), (?) others. Ja, so...maybe with that one
Marissa	...And also that fair test, you've got to say if it's a fair

Appendix 12: Video lesson transcriptions (VLT)

Sibanda E.T 584250

Video lesson transcriptions (VLT) Teacher	Let us say I have an amount of oranges. What comes to your mind if I say I have an amount of oranges/tomatoes/potatoes?
Richard(L1)	I think it has to do with number of oranges.
Teacher	Right it has to do with number of oranges. So if I have 2 oranges it means that there is the number of oranges.
Teacher	What else did you think of?
Learner 2	Grams
Teacher	Now, grams are the units, for measuring what? which physical quantity?
Learners(chorus)	Mass
Teacher	So when I talk about amount of oranges you are saying I will be talking about mass. How many grams? What is the mass of the oranges that I have. Any other thing?
Learners	No response
Teacher	So someone is saying, is thinking about the number, someone else is saying it's about the mass. If we go back to what you are saying that amount is related to mass. Does it mean that mass and amount is the same thing. Amount and number of oranges is it the same thing?
Learners	No
Practical activities	
Teacher	What we want to find out is whether the same amount of spoonfuls of those substances will give the same mass. Now what do you think, before you can do that activity? So if you measure out one spoonful of sulphur, one spoonful of sodium chloride, will you get the same mass?
Banele	I think you won't get the same mass since the size of particles are not the same.
Teacher	Sizes of particles are not the same. By size what do you mean? (silence) How big or small the particles are.... May be that's what you are referring to.
Banele	yes

Appendix 13: Video analysis template (VAS)

VAS

Video analysis: edmore thabo sibanda
VAS: video analysis segment

Video segment and time.	Description of segment.	Was this part of the planned lesson? Did it work? If it was not why did you deviate from the plan?	What components of TSPCK are in this segment? Explain.	What within your actions can help or constrain learning. Why?
First clip				
00-03:46 V/451	Introduction on lesson objectives. Drawing from learners' everyday life experiences with regards to the term 'amount' and the way of counting/measuring objects. Attempts to elucidate the differences between mass, volume and amount. Leading to summary on the need to have a universal way of measuring by scientists	This was part of the planned lesson but I had to use examples that I thought were closer to learners' everyday experiences. The strategy worked as learners could identify the different ways of measuring and hence I used this to emphasise the need for a universal way of measuring /counting amongst a community of scientists.	Learners' prior instruction conceptions were covered in this segment as learners used their experiences about amount referring to mass/numbers and how price of tomatoes is determined by street vendors by counting while supermarkets will weigh and price according to the mass.	Directing learners to the objectives of the lesson help learners to keep in mind what it is that they are expected to know at the end of the lesson. Focusing much on the use of the word amount in everyday life could validate and legitimise the use of this word and learners may fail to relate it to its scientific context.
06:37-09:38 V/452	Measurement of mass of same amount of 'spoonfuls' of each substance provided by learners in groups. Learners predict, observe and explain whether the same amount of substances will have the same mass.	This was executed as per the plan. More emphasis was placed on the predict, observe and explain strategy.	Science oriented instructional strategy. This was an attempt to have learners concretise mass as physical quantity and relate it to amount. At the same time to draw upon learners' conception that could be dealt with in the next stages of the lesson.	The response that masses will be different because of different size of particles could have been probed further or reserved for later discussion to gauge learners understanding about the atomic structure and link this to atomic structure.
18:59-22:05	Learners give feedback. Teacher pose question on whether we get same mass.	Feedback was expected from the learners as per the	Learners' procedural knowledge. Learners	The conceptions held by learners were not

