# Examining the interaction between in-service Physical Science teachers' teaching orientations and teacher professional knowledge (TPK) domains

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# ABSTRACT

This doctoral thesis reports on a study that sought to examine the interaction between science teachers' science teaching orientations and their teacher professional knowledge domains. This study took place in three schools in the Zomba Urban Education District, Malawi, from which five experienced science teachers were drawn. Specifically, the five teachers were teaching two core science subjects: Physics and Chemistry. Even though there are several definitions of science teaching orientations in the literature, for the purposes of this study, I used the Friedrichsen, Van Driel, and Abell (2011) definition of science teaching orientations. Aligned with this definition of science teaching orientations, I explored the *teachers' beliefs about goals and purposes of science teaching, teachers' beliefs about teaching and learning of science and teachers' beliefs about the nature of science*. Then I explored the extent to which STOs influence classroom enactment of *content knowledge, pedagogical knowledge, assessment knowledge, curriculum knowledge and knowledge of students* during instruction.

Since the phenomenon is tacit and elusive, I gathered data using a variety of tools. I used semi-structured interviews as well as a questionnaire to gather data on the three dimensions of teaching orientations. Specifically, I used semi-structured interviews to gather data on teachers' beliefs about the goals and purposes of science teaching and teachers' beliefs about teaching and learning of science. I used a questionnaire to gather data on the third dimension of teaching orientations: beliefs about the nature of science. To gather data that would help me understand the interaction between science teaching orientations and teacher professional knowledge domains, I used classroom observations and teachers' tasks – Content Representations (CoRes). CoRes and classroom observations complemented one another. I also used unstructured post-observation interviews in order to get an in-depth understanding of the reasons for teachers' decisions that I had observed during instruction.

I used two approaches to analyse the data set that I had gathered. I used a deductive analysis approach to analyse interviews, questionnaires as well as classroom observation data to determine the teaching orientations that science teachers held. This was achieved by comparing the data against predetermined categories from the literature. An inductive analysis approach was used to analyse data mainly from classroom observations, CoRes, and post-observation interviews, to determine the interactions between science teaching orientations and teacher

professional knowledge domains.

Deductive data analysis showed that teachers' beliefs are complex. Teachers had multiple goals and purposes of science teaching. Further, their beliefs about the teaching and learning of science were moderately sophisticated and appeared to be compartmentalised. Their beliefs about the nature of science were sophisticated however, these could be not be made explicit during instruction. Inductive analysis, on the other hand, revealed that STOs interact with TPK domains through active engagement with the various sub-domains of TPK. This is exemplified in the three main claims: (1) that the goals and purposes of science teaching interact with teacher professional knowledge domains; (2) beliefs about teaching and learning of science interact with teachers' professional knowledge domains, and (3) beliefs about the nature of science do not interact with teacher professional knowledge unless the teachers are teaching a topic that relates to the nature of science itself. Beyond these primary findings, I also identified the following: (1) that there is uniform interaction between STOs and TPK domains, (2) that the interaction between STOs and TPK domains is influenced by several factors (3) that there is apparent lack of interaction between the items on the beliefs about teaching and learning of science schedule. These contributions may be useful when developing PD or initial teacher programmes. I discuss these findings and their implications both on theory and teacher training in the last chapter of this research report.

**Keywords**

*Interaction, science teaching orientations, physical science teacher professional knowledge, nature of science teacher knowledge*

# DECLARATION

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

(Signature of the candidate)

30th day of September 2020

# DEDICATION

I dedicate this dissertation to my wife, Doreen, and my two daughters, Walusungu and Watipa. Throughout our relationship, Doreen has been my greatest supporter and source of inspiration. She routinely asked me, “how is everything?” and “what is your supervisor saying about your work?”. Throughout the three years of hard work, she has always been supportive of my journey. My two little daughters usual question, “dad where are you?” has always been a source of inspiration that I need to finish this and be close to these two souls. Their constant support has always been a source of inspiration for me to go on till the finishing line.

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## PUBLICATIONS

### Book chapter

Nampota, D., Mbano, N., & **Maseko, B.** (2020). The pedagogical orientations of Malawian science teachers towards practical work. In U. Ramnarain (Ed.), *School Science practical work in africa: Experinces and challenges* (pp. 67–93). Routledge. https://doi.org/10.4324/9780429260650-5

### Work under review

Influence of Science Teaching Orientations on Teacher Professional Knowledge domains in the *African journal of research in science and technology education* see the attached email.

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# ACRONYMS

| | | |
|---|---|---|
| CDSS | - | Community Day Secondary School |
| CoRes | - | Content Representations |
| DEC | - | Distance Education Center |
| DEM | - | District Education Manager |
| FPE | - | Free Primary Education |
| JICA | - | Japanese International Cooperation Agency |
| MANEB | - | Malawi National Examinations Board |
| MoEST | - | Ministry of Education Science and Technology |
| MSCE | - | Malawi School Certificate of Education |
| PCK | - | Pedagogical Content Knowledge |
| PD | - | Professional Development |
| POI | - | Post-Observation Interview |
| PS | - | Physical Science |
| SMASSE | - | Strengthening of Mathematics and Science in Secondary Education |
| STOs | - | Science Teaching Orientations |
| TPK | - | Teacher Professional Knowledge |
| TSPK | - | Topic Specific Professional Knowledge |
| ZUED | - | Zomba Urban Education District |

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# CHAPTER 1. INTRODUCTION

## 1.0. Chapter overview

*"How can in-service teachers apply the knowledge gained from Professional Development (PD) programs in their practice?"*

This question has been at the centre of discussion regarding science education in Malawi. Science education researchers mostly raise this question in the context of poor performance in science as well as poor quality science instruction that students receive from their science teachers. These two areas of concern have characterised the discourse on science education in Malawi as I will show in the following sections of this chapter as I introduce the study. Hence, the Malawian education system is the premise of this study. In this chapter, therefore, I present how and why I conceptualised the study. Specifically, I look at the problems/challenges on the issue of Professional Development (PD) programs and why teachers do not make use of knowledge gained from such programs. It is within this context that I explicitly link Science Teaching Orientations (STOs) and Teacher Professional Knowledge (TPK) domains. However, before I do this, I will briefly talk about TPK, STOs and thereafter make explicit links between STOs and challenges or barriers related to PD and argue that the relationship between STOs and TPK domains be examined. Towards the end of the chapter, I will also highlight the reasons for carrying out this study and the rationale. Lastly, I will outline the research questions that guided the study. I then close the chapter by providing a summary of the structure of the thesis.

## 1.1. Introduction

Research in science education has focused on understanding teachers' practices to improve the teaching and learning of science. More specifically, the focus has been on understanding TPK as it informs teachers' practices (Gess-Newsome, 2015). Grappling with the question of "what constitutes teachers' knowledge", Shulman (1986) and Shulman (1987) introduced the notion of TPK as the knowledge that teachers need to teach effectively. He argued that this knowledge has domains, i.e., Content Knowledge (CK), Pedagogical Content Knowledge (PCK), knowledge of the learners and their characteristics, knowledge of educational contexts and knowledge of educational ends. Since then, researchers have used this as a basis for

understanding TPK and their practices.

Furthermore, extensive research studies have resulted in more refinements of TPK as more evidence emerges. For example, one of the most recent studies on TPK by Gess-Newsome (2015), lists five domains of TPK. These are *assessment knowledge, Pedagogical Knowledge, Content Knowledge, Knowledge of students* and *Curricular knowledge*. I consider these in detail in the literature review section (Chapter 2). As can be seen, one major difference between TPKs of Shulman and Gess-Newsome is that Gess-Newsome considers PCK to be a separate knowledge domain and hence not part of the TPK (I will be highlighting more on this in Chapter 2). Even though research suggests that this listing is not exhaustive (Gess-Newsome, 2015), it is quite apparent that the notion of TPK has been extensively explored and findings suggest that TPK domains are enacted differently in different settings.

Of all the TPK domains, PCK has received the most attention. Shulman views PCK as the amalgam of content knowledge and pedagogical knowledge that "represent the blending of content and pedagogy into an understanding of how particular topics, problems, issues are organised, represented and adapted to the diverse interest and abilities of the learners, and presented for instruction" (Shulman, 1987, p. 8). This view has led to the construction of several different models that explain the notion of PCK and hence further enhance our understanding of teachers' knowledge. What is collective among these models (as I show in chapter 2) is the conceptualisation of PCK as constituting various sub-domains. One of these sub-domains is the STOs. Magnusson, Krajcik, & Borko (1999) introduced this notion to science education and argue that they are central to PCK. The authors define teaching orientations as a "general way of viewing or conceptualising science teaching" as well as "knowledge and beliefs about the purposes and goals for teaching science at a particular grade level" (p. 97).

Furthermore, they contend that these teaching orientations help to "shape" teachers' teaching practices. I further explore the connection between STOs and teachers' practice in the context section of this chapter. Magnusson et al (1999) identify nine teaching orientations, which I consider in detail in Chapter 2. However, Friedrichsen, Van Driel, & Abell (2011) criticise the Magnusson et al. (1999) definition on the basis that it lacks clarity as I am later going to show in the literature review section of Chapter 2. While acknowledging the importance of teaching

orientations, the authors present arguments for the need to ensure that the notion retains the complex nature it deserves. Hence, they define teaching orientations as a set of the interrelated beliefs having the following dimensions: *beliefs about teaching and learning of science, beliefs about the purpose and goals of science teaching and views about nature of science.* These three dimensions ground this study.