VAS

V/453	Learners respond with chorus answer-NO. Why do we get different masses for the same amount LR: it has to do with the type of bonding. No response given by teacher on whether the response is correct or not. Probing and prompting as to what contributes to the mass.	plan. The strategy worked as learners tried to give reasons as to why masses were different.	seemed to relate the mass the macroscopic size of particles, that bigger particles (by looking at them) have larger mass. The type of bonding seemed to have a role in contributing to the mass of the substances. Probably due to ionic compounds having higher b.pts and m.pts than covalently bonded compounds.	conclusively dealt with (I did not a firm or reject the learners response) as this would have led directly into the activity on counting of protons and neutrons that was to follow in the next stages. One of the salient /implied purpose of this activity was to make learners appreciate that mass is not the same as amount in science.
24:04-37:50 V/454	Measurement of the same mass of each substance-attempt to relate mass to volume. Learners make predictions. Teacher guides and gives objectives of the activity.	Yes it was planned. But learners had to keep their samples for display towards the end of the lesson. This would ensure that learners recognise that same mass does not translate to same amount/volume from what they can observe.	Science oriented instructional strategy. This strategy used was an attempt to help learners recognise that mass and volume are not same, that same mass does not necessarily translate to same volume.	The language that I used when giving instruction to one group that they can tell how heavy or light a substance is by noting the number of spoonfuls that need to be added to get to the same mass (3g). This confusion that could have been caused by this was dealt with in the feedback and explanation phase that followed.
38:25 V/455	Learners give feedback. One response was that elements with bigger particles the spoons were less than elements with smaller particles. Probing, prompting were done to relate their findings to volume	Feedback was sought from the learners. Different ideas were given by learners, at this stage the main objective was to	Learners' procedural knowledge. Learners continued to relate the size of the particles as they see them to the mass	Lack of emphasis and precision that same mass does not necessarily imply same volume. I continued to use the term amount i.e.

VAS

		show them that same mass does not mean same volume or amount		same mass gives different amount as seen by eyes, yet it also applies to the microscopic- mole.
Second clip				
03:32-04:36 VAS6	Explanation to dispel the idea that adding more spoonfuls to get to three grams meant that the substance was lighter and therefore smaller mass as noted with iron. Engagement with learner conceptions.	Not planned but this came as response to the observation that Fe was the lightest because more spoonfuls were added to get to the 3g CS	Subject matter knowledge and curriculum saliency. My content knowledge on other factors that may lead to misconceptions had to be drawn in. For instance I referred to the state of division of iron as necessitating more of it to be added to get to 3g and other intrinsic factors such as density. At the same time I had picked up that my language the language that I used when instructing could lead to incorrect conclusion and therefore kept this in mind for clarification during the explanation stages.	Intervention by way of explaining could have prevented the entrenchment of misconception in the minds of learners. I should have emphasised that you cannot tell the mass of the substances by just looking at the size of particles. Over and above this was expected as they were supposed to predict and explain based on what they observed.
07:14 VAS7	Learners engage in activity on counting of the number of protons and neutrons in models of the substances provided to explain why different substances have different masses.	A part of the plan. LPL	Learners' prior conceptions were drawn upon to determine what contributes to the mass of the substances. The activity is also an attempt to link the micro and	As shown in the models masses of the substances were deduced by counting the numbers of sub atomic particles. However I feel I should have related these masses to the masses or

VAS

Video analysis: edmore thabo sibanda
VAS: video analysis segment

VAS

21:35-25:27 V/AS14	Presentation by learners. Learners describe and explain how they measured 0.1 mole of each substance. Show the relationship in words between 0.1 mole of the substance and mass- an attempt to show the relationship between micro and sub-micro representations. Language issue cropped - 1 atom of sulphur has 32g amu.	Not part of the plan.	Learners procedural skills LPK	the same time keeping the samples for later discussion helped learners assume ownership of the learning process. Allowed learners to participate actively and allowed myself to get an understanding into the thought processes and their conceptual understanding.
Fourth clip				
05:03 V/AS15	Summary of the activity to show that same number of moles was used but different masses were obtained. Learners responded that mass was different for the same number of moles.	Part of the lesson	Science oriented instructional strategy/ Subject matter knowledge	Gauge students understanding of the mass and mole concepts
05:50 V/AS16	Teacher collected 0.1 mole samples from the groups measured and showed learners. Probing was done on whether the substances had the same amount. Chorus answer of yes and no given by learners. Learners requested to give explanations to their answer.	Part of the lesson	Science oriented instructional strategy/ Subject matter knowledge. Learners were a given an opportunity to relate the mole to the mass. Sols	Learners identified the differences between the mole and mass. Displaying the samples to the learners enabled me to gauge learners understanding of the relationship between mass and the mole. Most learners were able to identify that the samples were of the same amount but different masses while a few still held the view

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Appendix 14: Data analysis template (DAT)

Category	PCK aspect	Data Collection Tool	Descriptions	Findings
Engagement with learners' prior conceptions/misconceptions	Learners' Prior Conceptions/misconceptions (LPC),	- CoRes - Lesson plan (LP2) - Lesson plan (LP1) - Learner's written text (LWT) - TSPCK tool - Video analysis and transcriptions - Reflective journal (RJ2)	- Engaged/non engagement with LPCs reflected in the tool - Learners engaged in activities that illustrate engagement with LPCs - Used everyday life scenarios on how measurement is done: pricing of tomatoes by street vendors and supermarkets, counting using a system i.e. pair of shoes. - Prior conceptions not evident in lesson plan (LP1) and learner written text (LWT).	- Learners had their own understanding of the term amount - That there is confusion in the meaning of the term in science and everyday life context. - When probed, learners can give their conceptions on science ideas and these can be used to design teaching strategies.
Incorporation, structure and effective use of Science strategies.	- Science Oriented Instruction Sequencing (SOIS). - Curriculum saliency	- Lesson plan (LP2) - Video analysis and transcriptions	- Learners engaged in practical activities - Logically sequenced, one concept led to another.	- Learners came to the correct conclusions most of the time although they took a long time to finish the activities. - Generally learners could not go
Involvement of learners during the lesson and their approach to problem solving.	Learners' Procedural Knowledge (LPK).	- CoRes - Lesson plan (LP2) - TSPCK tool - Video analysis and transcriptions - Reflective journal (RJ2)	- Besides involving learners in practical activity, learners interacted with each other and the teacher verbally. - Learners gave presentations on their findings.	Learners could connect the macroscopic, microscopic and the symbolic levels of matter. - Conceptual and formulaic approaches to problem solving were evident. - Basic understanding of ideas as presented in concepts maps.

Appendix 15: Pre Topic Specific PCK tool (pre TSPCK tool)

PRE

MASTERS RESEARCH Protocol number: 20131CE08004	
CATEGORY B: CURRICULAR SAGENCY 3. The following questions relate to planning and sequencing of concepts. 3.1. What concepts in stoichiometry at Grade 11 do you believe are the main ideas¹ for understanding by students at the end of the instruction of this topic? Choose at least three concepts from the provided list and place them in a sequence that depicts the best order of teaching. Provide reasons for both your choice and suggested sequence.	CODE:
Theoretical yield is the amount of product that is formed when a reaction goes to completion based on the stoichiometry of the reaction. Molar Mass of an element or compound expresses the equivalent relationship between one mole of a substance and its mass in grams. Stoichiometric calculations combine balanced chemical equations and the concept of the mole to calculate the masses of all reactants required and products formed in a chemical reaction. Conservation of mass is a chemical law that allows quantitative relationships to be established in chemical reactions. Concentration is a property of a solution and relates to the number of solute particles per unit volume. Limiting reagent is the reactant that used up in a chemical reaction and determines the amount of product formed. Concentrated solutions have more particles per unit volume than dilute solutions. The actual yield of product formed depends on the reagent that limits the amount of the other reactant that reacts. Reaction stoichiometry involves the determination of molar ratios of the amount of reactants and products in a chemical reaction through balanced chemical equations. Volume is the amount of space occupied by a sample and from the volume of a gaseous substance the amount of substance can be determined.	Molar ratios can be used to determine the amount of reactants used or the yield of product formed. Balanced chemical equations provide the combining ratios of reacting substances and their products in a chemical reaction. Molar Volume of a gaseous substance expresses the equivalent relationship between one mole of a gas and its volume of 22,4dm³ and standard temperature and pressure. Dilution is the process of decreasing the concentration of a solution by addition of solvent to a solution. The amount of substance in a given mass or volume can be expressed as a constant amount of elementary particles. The mole is the SI unit for amount of substance and allows us to connect the macroscopic scale of matter with the microscopic scale of matter and can used to help count elementary particles that make up substances. Gravimetric and volumetric analysis are quantitative analysis methods to determine the amount of substance. Avogadro's number expresses the equivalent relationship between one mole of a substance and the number of entities it contains. Avogadro's number has been experimentally determined to be $6,02 \times 10^{23}$ particles. Mass is the amount of matter contained in a sample and from the mass of a chemical substance the amount of substance can be determined.