There seems to be a clear picture of what constitutes TPK, how TPK manifests itself in the classroom and the nature of STOs. In other words, literature shows that there is a link between TPK domains and STOs. For instance, Magnusson et al. (1999), in their PCK model for science teachers, show that STOs "shape" teachers' practices. Similarly, Gess-Newsome (2015) claims that STOs are among the reasons why there is always a misalignment between teachers' beliefs and their practices because, according to Gess-Newsome (2015), STOs either amplify or filter teachers' decisions. However, the question of how teachers do that is not well-researched, that is, few studies have attempted to explore the interactions between TPK domains and teaching orientations. Hence the focus of this study was to examine the interactions between TPK domains, as described by Gess-Newsome (2015), and science teaching orientations as described by Friedrichsen et al. (2011). By interaction, I mean the influence of teaching orientations on the enactment of TPK domains in the classroom.

### 1.2. Context of the study

In this section, I discuss the context of the study to explain the study's conceptualisation. I will briefly talk about students' performance in Malawi focusing on underlying factors leading to poor performance. I will later highlight the steps being taken to address the issue of poor performance and quality education. I have briefly highlighted that teaching orientations "shape" teachers' practice hence, in this section, I will link teaching orientations to teachers' practices and argue for the need to have a comprehensive understanding of them.

Prior to Free Primary Education (FPE), students' performance on public examinations was relatively good. For example, the average failure rate of students during Malawi School Certificate Examinations (MSCE) between 1984 and 1993 was 31% (Dzama, 2006). This means that 69% of students passed their examinations. At the time, students attended secondary school education through various conventional secondary schools in Malawi, which were few in number. However, the introduction of the FPE policy in 1994 aggravated the situation.

Increased student enrolment at primary schools implied that more students were enrolling for secondary school education. In 1998, the Malawi government converted all self-governing, Distance Education Centres (DECs), which offered secondary school education, to Community Day Secondary Schools (CDSSs) to mitigate the ripple effects of FPE on secondary school education (Trigu, 2004). This policy initiative resulted in an increased demand for teachers at the secondary school level. As a result, unqualified as well as primary school teachers were employed to teach in secondary schools to mitigate the situation (USAID, 2012; World Bank, 2010). This idea of employing underqualified teachers as well as primary school teachers to teach at this level harmed the quality of education in general. For instance, the average failure rate of 31% between 1984 and 1993 increased to 41% between 1999 and 2006. Similarly, the recent performance of students on public examinations remains unsatisfactory, as shown in Table 1-1.

**Table 1-1: Trends on the performance of Students on MSCE from 2013 to 2016**

| Year | Candidates Entered | Candidates Passed | Percentage |
|---|---|---|---|
| **2013** | 127 383 | 66 853 | 52.4% |
| **2014** | 130, 293 | 71,486 | 55% |
| **2015** | 136,296 | 75,296 | 55% |
| **2016** | 139, 606 | 81, 414 | 58. 32 % |

Table 1-1 shows the overall performance of students in national examinations at the Malawi School Certificate Examination (MSCE) from 2013 to 2016. The table depicts how students performed on MSCE in all subjects at the national level over the period. However, the pass rate has stagnated as it remains slightly above 50%. Even though students' performance on examinations is slightly above 50%, their performance in science subjects is, however, not impressive (MANEB, 2013, 2014, 2015).

In an attempt to understand the poor performance trend in Malawi, Dzama (2006) investigated Malawian secondary school students' learning of science to uncover the factors that lead to poor performance in sciences. He reported factors, such as students' efficacy values, under-resourced schools as well as **teachers' presentation of content**, as factors contributing to the perennial poor performance of students in sciences. Literature shows that poor performance in science subjects is not a Malawian problem only. In South Africa, for example, a study carried

out by Makgato (2007) investigated factors associated with poor performance in Mathematics and PS. He reported that factors, such as laboratory apparatus, **teacher's content knowledge**, time management, parents' commitment to children's education, motivation and interest, and teaching strategies, contribute to the poor performance of learners in science. Another study carried out in Tanzania (see King'aru, 2014) analysed factors leading to observed poor performance in science subjects. The author attributed poor performance in science to the following factors: **poor pedagogy** in science education, **negative attitude towards science subjects** among students, lack of resources such as books and well-equipped laboratories.

Further analysis of these factors shows that they directly link to the various TPK domains mentioned above. For instance, the poor pedagogy factor speaks to teachers' pedagogical knowledge as it demonstrates a teacher's lack of developed pedagogical knowledge domain. Poor teacher's content knowledge, on the other hand, demonstrates the teacher's deficiency in content knowledge. The students' attitude in science' aligns itself to teachers' knowledge of the students. If a teacher is aware of the student's knowledge of the particular subject, he/she will strive to modify instruction to help the learners to develop or maintain a positive attitude towards the subject.

This array of factors contributing to poor student performance in sciences signifies the complexity of students' performance in national examinations. In other words, this means that to address the issue of poor performance in science subjects successfully, researchers, as well as stakeholders, should approach the problem of poor performance in science subjects holistically, that is, by taking into consideration all the contributing factors. However, the Malawi Ministry of Education Science and Technology (MoEST), in conjunction with Japanese International Cooperation Agency (JICA), further pursued the issue of *poor pedagogy*, *unqualified teachers* as well as *poor content knowledge* by launching a Strengthening of Mathematics and Science in Secondary Education (SMASSE) project in 2004. The impetus for this was that most teachers appear to have an undeveloped TPK as well as PCK for effective science instruction. The aim of the project was two-fold: firstly, the project aimed at training more qualified science teachers to teach science at the secondary school level. In order to do this, they identify and train candidates at any of the public teacher training institutions in Malawi.

Secondly, the project conceptualisation, at the same time, focused on enhancing the teachers' TPK through the provision of Professional Development (PD) activities to all in-service science and mathematics teachers. By using the cascaded model approach, the focus of PD is to equip science and mathematics teachers with effective ways of teaching science through qualified divisional trainers. Even though the focus of PD is on effective pedagogical practices, they have adopted a holistic approach in training the teachers, that is, apart from training teachers in effective science instructional practices, divisional trainers orient teachers to other forms of TPK such as *assessment knowledge, content knowledge, curricular knowledge* as well as *knowledge of the students.* The belief is that these knowledge domains are interrelated hence, the need for a holistic approach. Concerning effective methods of teaching, the trainers emphasise learner participation in the teaching and learning of science (World Bank, 2010). For PD, teachers meet quarterly at their divisions. During this time, divisional trainers train the teachers on effective methods of teaching and other domains of teacher knowledge on particular topics. Mostly, the topics chosen are the ones that are deemed difficult by the teachers (World Bank, 2010). During the training, the teachers are encouraged to practice these methods of teaching to improve their practices.

However, since the launch of the project in 2004, the quality of teaching has not improved and also students' performance in science subjects remain unsatisfactory (Nampota, 2016). Nampota (2016) noted that, despite teachers being trained to use participatory approaches during instruction, in practice, science teachers' instruction remains didactic interspaced with question and answer techniques. The observations by Nampota (2016) echo what has been a major concern of PD programs – that there is un-sustained use of knowledge and good practices learned from PD programs (ter Beek et al., 2019). Furthermore, Guskey (2002) and Yue, Chen, Wang, & Liu (2017) report that teachers may become reluctant to implement new and novel approaches to teaching for different reasons.

Various factors have been identified to explain this observation. For instance, Selemani-Meke (2013) attributed this to motivation issues in terms of teachers' salaries, allowances during PD, and general welfare and conditions of service. She argues that, if teachers are not motivated, receive low salaries or are not provided with sitting allowances during PD activities, they will probably not implement what they have learnt during PD. Low salaries inhibit teachers' motivation as they need to raise money in other ways rather than concentrating on instruction

activities for their students, let alone implementing new knowledge learnt from PD activities. Similarly, Yue et al. (2017) identify several barriers to the successful implementation of knowledge gained from PD such as psychological motivation, professional competency, teaching experience, shared vision, as well as financial security.

On the other hand, Gess-Newsome (2015) is of the view that "teachers' beliefs" (in this study, their science teaching orientations) significantly contribute to this. This tendency is because, as already shown above, these beliefs – STOs – "shape" teachers' practices since they act as filters or amplifiers that enable teachers to decide whether to implement/accept/reject what they have learnt during PD. To mitigate these issues, Guskey (2002) stresses the importance of the structure of the PD activities. He argues that, if a PD is to be successful and hence teachers adopt knowledge gained from them, it should consider delivering on both content and methodology. This demonstrates the value the author attaches to the two knowledge domains.

A study by Nampota (2016) reports on the need to work around the issue of class size; she believes that class size is also one of the contributory factors that prevent teachers from implementing what they learnt from PD programs. While these are all plausible factors that explain the problem of poor student performance in science subjects, Gess-Newsome (2015) calls for a comprehensive understanding of the role played by amplifiers and filters, which include STOs, in terms of how the STOs influence the enactment of TPK domains during instruction. Gess-Newsome (2015) argues that experienced secondary school teachers have developed TPK domains, and hence, they are expected to deliver effective instruction. However, as I already highlighted above, this *interaction between STOs and TPK domains* has been neglected as few studies have explored the relationship between teaching orientations and TPK domains. Hence, it was due to the reasoning of Gess-Newsome (2015) that I conceptualised this study. I wanted to examine the extent to which in-service (experienced) teachers' STOs interact with content knowledge, pedagogical knowledge, assessment knowledge, curriculum knowledge and knowledge of students.

In the above section, I have looked at the issue of poor performance in science for the Malawian context. I have also shown the steps various stakeholders have taken to address the problem. Hence, I believe that an understanding of the interaction between teaching orientations and TPK domains would alleviate the problems identified in this section. Through an understanding

of this interaction, teacher educators would be more informed regarding how they can structure their programs as well as instructional strategies to ensure that teachers are aware of this. Furthermore, PD facilitators would be more informed concerning how they can structure their activities, taking into account the interaction between STO and TPK domains.

### 1.3. Statement of the problem

Questions about the notion of teaching orientations as well as their interaction with TPK components have prompted various research studies. The majority of this research, however, is grounded in the pre-service teacher's education. According to Cochran, DeRuiter, & King (1993), pre-service teachers have incomplete and undeveloped TPK. Furthermore, these studies have traditionally relied on the Magnusson et al. (1999) definition of teaching orientations (e.g. Avraamidou, 2013; Cansiz & Cansiz, 2016; Kind, 2016) which other researchers have criticised as lacking clarity.

Research conducted recently using the Friedrichsen et al. (2011) definition of teaching orientations has also predominantly focused on pre-service teachers (for example, Demirdöğen, 2016). This situation has left a gap in knowledge in terms of the extent to which in-service teachers' STOs interact with content knowledge, pedagogical knowledge, assessment knowledge, curriculum knowledge and knowledge of students in the secondary school sector. Given that teachers are critical in the teaching and learning process (Ansari & Malik, 2013) and that teachers are responsible for the quality of instruction that students get from schools (Kyriacou, 2009), it is essential that the relationship between teaching orientations and TPK is further examined and understood from different perspectives (*secondary school experienced teachers*). These different perspectives will ensure that we have a comprehensive understanding of the issue. It is for this reason that the primary purpose of this study was to examine experienced secondary school Malawian in-service PS teachers' teaching orientations as defined by Friedrichsen et al. (2011) on their nature of interaction with teachers' TPK domains.

### 1.4. Research Questions

The central question addressed by this study is: how do science teachers' teaching orientations interact with the various TPK domains, i.e., content knowledge, curricular knowledge,

pedagogical knowledge, assessment knowledge and students' knowledge?

This question has the following sub-questions:

1. What science teaching orientations do Malawian Physical Science teachers exhibit?
2. To what extent do STOs influence the enactment of content knowledge, curricular knowledge, pedagogical knowledge, assessment knowledge, and knowledge of the students during instruction?
3. What insights can we draw from the understanding of these interactions?

The first question is an attempt to understand the teachers' science teaching orientations that experienced Malawian PS teachers exhibit. Specifically, these science teaching orientations are taken as the teachers' beliefs about ***teaching and learning of science, beliefs about goals and purpose of science teaching as well as their beliefs about the nature of science***. As can be seen, these beliefs or science teaching orientations align with the three dimensions of science teachers' teaching orientations as defined by Friedrichsen et al. (2011). The reason for this alignment is the main focus of the study, i.e., the interaction between teaching orientations and TPK domains. Furthermore, the conceptualisation, as well as the design of the study, was based on the same definition. As a result, data generation tools were aligned to these three dimensions as discussed in Chapters 2 and 3. The second research question was central to this study as it was an attempt to understand the interaction between science teachers' teaching orientations and TPK domains. Research question number three attempts to highlight the lessons learnt from the findings of the study.

### 1.5. The rationale of the study

The justification for this study is based on the following:

Theoretically, the study intends to build a TPK model that contributes to the understanding of the extent of influence STOs have on the enactment of TPK domains. Literature shows that teaching orientations are instrumental in "shaping" (Magnusson et al., 1999) other PCK as well as TPK domains; however, their relationship with TPK domains remains largely unexplored especially with experienced teachers. Similarly, Gess-Newsome (2015) shows that STOs are a critical element in filtering or amplifying the various TPK domains. However, this subject

remains mostly unexplored with experienced science teachers; hence, the conceptualisation of this study.

Practically, I envisage that findings from this study will help in designing effective teacher training as well as PD programmes that ensure the production of quality science teachers. I have already shown that teaching orientations filter or amplify teachers' decisions when they are thinking about teaching and learning; hence, an understanding of this interaction would enhance insights on the design of PD courses to ensure that they are active, i.e., that teachers use the various knowledge they have gained from the courses. Furthermore, the fact that I conducted this study in a third world context will contextualise understanding regarding the interaction of teaching orientations and TPK domains. Lastly, the study also responds to the call by Friedrichsen et al. (2011) for more empirical studies on this phenomenon.

### 1.6. Structure of the thesis

I have divided the thesis into seven chapters; starting with the introductory discussion of the problem in this chapter—where I discuss the problem (poor performance of students in science subjects) that led to the conceptualisation of this study as well as explicitly state the research problem. I also highlight the justification as well as the envisaged contribution of the study to both knowledge and teacher education in Malawi. In Chapter 2, I selectively review the literature on STOs, TPK, as well as PCK. Since it is PCK rather than TPK that is observed in the classroom during instruction, it was thus imperative to review the literature on PCK. This literature was also instrumental in the design of the study, especially on the data generation tools as I explain in Chapter 2 and Chapter 3. In Chapter 2, I acknowledge previous studies that have contributed to the notions of STOs and TPK as well as PCK. I also point out the gaps identified from these studies that led to the conceptualisation of this study. In the same chapter, I also discuss the theoretical and conceptual framework that guided the study from conceptualisation to data analysis. In Chapter 3 I discuss the methodology, that is, the methods, philosophical position (paradigm) and instruments that I used in this study. I also provide the rationale for the sampling process, the participant's profiles, as well as how data that was generated from the participants were analysed. Chapters 4, 5 and 6 report the findings of the study according to the three sub-research questions, as shown in this chapter. Specifically, Chapter 4 reports findings concerning the STOs which the teachers have concerning beliefs

about the goals and purposes of science teaching, beliefs about teaching and learning of science and beliefs about the nature of science. Chapter 5 reports findings relating to the interaction between STOs and TPK domains, i.e., the second sub-research question. Chapter 6 responds to the third sub-research question: What insights can we draw from the understanding of these interactions? In the same chapter, I provide answers to the three sub-research questions. Lastly, in Chapter 7, I provide insights, interpretations and explanations of the findings. Within the same chapter, I also provide the implications, as well as the contribution of the study to knowledge as well as to teacher education in Malawi. Within the same chapter, I also offer a conclusion.

# CHAPTER 2. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

*In this chapter, I present a review of literature relevant to TPK and STOs. I have divided this chapter into two main sections: STOs and TPK. Within these sections, are sub-sections where I discuss essential aspects regarding the two notions and how they influenced the design and implementation of this study. I pay particular attention to literature on the theoretical position of STOs, how STOs influence or interact with TPK domains as well as literature on STOs in practice. Similarly, I present a discussion of the construct of TPK in the literature as it is a broad and well-documented field. Specifically, I focus on the origins as well as the definition of TPK. This provided the definitions, the conceptualisation as well as the methodological issues that I used in this study.*

*I also focus on the current trends of TPK, particularly the consensus model, which redefines both TPK and PCK. I have devoted the last section of this chapter to the discussion of how STOs, as well as TPK, influenced the conceptualisation as well as the implementation of this study and the conceptual framework that guided this study.*

## 2.0. Introduction

This study started by acknowledging the positions of Magnusson et al. (1999) and Gess-Newsome (2015) that STOs are critical in influencing TPK or PCK. STOs are the beliefs that teachers possess which, according to Friedrichsen et al. (2011), include three interrelated dimensions: *beliefs about teaching-learning of science, beliefs about goals and purpose of science teaching as well as teachers' views about the nature of science.* On the other hand, TKP is all the professional knowledge that teachers have and tap from when they are thinking and planning about teaching.

## 2.1. Teacher Professional Knowledge (TPK)

In this section, I discuss literature related to TPK as well as PCK (see Chapter 1). Studies show that TPK informs PCK (see Gess-Newsome, 2015; Grossman, 1990). However, researchers do not directly observe TPK in the classroom. They observe teachers' PCK. This interplay is what

Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu (2008) call "manifestations of teachers' knowledge". These are "directly observable products" (p. 1380) of teachers' knowledge. What this means is that PCK is a critical link between TPK and teachers' practices therefore I review literature related to PCK in the remainder of the section. I will then explain how TPK and PCK informed my study.

### 2.1.1. Knowledge base for Teaching: Teacher Professional Knowledge (TPK) origins

Several studies have focused on establishing an understanding of a knowledge base for teaching, for instance, Shulman (1986) on the nature of TPK, Carlsen (1999) on names for TPK as well as Gess-Newsome (2015) on the model of TPK and PCK. The underlying assumption of these researchers is that teachers are unique and, as a result, they are bound to have knowledge that distinguishes them from other professionals even if they received the same content knowledge. Content knowledge, in this study, means the raw, untransformed knowledge found in books that include practices in science and engineering for knowledge generation (scientific process), core ideas of the discipline, crosscutting concepts, among others, that form the academic content of the discipline.

Before Shulman's work, as well as in the early 1980s, there was growing dissatisfaction with American educational research (Carlsen, 1999) which was deeply rooted in the "process-product" research. Process-product research emphasises the identification of teachers' characteristics that translate into higher students achievement (Verloop et al., 2001). Consequently, teacher educators, as well as PD trainers, could train pre-service teachers as well as in-service teachers based on these desirable characteristics. This pattern of reasoning regarding teacher education as well as research on teacher education faced increasing criticism. For instance, in the process of searching for the best characteristics of teachers, a bigger picture regarding teachers' practices was overlooked as "research and the interventions that were based on its findings, led to a fragmented and mechanistic view of teaching, in which the complexity of the teaching enterprise was not acknowledged" (Verloop et al., 2001, p. 442). What this means is that there was a simplistic focus of research in teacher education. "*A Nation at Risk: The imperative for education reform"* (*A Nation at Risk: The Imperative for Educational Reform.*, 1983, p. 22) report summarised this concern as follows:

*Too many teachers are being drawn from the bottom quarter of graduating high school*

> *and college students. The teacher preparation curriculum is weighted heavily with courses in 'educational methods' at the expense of courses in subjects to be taught.*

The implication of the above is that there is a need for a comprehensive review concerning pre-service teacher programs. Despite the different reactions to the above, the need to "professionalise" (Cochran-Smith & Fries, 2001) the teaching profession remained dominant. This means that teacher training institutions should advocate standard-based training, the need for professional development as well as assessment based performance of the teachers.