¹ Main ideas are statements describing key understanding that must be learnt in a topic.

University of the Witwatersrand | Stoichiometry TSPCK Tool

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CODE:

Suggested concepts and sequence	Reasons
2. Stoichiometric calculations	Assuming that learners already have an understanding of atom, molecule and compound concepts, the mole becomes one critical concept. They have to understand what it is and when reading a balanced equation we use the mole. Calculations on the reactants and products are based on balanced equation using the mole concept. The mole concept encompasses all other aspects/concepts for a variety of equation/formulae $n = \frac{m}{M}$, $c = \frac{n}{V}$, $n = \frac{N}{N_A}$.
1. The mole	
3. Quantitative analysis methods	Quantitative analysis involve practical application of mole concepts. Reactants occur / reactants combine in ratios determined by a balanced chemical equation. Hence all other concepts can be explored within quantitative methods.

Sequence can be followed

Appendix 17: Wits clearance

Wits School of Education

UNIVERSITY OF THE
WITWATERSRAND
JOHANNESBURG



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

21 September 2015

Student Number: 584250

Protocol Number: 2015ECE016M

Dear Edmore Thabo Sibanda

Application for ethics clearance: Master of Science

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

Exploring the effect of my development of Topic Specific PCR on learner achievement in stoichiometry concepts through self study within a learning study group

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

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

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

All the best with your research project.

Yours sincerely,

M Makela

Wits School of Education

011 717-3416

cc Supervisor - Dr Mpumli Nkedi

**GAUTENG PROVINCE**

Department: Education

REPUBLIC OF SOUTH AFRICA

For administrative use:

Reference no: D2016 / 179

enquiries: Diane Bunting 011 843 6503

GDE RESEARCH APPROVAL LETTER

Date:	2 September 2015
Validity of Research Approval:	2 September 2015 to 2 October 2015
Name of Researcher:	Sibanda E.T.
Address of Researcher:	P.O. Box 6983; Westgate; Soweto; 1734
Telephone / Fax Number/s:	073 704 7232
Email address:	etaboe@yahoo.com
Research Topic:	Exploring the effect of my development of Topic Specific PCK on learner achievement in Stoichiometry concepts through self-study within a learning study group.
Number and type of schools:	ONE Secondary School
District/s/HO	Gauteng West

Re: Approval in Respect of Request to Conduct Research

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

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

CONDITIONS FOR CONDUCTING RESEARCH IN GDE

1. The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter;

2015/09/03

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Making education a societal priority

Office of the Director: Knowledge Management and Research9th Floor, 111 Commissioner Street, Johannesburg, 2001

P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506

Email: David.Makhado@gauteng.gov.za

Website: www.education.gqa.gov.za

2. A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB);
3. A letter / document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned;
4. The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, SGBs, teachers and learners involved. Participation is voluntary and additional remuneration will not be paid;
5. Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal and/or Director must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage;
6. Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year;
7. Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education. It is the researcher's responsibility to obtain written parental consent and learner;
8. The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources;
10. The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations;
11. On completion of the study the researcher must supply the Director: Education Research and Knowledge Management with one Hard Cover, an electronic copy and a Research Summary of the completed Research Report;
12. The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned; and
13. Should the researcher have been involved with research at a school and/or a district/head office level, the Director and school concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