It was against this background that Shulman (1986) described the various domains of TPK. Grappling with a series of questions that interrogated the nature of TPK, Shulman (1986) described three categories of content knowledge for teachers: subject-matter content knowledge (SMK); subject-matter pedagogical knowledge (PK) and curricular knowledge. For Shulman (1986), SMK meant all the knowledge in the teachers' minds, e.g. Physics teachers' knowledge about the subject discipline. PK, on the other hand, is about the "ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 13). This knowledge includes analogies, illustrations and explanations that the teacher uses during instruction. The last category, curricular knowledge, includes teachers' knowledge about materials to use when presenting a lesson to the students. In *Knowledge and teaching: Foundations of the new reform*, Shulman (1987) further extended the above list to seven knowledge domains. This list included knowledge domains such as Content Knowledge (CK), general pedagogical knowledge, curriculum knowledge, PCK, knowledge of learners and their characteristics, knowledge of educational contexts and knowledge of educational ends. A recent study by Gess-Newsome (2015) draws from Shulman (1987)'s listing except for PCK, to construct a TPK model called "the consensus model of PCK". She describes five knowledge domains of TPK, considered in detail below, from where teachers draw their insights when planning their teaching. She, however, points out that this is not an exhaustive list but is compiled to "recognize and define the kind of knowledge that falls into this category" (p. 32). This listing of knowledge domains for teaching by Shulman appears to be the theoretical basis of various studies concerning teacher knowledge.

### 2.1.2. TPK in the literature

Various researchers have conducted studies to investigate the notion of TPK using different terms or names for TPK. Clandinin (1985), for instance, conducted a study where she focused on examining the teachers' classroom images with two primary school teachers. In her analysis, she concluded that teachers "develop and use a special kind of knowledge".

On the other hand, Elbaz (1991) conducted a review of research on TPK. The review mainly focused on published studies that had examined TPK concerning teacher thinking, the culture of teaching and the personal knowledge of teachers. In these two studies, TPK was referred to as "personal knowledge" as it is influenced by "the personal background and characteristics of the teacher" (Clandinin, 1985, p. 361). In one of their articles concerning TPK, Connelly & Clandinin (1988) explain that personal knowledge is:

> *"[a] term designed to capture the idea of experience in a way that allows us to talk about teachers as knowledgeable and knowing persons. Personal practical knowledge is in the teacher's past experience, in the teacher's present mind and body, and in the future plans and actions. Personal practical knowledge is found in the teacher's practice. It is, for anyone teacher, a particular way of reconstructing the past and the intentions of the future to deal with the exigencies of a present situation" (p. 25).*

This means that TPK is unique in the sense that teachers have different past experiences and interpret these experiences differently therefore this personal knowledge manifests in teachers' practices differently.

TPK has also been referred to as "craft knowledge" by other researchers. For instance, in the *Japanese model of professional development: Teaching as craft,* Shimahara (1998) reviews the model of PD for the Japanese education system. In this publication, TPK is referred to as "craft knowledge" because Shimahara (1998) believes that teachers construct much of what they know about teaching through practical experience as well as informal settings. He claims:

> *Craft knowledge is sensible, experientially grounded know-how constructed by teachers to deal with evolving events in the classroom. Craft knowledge is neither technical skill, the application of a theory or general principles to practice, nor critical analysis (p. 452).*

This means that practical experience is influential in developing teachers' TPK. The quote

further suggests that teachers develop their TPK from natural settings and that general principles regarding knowledge acquisition are not applicable in this case. Additionally, Shimahara (1998) proposes that it is difficult for teacher educators to teach this kind of knowledge as it seems to be context-specific and haphazard. Carter (1990), on the other hand, referred to TPK as "tacit knowledge". This is because TPK, according to him, is not well spoken of by the one holding it. According to Kratka (2015), tacit knowledge is specific to both the individual and the context: "Tacit knowledge is action/activity oriented knowledge gained without direct aid from other people, which enables the individual to attain goals bearing a personal value" (Kratka, 2015, p. 841). This makes it challenging to share as it is beyond rules and propositions.

Despite the apparent challenges concerning TPK, as it is personal or tacit, Verloop et al. (2001) give a comprehensive definition of TPK. The authors define TPK as "all professional-related insights that are potentially relevant to the teachers' activities" ( p. 443). The authors also state that TPK is "the total knowledge a teacher has at his or her disposal at a particular moment, which by definition, underlies his or her actions" (p. 445). This definition is comprehensive in the sense that the authors claim that the insights teachers use when planning about teaching or in the course of teaching imply TPK. Furthermore, the authors suggest the apparent interaction between teacher knowledge and teacher actions. Gess-Newsome (2015) claims that this apparent interaction is aggravated by factors such as teaching orientations of the teachers – a gap that I set out to examine with experienced secondary school science teachers. What the authors did not address, however, is the question of "what constitutes these insights?" This seems to resonate well with Elbaz (1991) who calls TPK "personal knowledge" which means these "professional related-insights" are unique to each person.

Regardless of this challenge, research shows that some domains are shared by all teachers or a large group of teachers either teaching at the same level or teaching the same age group of learners. These common domains are "canonical" (Gess-Newsome, 2015) since they are products of research as well as good practices of expert teachers who have developed successful methods/strategies of teaching. TPK domains, on the other hand, are also "public" (Gess-Newsome, 2015) in the sense that they are freely available in textbooks and journal articles which can be accessed by everyone including the teachers. The idea that TPK is both canonical and public implies that teacher educators may prescribe (Gess-Newsome, 2015) this knowledge

to pre-service or in-service teachers during teacher training or PD programs, respectively. Eventually, the idea that some TPK domains are shared or common among some teachers means that there is uniformity of TPK that teachers have at their disposal. The idea of uniformity in TPK is crucial for the following reasons: firstly, uniformity in TPK ensures that students receive similar instructions during the teaching and learning process. Secondly, for this study, uniformity in TPK was one of the assumptions I had while I conceptualised the study. Since I did not scientifically establish the teachers' TPK, I assumed that it was uniform.

### 2.1.3. Current trends of TPK

Shulman (1987) model of TPK has been the subject of various research studies. However, a review of the literature shows that research on this tends to be skewed towards three domains of TPK that Shulman initially proposed: SMK, PCK and PK. For example, Rollnick et al. (2008) focus on understanding the place of SMK in PCK and Mavhunga, Ibrahim, Qhobela, & Rollnick (2016) focus on the development of PCK in pre-service teachers.

Content knowledge is the untransformed knowledge a teacher has about the subject matter. It has two critical components (Günther et al., 2019). These are: (1) the fundamental knowledge of facts, concepts, theories, laws, as well as principles documented in the textbooks, (2) the knowledge of how scientific knowledge is developed, how it relates to other knowledge and why it is worth having (Günther et al., 2019). Research demonstrates that CK is central when it comes to teaching. For instance, in a one year study, Baumert et al. (2010) assessed teachers' CK as well as PCK to establish a link between CK and quality of instruction as well as students' progress. Students and teachers participated in the study where they took a paper and pencil test consisting of 13 items that included arithmetic, algebra, geometry and functions, among others. The researchers concluded that CK is a critical aspect of the quality of teachers' PCK. Driel, Jong, & Verloop (2002) also made similar conclusions. The authors investigated how pre-service chemistry teachers teach the topic of the particulate nature of matter. The findings suggest that a university-based PD workshop and high quality mentoring helped the teachers to enhance their awareness of their tendency to jump between macro and micro levels, without considering the impact of this on students. From these studies, it seems clear that good CK is a critical factor in the efficacy of the lesson. However, Baumert et al. (2010) still contend that mere possession of CK "alone is not a sufficient basis for teachers to deliver cognitively

activating instruction that, at the same time, provides individual support for students' learning" (p. 163). This means that teachers still need other equally important knowledge domains that must be blended with CK to bring forth a PCK for effective teaching. This is true, especially for those teachers who are experts in content but fail to unpack the same content into units that can be understood easily by the students due to the lack of a PCK that can enable him/her to teach that content effectively.

PK, on the other hand, goes beyond CK. Shulman (1987) defines PK as the knowledge of the "broad principles and strategies of classroom management and organisation" ( p. 8). Grossman (1990) extends this definition by including three subdomains of this knowledge that interact to bring out this knowledge. These include learners and learning, classroom management and curriculum, instruction and "others" which are sub-domains beyond what the author had highlighted. This means that a teacher should have these knowledge sub-domains from which to draw insights. In a study aimed at identifying the strategies used for mentoring pre-service teachers in PK, Hudson (2013) reports the existence of several strategies that he deems effective in helping the teachers. These include students' contexts, differentiated learning, reflection on practice and interaction with other school staff.

TPK is all the professional knowledge that informs teachers' activities that is only manifested in the classroom through the enacted PCK (Rollnick et al., 2008). The section below reviews the literature on PCK and research on the notion of PCK which led to the revised consensus model.

### 2.1.4. Pedagogical Content Knowledge

PCK has the potential to provide a framework for teacher training and PD programs (Gess-Newsome, 2015; Kind, 2009). According to Shulman (1987), PCK is the knowledge that enables teachers to transform content knowledge into units that students can easily understand. These transformed units are "pedagogically powerful" (Shulman, 1987, p. 15) in explaining the content. He also states that PCK is unique in that it "identifies the distinctive bodies of knowledge for teaching" (p. 8). By "distinctive", Shulman suggests PCK has discrete sub-domains that are: *representations and instructional strategies,* and *students' subject-specific learning difficulties*. While representations include *analogies* and *explanations*, students' subject learning difficulties include understanding the various misconceptions that learners

bring into the classroom and working on them for effective teaching and learning, among others. It is therefore clear that PCK is not only about the content that a teacher has to master but also about how to teach a particular content to students (Mavhunga & Rollnick, 2013).

Several researchers have since used Shulman's propositions as a theoretical framework to advance their understanding of PCK that includes the concept of TPK which has led to the conceptualisation of different models of PCK in the literature. For example, following Shulman's work, Grossman (1990) advanced a TPK model that further synthesised Shulman's ideas. In her book, *The Making of a Teacher: Teacher Knowledge and Teacher Education* Grossman presents a TPK model (Figure 2-1) which shows how PCK, as a domain of TPK, relates to other TPK domains. In this model, Grossman shows that PCK has sub-domains that interact in a particular way to bring about "effective" teaching during instruction. There is a slight difference in the conceptualisation of PCK between Grossman and Shulman. While Shulman, highlights the two sub-domains, shown above, PCK, according to Grossman, has four sub-domains: *conceptions of purpose for teaching a subject matter, knowledge of students understanding, knowledge of instructional strategies* and *curricular knowledge*. Conceptions of purpose for teaching a subject matter is the "knowledge and beliefs about the purpose of teaching a subject at different grade levels" (p. 8). In science education literature, these conceptions of purposes for teaching a subject matter are the **science teaching orientations** (see section 2.2.1). This definition means that the contents of teachers' goals about teaching a specific subject matter reveal the teachers' beliefs. This definition affected how I conducted this study. I used interviews and teachers' documents (CoRes see Chapter 3) to reveal their beliefs. Figure 2-1 shows that teaching orientations have an overarching role. PCK amalgamates these knowledge domains that interact in a particular way to present a knowledge that is manifested in the classroom.

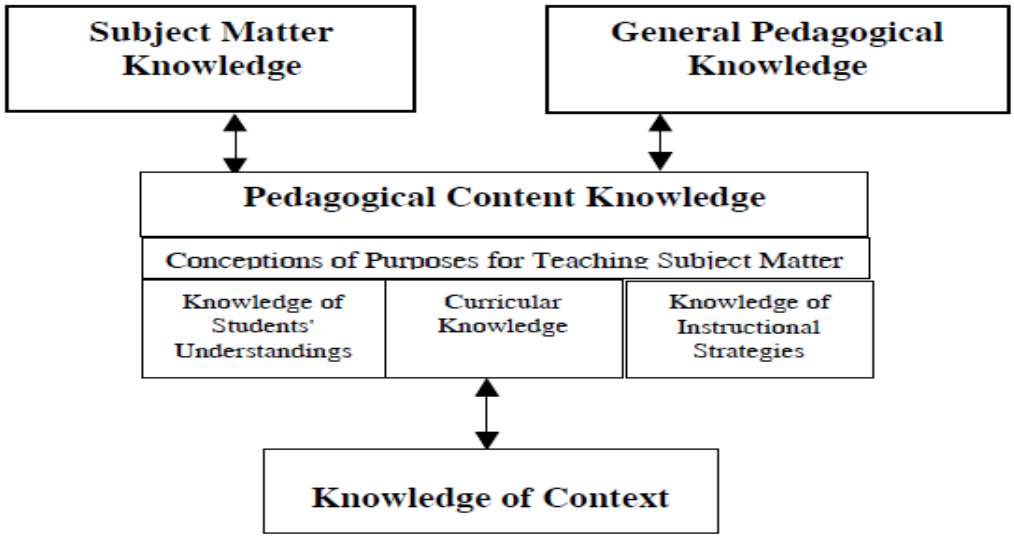


**Figure 2-1: Model for teacher Knowledge according to Grossman**

Source: *The Making of a Teacher: Teacher Knowledge and Teacher Education* (Grossman, 1990, p.5).

Studies conducted in the language context informed the PCK of Shulman and Grossman but Magnusson et al. (1999) were the first to present a science-based model of PCK where they discuss the nature, sources as well the development of PCK for science teaching. Their interest was to answer a series of questions, which were at the heart of most science teachers, such as: "what shall I do with my students to help them understand this science concept?" Their answer was to advance a science-based PCK model (Figure 2-2) that responded to the demands of science teaching. By developing a science-specific PCK model, the authors insinuated that different disciplines have different ways of handling things, hence the science-specific PCK model. Similar to Grossman (1990), their PCK model had sub-domains, however, unlike Grossman, these knowledge sub-domains were science-specific: *orientations to teaching science*, *knowledge of science curricula*, *knowledge of assessment of scientific literacy*, *knowledge of instructional strategies* and *knowledge of students' understanding of science*. Furthermore, and analogous to Grossman's reasoning, teaching orientations were given an overarching role (see Figure 2-2) however, instead of calling them "conceptions of purpose for teaching a subject matter", they called them "orientations to teaching science". Additionally, the relationship between STOs and other PCK domains appear unclear as they are connected by the phrase "which shapes". The phrase is not explicit as to what it entails therefore this study

was conceptualised to understand this interaction i.e. interaction between STOs and other knowledge domains.

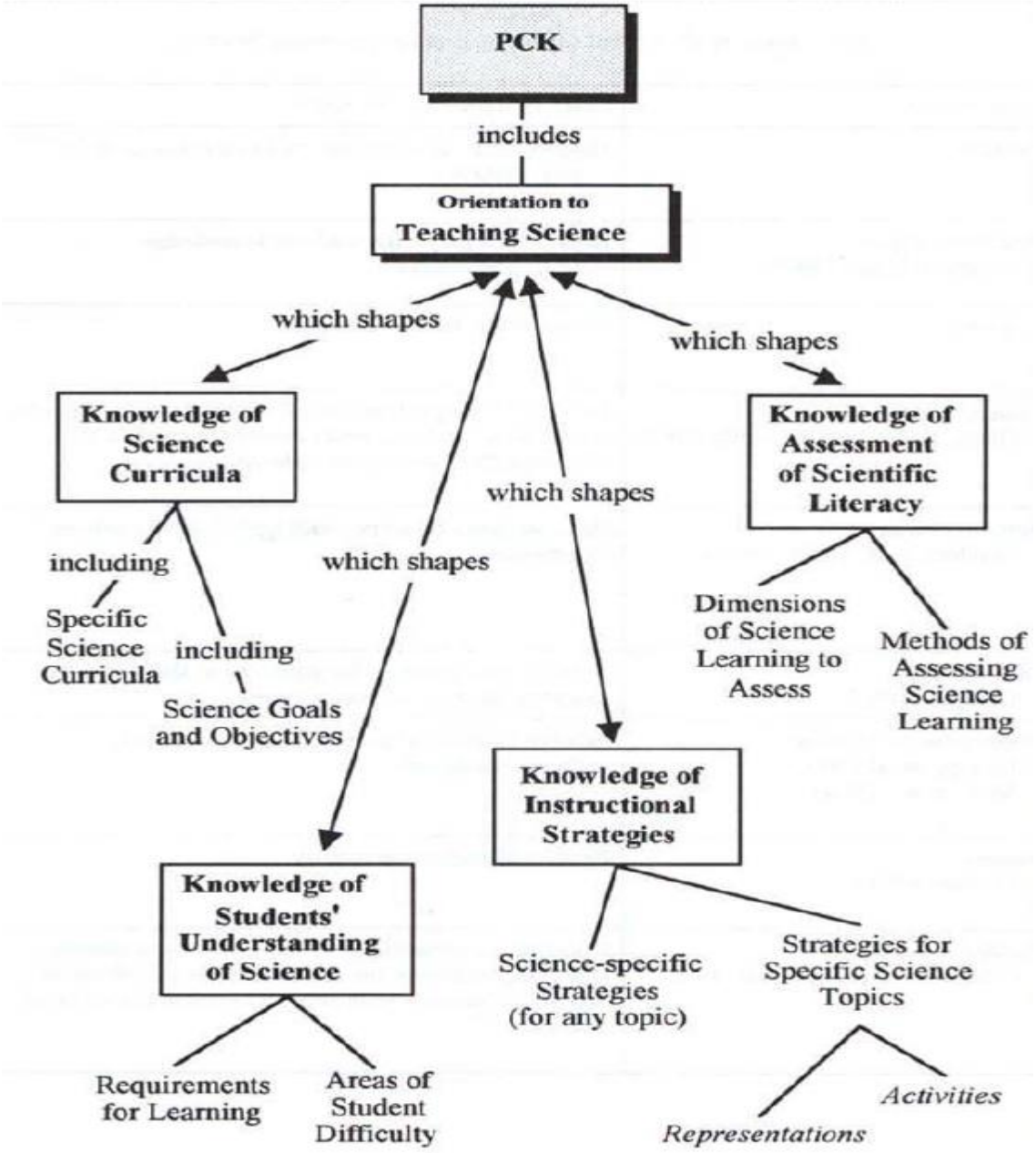


**Figure 2-2: Domains of PCK for science teaching**

Source: *Nature, sources, and development of pedagogical content knowledge for science teaching* (Magnusson et al. 1999, p. 99).