David Makhado

Dr David Makhado

Director: Education Research and Knowledge Management

DATE: *2015/09/03*

Office of the Director: Knowledge Management and Research

9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.gpg.gov.za

Appendix 19: Principal consent

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University of the Witwatersrand Private Bag 3 Wits 2050 Johannesburg, SA

RESEARCHER: Stephen Andrew Malcolm
Phone: 084 624 2220
E-mail: stephen.malcolm@wits.ac.za



Informed Consent to participate in the Topic Specific PCK development Research Project
(Ethics Protocol: 2014 FCE 0143)

Project Title: 'The Impact of Professional Development of Experienced Physical Sciences Teachers Topic-Specific Pedagogical Content Knowledge in Stoichiometry on their Teaching Practice and their Students' Performance' AND 'Self-Study of TSPCK while Teaching Grade 11 Stoichiometry'.

Date: 1st August 2015

Dear Dr. V.K. Joseph / Chairman of the Governing Body

Invitation to Participate:

My name is Stephen Andrew Malcolm I am a full time student in the School of Education at the University of the Witwatersrand and was until recently a Physical Sciences teacher at Sir Pierre van Ryneveld High School. I am currently completing my Doctoral degree focusing on science education. I am working with Edmore Thabo Sibanda who is completing his M Sc in Science Education

We are carrying out a study that is part of a larger project of Marang Centre for Maths and Science Education. My particular project investigates the impact of collaborative and reflective practices of experienced Physical Sciences teachers' on the development of topic specific pedagogical content knowledge, teaching practice in the classroom and student achievement by working together in a community of practice. The topic of interest is stoichiometry, which is introduced in Grade 10, continued in Grade 11 and examined in the Grade 12 chemistry examination. Stoichiometry, which deals with the quantitative aspects of chemical reactions, has been part of the secondary school curriculum for many years as it is considered one of the fundamental concepts in chemistry. However, learners generally hold a number of alternative conceptions regarding key stoichiometric concepts and find stoichiometry difficult for a number of reasons. Due to these difficulties learners tend to find stoichiometry both discouraging and uninteresting. This tends to be problematic since an understanding of stoichiometric concepts is required for topics in Grade 12 such as acids and bases and chemical equilibrium and learners' misconceptions in stoichiometry persist and affect the performance of learners that study chemistry at a tertiary level. The examiner reports of the final matriculation examinations on the questions relating to stoichiometry highlight learners' lack of understanding of this topic and inability to solve stoichiometry and recommend the topic be taught more thoroughly to ensure student understanding. Experienced practicing teachers often have the ability to transform content knowledge in such a way when teaching stoichiometry in order to help learners' understand the necessary concepts. By participating in a community of practice the topic specific pedagogical content knowledge of experienced teachers can be developed and captured in practice in order to demonstrate the impact of learner performance in solving stoichiometric problems.

- The Head of department for science complete a questionnaire.

Your participation means that the learners the following will be required by the students:

- Complete an attitudinal and self-efficacy survey before the lessons are conducted since these factors can influence student achievement
- Complete short multiple choice diagnostic tests before and after the lessons are taught to determine if the lessons have any effect on their conceptual understanding of stoichiometry
- Attend the lessons and participate in the teaching learning process. The lessons will be video-taped to capture any instances of how the teacher deals with specific problems relating to the content.
- Possibly participate in think aloud interviews to gauge stoichiometric problem solving skills. These will be audio recorded for accurate transcriptions
- Provide examples of work from assignments and examination questions relating to stoichiometry and stoichiometric problem solving to analyse their performance in stoichiometry.

Risks and potential benefits:

There are no harmful risks, neither physical nor psychological that are envisaged to occur as a result of your teachers and learners participation in the study.

Our research may benefit your school in the following ways:

- The Grade 11 learners will be provided with an opportunity to revise Grade 11 on a difficult topic and possibly improve their marks.
- The learners will receive a better understanding of stoichiometric concepts that are essential for understanding in other topics such as chemical equilibrium and acids and bases.
- The participating teachers will be provided with an opportunity to develop their topic specific pedagogical content knowledge in stoichiometry by being involved in a community of practice and reflecting on their teaching practice.
- The participating teachers will be involved in a professional development activity that can be viewed as part of the IQMS appraisal.