In a study that investigated how the National Board Certification (NBC) process influences the teachers' PCK, Park & Oliver (2008a) developed a pentagonal PCK model (Figure 2-3). Using

the interviews as well as teacher reflection data from three experienced teachers, the researchers found that the NBC process had influenced five teachers' instructional practices. These aspects are (a) reflection on teaching practices; (b) implementation of new and innovative teaching strategies; (c) inquiry-oriented instruction; (d) assessments of students' learning; and (e) understanding of students. Similar to Magnusson et al. (1999), their pentagonal model of PCK, similar had five domains, as shown in Figure 2-3

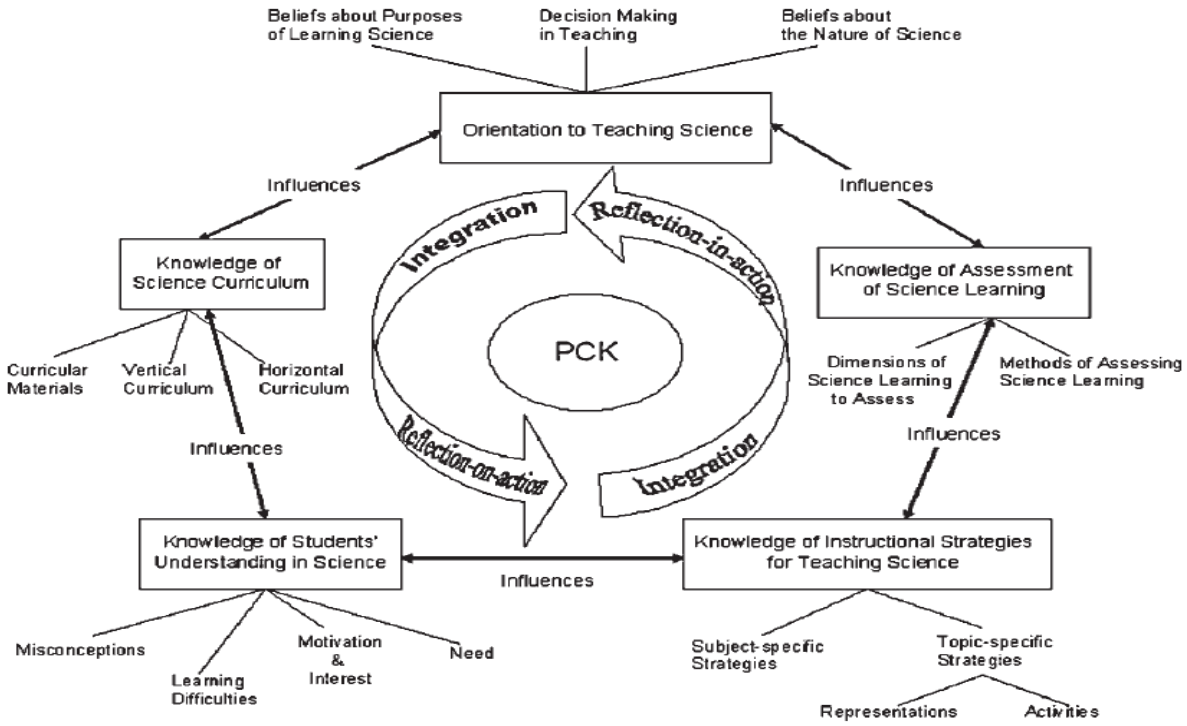


**Figure 2-3: Pentagonal Model of PCK for science teaching**

**Source:** Park and Oliver (2008a).

In a related study, Park & Oliver (2008b) revisited the notion of PCK to rethink the conceptualisation of PCK with the purpose of understanding teachers as professionals. They conducted a multiple case study grounded in the constructivist framework with three experienced in-service teachers. Since PCK is elusive (Baxter & Lederman, 1999), the authors used multiple instruments to collect data such as classroom observations, semi-structured interviews, lesson plans, teachers' written reflections, students' work samples and researcher's field notes. A multi-data analysis approach yielded similar results, as reported above, however, "teacher efficacy" proved to be an important affiliate of PCK. As a result, the researchers

proposed a hexagonal PCK model (Figure 2-4) to include this aspect. Teachers' self-efficacy describes teachers' "ability to enact effective teaching methods for specific teaching goals and was specific to classroom situations/activities" (p. 270). They argued that this is a crucial sub-domain of PCK hence the need for its reflection in the model. The two models, however, appear to be slightly different from that of the Magnusson et al. (1999) model in the sense that, in the Park and Oliver models, the knowledge domains are interrelated by simple-influence arrows to form a loop unlike in the Magnusson model where the knowledge domains are discrete. In the Magnusson et al. (1999), this means that, while the knowledge domains all relate to orientations of science teaching, they do not relate to one another. For instance, knowledge of science curricula is not related to knowledge of instructional strategies. Whereas the Park and Oliver models appear different from the overly used Magnusson et al. (1999) model, my observations of these two models are that PCK, just like any other knowledge domain, has the potential to be developed. As the model highlights, a teacher may develop his PKC through "reflection-in-action" and "reflection-on-action". Furthermore, the authors use of various instruments when collecting data are a critical insight when it comes to studying and capturing teachers' PCK.

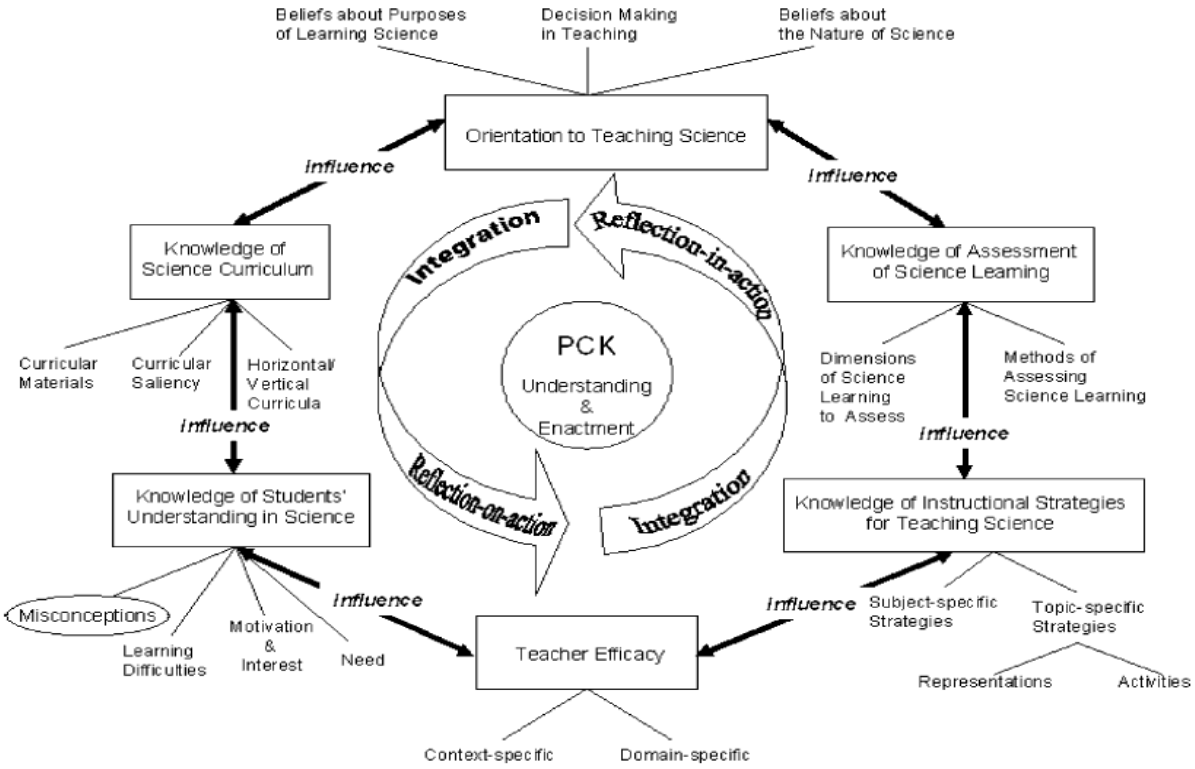


**Figure 2-4: Hexagonal Model of PCK for science teaching**

Source: Park and Oliver (2008b).

In another study, Rollnick et al. (2008) investigated the place of SMK in PCK. Specifically, the authors examined the influence of SMK on PCK using two case studies on two different topics: *the mole* as well as *chemical equilibrium topics*. The mole topic was offered in the high school context while the chemical equilibrium topic was offered at the access program at the tertiary level. Various data collection techniques such as classroom observations, pre and post-observation interviews and teacher resources such as textbooks were used. Examining their data, the authors saw the possibility of proposing a tailored PCK model (Figure 2-5). One thing that sets this model apart from most PCK models is that it connects teachers' observable practices to the knowledge domains. Similarly, PCK, according to these authors, consists of four knowledge domains, as shown in Figure 2-5. These knowledge domains are amalgamated to produce what is observed in the classroom, which the authors have called "manifestations of teacher knowledge". From the authors' perspective, these manifestations are observed in four main ways: curricular saliency, topic-specific instructional strategies, representations and assessment.

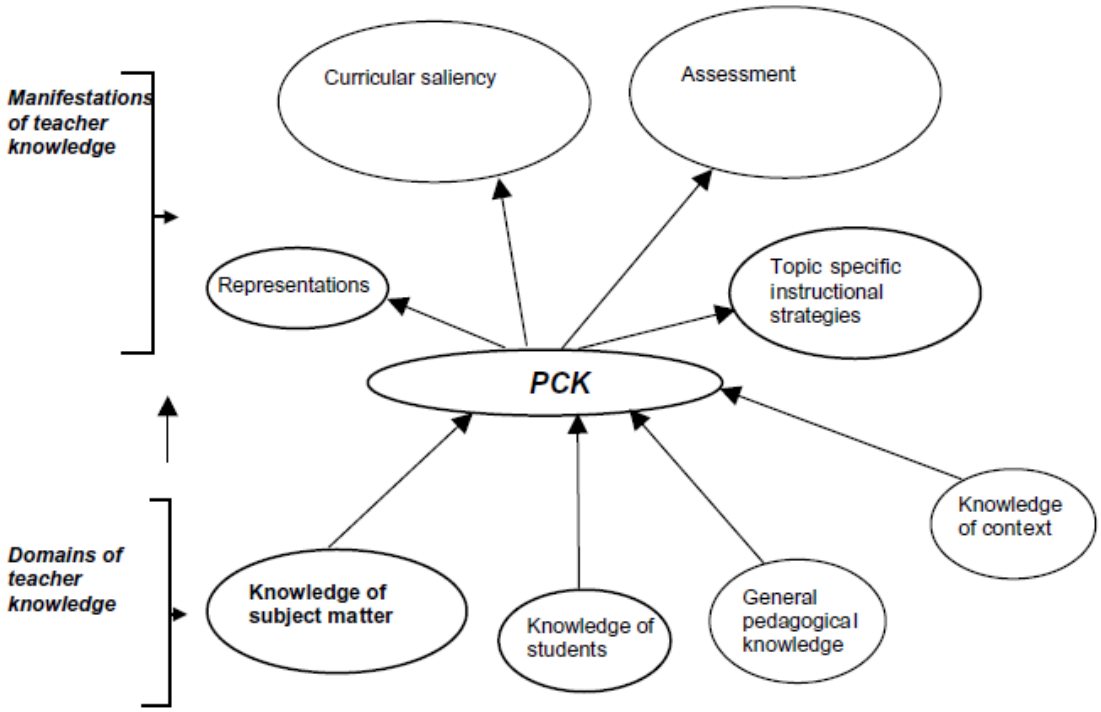


**Figure 2-5: Tailored Model for PCK**

Source: Rollnick et al (2008).