Disclaimer/Withdrawal:

If you agree to take part in my study, I'd like to make it clear that your participation is entirely voluntary and no negative consequences will result from your participation. Informed consent forms will be provided to all participating teachers, the learners and their parents/guardians. If you do choose to participate, the teachers and the Grade 11 Physical Science learners may decline to answer any questions, to be videotaped or supply examples of their work. The necessary consent to conduct research in your school will be obtained from the Department of Basic Education to conduct research in your school. Neither penalty nor prejudice will be imposed against you as a result of your withdrawal or participation. This means that you may withdraw from the study at any time.

Confidentiality:

You are assured that all information obtained from this study will be securely and privately kept under lock and key and all information will be treated with confidentiality. All research data will be destroyed between 3-5 years after completion of the project. In order to protect confidentiality pseudonyms will be used, teachers and learners will NOT be identified by their real names. Anonymity and confidentiality will be maintained and guaranteed throughout the study. Should I present the results of my study at a conference or in a teaching journal the school's identity will remain anonymous.

School Consent Form to Participate in Research

Please fill in and return the reply slip below indicating your willingness to allow your school to participate in these two research projects called:

- (1) The Impact of Professional Development of Experienced Physical Sciences Teachers Topic-Specific Pedagogical Content Knowledge in Stoichiometry on their Teaching Practice and their Students' Performance
- (2) Self-Study of TSPCK while Teaching Grade 11 Stoichiometry

By signing this consent form you agree to participate in this research project. The purpose of, procedures to be used, as well as the potential benefits and risks have been explained to you in detail. Please read the following and indicate your preference.

I, Dr. V. V. Thirumala

I agree to allow the researcher to observe the planned lesson and my teacher to participate in delivering the planned lesson to the students in my school.

Yes ☒ No ☐ Initial VT

I agree allow the lessons to be videotaped with the understanding that the teachers and students' individual preferences will be taken into consideration.

Yes ☐ No ☐ Initial VT

I agree to allow aspects of the lessons to be photographed with the understanding that the teachers and students' individual preferences will be taken into consideration.

Yes ☐ No ☐ Initial VT

I agree to allow the students in my school to participate in the collection of information about their performance in the topic of stoichiometry.

Yes ☐ No ☐ Initial VT

I agree to allow the students in my school to be interviewed if they so wish about how they solve problems in stoichiometry.

Yes ☐ No ☐ Initial VT

I agree allow the samples of the learners' assignments and exam questions to be collected for analysis with the understanding that the students' individual preferences will be taken into consideration.

Yes ☐ No ☐ Initial VT

Please read through the following statements and acknowledge these by placing a tick next to each statement.

- [] I know that my school's participation is voluntary and that I may withdraw from the study at any time and that I will not be advantaged or disadvantaged in any way.
- [] I am aware that the researcher will keep all information confidential in all academic writing and that results will be reported so that my school remains anonymous.
- [] I understand that the results of the study may be published, but my school's identity will be anonymous.
- [] I am aware that all data will be destroyed between 3—5 years after the completion of the project.

Principal's Signature: VT

Date: 1/5/2015

We would like to thank you in advance for your time and your voluntary participation.

GOVERNMENT OF TAMIL NADU
MADRAS UNIVERSITY HIGH SCHOOL
No. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000

Appendix 20: Parent consent

Parent



University of the Witwatersrand Private Bag 3 Wit 2050 Johannesburg, SA

RESEARCHER: Stephen Andrew Malcolm
Phone: 064 624 2220
E-mail: stephen.malcolm@wits.ac.za



Informed Consent to participate in the Topic Specific PCK development Research Project
(Ethics Protocol 2014 REC 0145)

Project Title:
'The Impact of Professional Development of Experienced Physical Sciences Teachers Topic-Specific Pedagogical Content Knowledge in Stoichiometry on their Teaching Practice and their Students' Performance' AND 'Self-Study of TSPCK while Teaching Grade 11 Stoichiometry'

Date: 3 August 2015

Dear Parent/Guardian,

Invitation to Participate:

My name is Stephen Andrew Malcolm, I am a full-time student in the School of Education at the University of the Witwatersrand and was until recently a Physical Sciences teacher at Sir Pierre van Ryneveld High School. I am currently completing my Doctoral degree focusing on science education. I am working with Edmore Thabo Sibanda who is completing his M.Sc in Science Education and teaches at your child's school.