In another related study (Davidowitz & Rollnick, 2011), the tailored model in Figure 2-5 was modified to include beliefs as an overarching domain of PCK, which influences and is influenced by the other knowledge domains, as shown in Figure 2-6. In this study, the researchers sought to understand what lies at the heart of good teaching in the undergraduate organic chemistry topic. In their case study, they worked with an accomplished undergraduate chemistry lecturer to capture and portray his PCK. From the analysis of the data, the authors modified their earlier PCK model (Figure 2-5) to include belief components to produce a modified, tailored PCK model (Figure 2-6). They argued that the participant's beliefs significantly influenced his practice of tertiary teaching. Hence the reason to include beliefs in their model. These beliefs might include teachers' beliefs about NoS, teachers' beliefs about teaching and learning of science as well as beliefs about the goals and purposes of science teaching. These beliefs, as shown in Figure 2-6, interact with the various knowledge domains of PCK. However, just like the other models, the nature of interaction or influence is not explicit. Hence, I conceptualised this study to examine this apparent interaction.

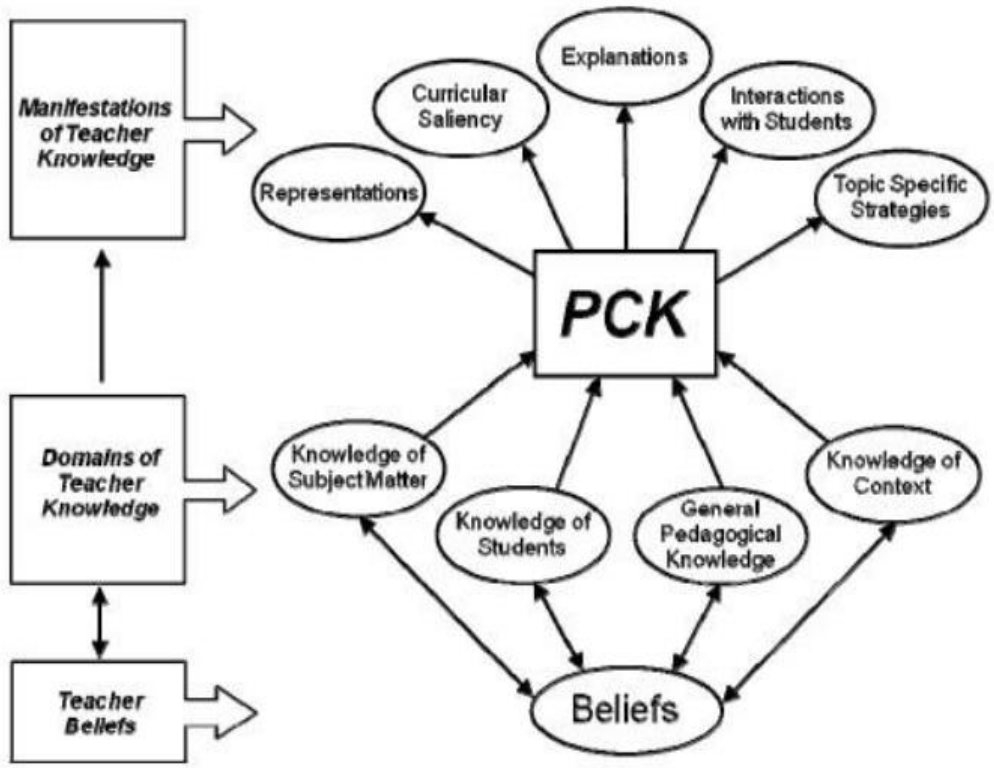


**Figure 2-6: a Modified model for PCK**

Source: Davidowitz and Rollnick (2011)

Over the years, it has been established that PCK is elusive (Kind, 2009, 2015). This is evidenced by the existence of many different models in the literature, as shown above. To illustrate this, I have tabulated (see Table 2-1) a few models of PCK to show the diverse range of conceptualisations regarding the notion of PCK. Even though many models exist, most of the models have returned Shulman's original propositions about PCK (columns 2 and 3 in Table 2-1). However, some have reconceptualised his original ideas before incorporating them in their models. The table, however, is not exhaustive of all the models that exist in the literature.

**Table 2-1: Different PCK models conceptualised over the years**

| | Knowledge Components | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| **Authors** | Model Name | Subject matter | Representations and instructional strategies | Students' subject-specific learning difficulties | General pedagogy/ classroom management | Curricular knowledge | Context for learning | Purposes/ orientations/ nature of science | Assessment | School knowledge |
| Shulman (1987) | **N/A** | **Y** | **X** | **X** | **Y** | **Y** | **Y** | **Y** | **O** | **O** |
| Grossman (1990) | **Teacher Knowledge** | **Y** | **X** | **X** | **Y** | **X** | | **X** | **O** | **Y** |
| Fernández-Balboa & Stiehl, (1995) | **N/A** | **X** | **X** | **X** | **O** | **O** | **X** | **X** | **O** | **O** |
| Magnusson et al., (1999) | **N/A** | **Y** | **X** | **X** | **Y** | **X** | **Y** | **X** | **X** | **O** |
| Park & Oliver, (2008a) | **Pentagonal** | **Y** | **X** | **X** | **Y** | **X** | **O** | **X** | **X** | **Y** |
| Park & Oliver, (2008b) | **hexagonal** | **O** | **X** | **X** | **O** | **X** | **O** | **X** | **X** | **O** |
| Rollnick et al., (2008) | **Tailored** | **X** | **X** | **X** | **X** | **O** | | **O** | **X** | **O** |
| Friedrichsen et al. (2009) | **N/A** | **Y** | **X** | **X** | **Y** | **X** | | **Y** | **X** | **O** |
| Gess-Newsome (2015) Consensus Model of PCK | **Consensus** | **Y** | **O** | **Y** | **Y** | **Y** | **O** | **O** | **Y** | **O** |

Note: X is a component thought to be part of PCK; Y is a component in teachers' knowledge considered to be essential but not necessarily part of PCK; O is a component not openly discussed.

Table 2-1 shows the various models that researchers on PCK have conceptualised. Columns 2 and 3 show the two components of PCK originally proposed by Shulman. It is clear that most researchers have returned these as components of PCK. However, they have added other components. A significant departure from these models is that of Gess-Newsome (2015), the consensus model. From the table, we see that all the components, according to the author, are components of TKP that belong to various layers of the model. Another critical thing to note is how STOs (column 7) has been conceptualised over the years. According to Shulman (1987), teaching orientations are not a PCK component. Instead, they are part of TKP. However, as can be seen from the table, other models included teaching orientations as part of PCK only to be removed from PCK in the consensus model.

Measuring teachers' PCK has also been one of the frequently investigated areas on TPK. However, it has increasingly been challenging to measure it because of the following reasons:

1. *PCK is not directly observable as it is mostly an internal construct of the one allegedly having it (Baxter & Lederman, 1999; Eames et al., 2011; Kind, 2009; Kirschner et al., 2016).*
2. *Even with carefully designed tools, teachers do not have a readily available language which they can use to articulate their ideas (Baxter & Lederman, 1999, p. 148).*
3. *A lack of consensus makes it difficult and time-consuming to develop PCK tools (Baxter & Lederman, 1999; Kirshner et al., 2015; Park, Jang, Chen, & Jung, 2011) hence making it difficult to measure.*

Despite these challenges, some researchers managed to develop tools for measuring the quality of PCK (e.g. Mavhunga & Rollnick, 2013). I am particularly interested in the one developed by Loughran, Mulhall, & Berry (2004). The tool, Content Representations (CoRe), is a qualitative tool which captures teachers' PCK hence the reason for my interest (see Chapter 3).

### 2.1.5. The consensus Model-Redefining TPK and PCK

To this far, I have shown how various researchers in teacher education had defined the notion of TPK. I have also highlighted the focus of research on TPK that is on PCK and the conceptualisation of different models of PCK. These different models of PCK have always resulted in problems as reported in the literature (Carlson, Stokes, Helms, Gess-Newsome, & Gardner2015). To deal with these problems, a group of 22 researchers on PCK met at a PCK summit which took place at Colorado Springs in the USA. The main aim of the PCK summit was to discuss problems related to the notion of PCK. In trying to justify the need for the summit, Carlson et al. (2015) state that the notion of PCK has been widely studied and:

> *It has become clear, however, that there is now considerable divergence in the interpretation and understanding of PCK. In particular, we noticed that there were significant and troubling divergences in the critical elements of science PCK that drive the research and make it meaningful, including definitions, conceptual frameworks, instruments, methods, and, subsequently, the findings (p. 16).*

As a result, issues of definitions, conceptual framework and instrument design limit the usefulness of the notion because it became increasingly challenging to design instruments that could measure as well as track the development of PCK since there were different conceptualisations of the notion. Hence, there was a need to re-consider the divergent views.