We are carrying out a study that is part of a larger project of Marang Centre for Maths and Science Education in the Wits School of Education. We are carrying out a study that investigates the effect of teachers working together to plan a series of lessons about a chemistry topic called stoichiometry. This topic is described as one of the most difficult topics in the syllabus and is introduced in Grade 10 and taught again in Grade 11. This is also one of the topics that is examined in the Grade 12 chemistry examination at the end of the year. Reports from the Department of Basic Education show that learners generally struggle with these questions and do not do very well. Research has also shown that learners tend to find this topic both discouraging and uninteresting. But this topic is very important in understanding other topics in Grade 12 such as acids and bases and chemical equilibrium. It is therefore very important that learners develop an understanding of this topic. Research has shown that when teachers work together to plan difficult topics it can help improve their teaching practice and learner performance. The reason I have chosen your child's class is because the teacher is willing to find ways to develop and improve their teaching of this difficult topic. I therefore would like to invite your child's class to be part of my research. We would like permission to work with your child as his/her teacher teaches the lessons as part of a co-curricular revision programme as an intervention for this difficult topic.

Procedures:

In order for the teacher to improve his/her teaching practice I would like your permission to video record these lessons so that the teachers can discuss the lesson and take photographs to capture the teacher's interaction with your child during teaching. I would possibly like to interview your child about how they solve problems in stoichiometry if they are willing. Your child has the right to ask not be recorded or photographed if they so wish. I would also like permission to collect information from your child using surveys, diagnostic tests, examples of their work and possibly interviews.

If you give your permission for your child to participate in this research it involves your child

- Completing a survey about their attitudes to science and belief in the science problem-solving ability before the lessons are conducted
- Completing short multiple choice diagnostic tests before and after the lessons are taught.
- Attending the lessons and participating in the teaching-learning process.
- Possibly participating in a think-aloud interview to see how they solve problems in stoichiometry.
- Providing examples of work from assignments and examination questions relating to stoichiometry and stoichiometric problem-solving.

Risks and potential benefits:

There are no harmful risks, neither physical nor psychological that are envisaged to occur as a result of your participation in the study.

My research may benefit your child in the following ways:

- Your child will be provided with an opportunity to revise Grade 11 work on stoichiometry and be provided with an opportunity to develop their understanding of a difficult topic.
- Your child may receive a better understanding of stoichiometric concepts that are essential for understanding in other topics such as chemical equilibrium and acids and bases and even improve their mark.
- Your child may benefit from the teachers reflection of their practice and development of their practice.

Disclaimer/Withdrawal:

If you agree to let your child take part in my study, I'd like to make it clear that her/his participation is entirely voluntary and no negative consequences will result her/his your participation. The diagnostic tests will only be used for research and will not form part of the teacher's assessment program. If you do consent to allowing your child to participate, she/he may decline to answer any questions, to be videotaped, photographed or allow samples of his/her work to be collected. Neither penalty nor prejudice will be imposed against your child as a result of his/her withdrawal or participation. This means that she/he may withdraw from the study at any time.

Confidentiality

You are assured that all information obtained from this study will be securely and privately kept under lock and key and all information will be treated with confidentiality. All research data will be destroyed between 3-5 years after completion of the project. In order to protect confidentiality pseudonyms will be used; your child will NOT be identified by his/her real name. Anonymity and confidentiality will be maintained and guaranteed throughout the study. Should I present the results of my study at a conference or in a teaching journal his/her identity will remain anonymous.

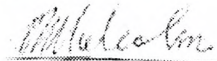
Participant's Rights:

You may obtain further information about the rights of participants in research from the University of the Witwatersrand's Human Research Ethics Committee (HREC) on at 0117173055 or contact Ms. Mabie Mabeta via email at Mabie.Mabeta@wits.ac.za.

What signing this form means:

You agree to allow your child to participate in this research project. This consent form serves to explain to you the nature, aims, purposes, and procedures to be used in the study. The potential risks and benefits have been outlined to you in detail. Your child may choose to refuse to participate or withdraw her/his participation from this study at any time without penalty or prejudice. Her/his refusal to participate in this study has no effect on her/him in any way whatsoever. I will provide the school with a summary of my research results on completion if you would like me to. Please let me know if you require any further information. I look forward to your response as soon as is convenient.

Thank you



Yours sincerely
Stephen Andrew Malcolm
Wits School of Education
Wits University
PO Wits
2050

Email: stephen.malcolm@wits.ac.za

Cell: 084 624 2220

Appendix 21: Consent form learner

University of the Witwatersrand Private Bag 3 Wits 2050 Johannesburg, SA

RESEARCHER: Stephen Andrew Malcolm

Phone: 084 624 2220

E-mail:

stephen.malcolm@wits.ac.za

Invitation and Informed Consent to Participate in a Research Project: Learners

(Ethics Protocol:2014 ECE 014S)

Project Title: 'The Impact of Collaborative Planning in a Community of Practice on the Professional Development of Topic-Specific Pedagogical Content Knowledge of Experienced Physical Sciences Teachers, Teaching Practice in the Classroom and Student Performance in Stoichiometry.'

Date: _____

Dear Learner.

Invitation to Participate:

My name is Stephen Andrew Malcolm. I am a full-time student in the School of Education at the University of the Witwatersrand and was until recently a Physical Sciences teacher at Sir Pierre van Ryneveld High School. I am currently completing my Doctoral degree focusing on science education. I am working with Edmore Thabo Sibanda who is completing his M.Sc in Science Education and teaches at your school.

I am carrying out a study that is part of a larger project of Marang Centre for Maths and Science Education. My particular project investigates the effect of teachers working together to plan a series of lessons about a chemistry topic called stoichiometry. This topic is described as one of the most difficult topics in the syllabus. This topic is introduced in Grade 10 and taught again in Grade 11. This is also one of the topics that is examined in the Grade 12 chemistry examination at the end of the year. Reports from the Department of Basic Education show that these questions are not answered very well. Research has also shown this topic both discouraging and uninteresting. But this topic is very important in understanding other topics in Grade 12 such as acids and bases and chemical equilibrium. It is therefore very important that you develop an understanding of this topic. Research has shown that when teachers work together to plan difficult topics it can help improve their teaching practice and help improve your performance.

The reason I have chosen your class is because *I taught at the school and would like to pilot the planned lessons with you because I still want to contribute to your learning / your teacher is willing to find ways to develop and improve their teaching of this difficult topic / your teacher is doing this as part of his/her research at the university. I therefore would like to invite your class to be part of my research.

I would like permission *to conduct lessons with you as part of a revision programme to pilot the planned lessons in the July holidays in preparation for your preparatory examinations / to work with your teacher to plan lessons that the teacher will teach to you as part of a co-curricular revision programme in preparation for the preparatory examinations / to work with your teacher in planning and teaching a series of lesson on this difficult topic.

Learner Consent Form to Participate in Research

Please fill in and return the reply slip below indicating your willingness to take part in this research project called: **The Impact of Collaborative Planning in a Community of Practice on the Professional Development of Topic-Specific Pedagogical Content Knowledge of Experienced Physical Sciences Teachers, Teaching Practice in the Classroom and Student Performance in Stoichiometry.**

By signing this consent form you agree to take part in this research project. The purpose of, procedures to be used, as well as the potential benefits and risks have been explained to you in detail. Please read the following and indicate your preference.

Learners Signature: _____

Date: _____

I would like to thank you in advance for your time and your voluntary participation.