For five days, these researchers discussed and synthesised empirical research and proposed a consensus model. The consensus model of Figure 2-7 has six layers related by double-edged arrows. The first layer constitutes the knowledge domains, similar to those of Shulman, with the exception of PCK. The second layer constitutes knowledge domains for handling specific topics which the author refers to as Topic-Specific Professional Knowledge (TSPK). As can be seen from Figure 2-7, this layer influences and is also influenced by TPK domains. Then the model acknowledges the role played by "filters and amplifiers". These are lenses that teachers use to evaluate all the professional knowledge, including TSPK domains. The result is the manifestation of PCK in the classroom.

Within the PCK framework, they identified: personal PCK as well as personal PCK & skill. Personal PCK refers to "the knowledge of, reasoning behind, and planning for teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes (Reflection on Action, Explicit)". Personal PCK and skill refer to the act of teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes (Reflection in Action, Tacit or Explicit). These ideas are a contribution of the research of Loughran et al. (2004) on PCK. However, unlike Rollnick et al. (2008) model, the consensus model is not explicit on how these manifestations occur in the classroom.

The belief is that classroom practices will eventually influence students' outcomes. The inclusion of students' outcomes is what sets this model apart from the rest of the models on PCK. In the other models, the focus appears to be on what PCK is and what constitutes PCK. However, the consensus model goes beyond this by recognising the importance of students' outcomes. Just like amplifiers filter TSPK before being integrated to bring forth a PCK, as explained above, teachers' PCK is also filtered before being translated into students' outcomes. This means that there are several factors that may hinder or amplify students' achievements during teaching and learning. Eventually, students' outcomes provide a critical feedback loop

to TPK and TSPK domains. Knowledge domains in the TPK and TSPK are both "canonical and public" as discussed in section 2.1.2. Therefore, having argued that TPK informs PCK which manifests in the classroom during instruction, I briefly highlight that issues related to PCK have a bearing on the design of any study related to TPK. For example, PCK is tacit; this implies a researcher should think of using several tools to collect data (see Chapter 3).

In Table 2-2 I briefly describe the various domains of TPK. This table is a synthesis of descriptions from the works of Gess-Newsome (2015) and Rollnick et al. (2008). The description of these knowledge bases is almost similar to those of topic-specific professional knowledge (Gess-Newsome, 2015) hence this study's focus on the interaction between teaching orientations and TPK. The consensus model resembles many models that portray PCK as an integration of knowledge domains. This idea agrees with Rollnick et al. (2008) who argue that PCK is an integration of various knowledge domains manifested in different ways in the classroom. Furthermore, within the same table, I have included a column which shows some of the sub-domains of these knowledge domains. These sub-domains illuminate the description in the middle column and are critical in establishing an interaction between STOs and TPK domains as is shown in the findings in Chapter 5

So far, I have reviewed literature by highlighting several issues concerning the notion of TPK. From the review, my observation is that TPK is broad and complex. Existence of several different models exemplifies this. Furthermore, it also shows how an understanding of the concept provides critical insights concerning teacher education as well as teachers′ practices.

Recent research (such as that of Gess-Newsome, 2015) provides critical insights concerning the notion of TPK. However, the lack of clear explanations connecting the various concepts, especially between amplifiers and knowledge domains of the consensus model, suggest the need for further research, specifically to interrogate the nature of the interaction between filters and amplifiers, and how these filters interact with the various domains of this model. Now I briefly describe the five knowledge domains from the consensus model in Table 2-2 (first layer of the consensus model).

## Table 2-2: Teacher Professional knowledge domains description

| KNOWLEDGE COMPONENT | DESCRIPTION | Sub-domains (coming from the description) |
|---|---|---|
| **Assessment knowledge** | Assessment knowledge is the knowledge that teachers tap from to assess their students' learning. This knowledge domain includes knowledge about the design and use of formative and summative assessments as well as how to use results from those assessments to design or modify instruction. Apart from that, it also includes how to carry out the assessment. | *What to assess*<br>*Methods of assessment*<br>*Reasons for assessment* |
| **Pedagogical Knowledge** | Pedagogical knowledge is the knowledge domain that includes principles and strategies for classroom management and student engagement, e.g. questioning techniques, instructional strategies to support differentiation based on student need, or how to design a lesson plan, teaching techniques, ways of setting up a classroom for instruction. Understanding what counts as good teaching, the best teaching approaches in a given context, informed by knowledge of applicable learning theories. | *Classroom management*<br>*Student engagement*<br>*Instructional strategies* |
| **Content knowledge** | This is the amount and organisation of knowledge per se in the mind of the teacher or the "teachers' raw, untransformed SMK". This domain includes things like practices in science and engineering for knowledge generation (scientific process), core ideas of the discipline, crosscutting concepts, etc. that form the academic content of the discipline and issues that spread beyond a discipline | *Practices for scientific knowledge generation*<br>*Core ideas in science (principles, theories, facts, laws)*<br>*Cross-cutting issues* |
| **Knowledge of students** | This is the knowledge that enables teachers to appreciate students' cognitive and physical development, differences that might require instructional differentiation, and how to capitalise on personal and community assets to enrich instruction. This knowledge makes teachers aware of students' prior knowledge, how they learn, their linguistic abilities, and interests and aspirations. | *Students' differences*<br>*Pre-requisite knowledge*<br>*Misconceptions* |
| **Curricular Knowledge** | This is the teachers' knowledge concerning the teachers' curricular proficiency. This knowledge includes teachers' knowledge about the goals of a curriculum, teachers' knowledge about the structure of the curriculum, as well as teachers' knowledge about the role of a scope and sequence of the curricular document. Furthermore, this knowledge also shows the teachers' ability to assess a curriculum for coherence and articulation. | *Goals and objectives*<br>*Scope and sequence of the curriculum*<br>*Curriculum coherence*<br>*Linkage to other topics* |

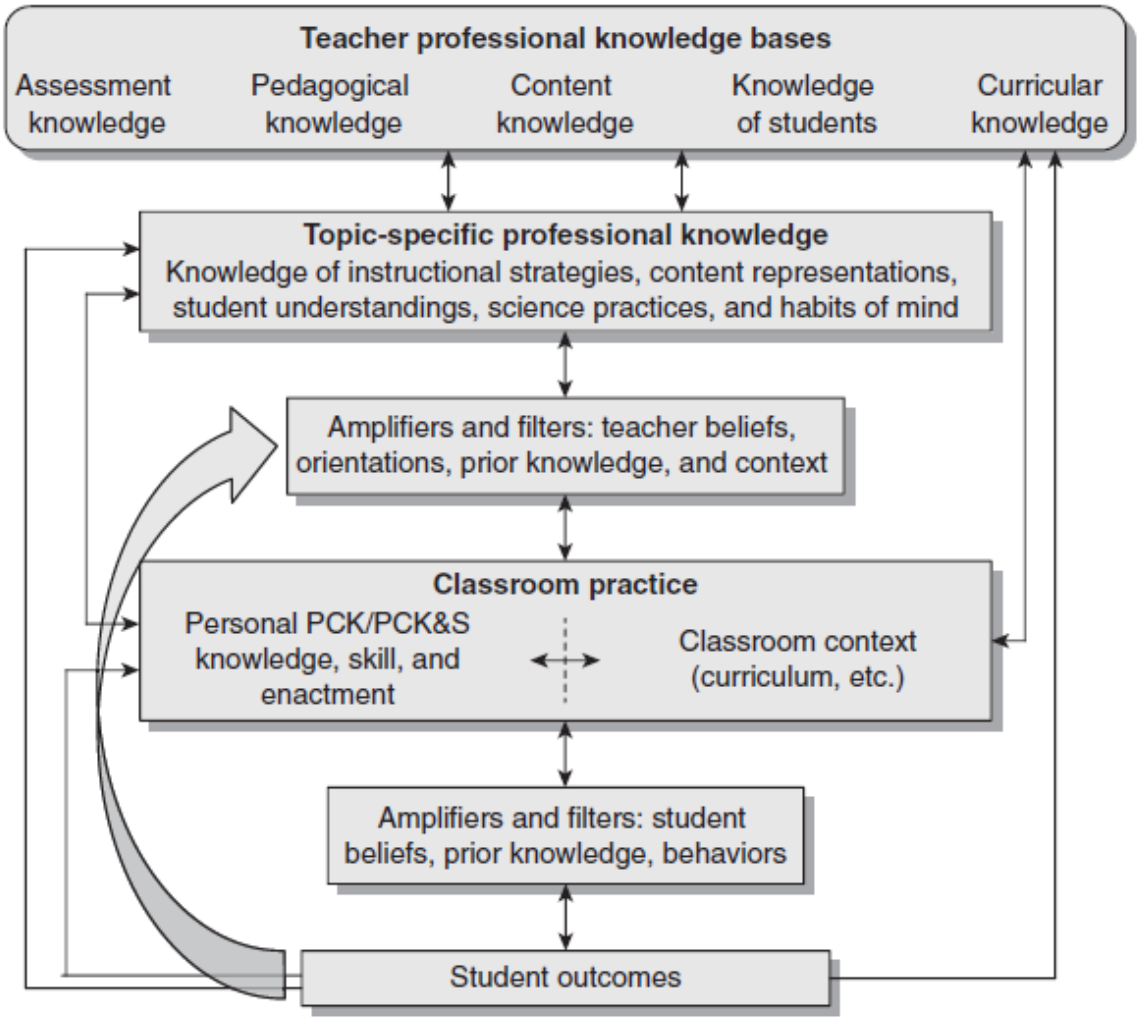


**Figure 2-7: Consensus Model of teacher professional knowledge and skill including PCK**

Source: *A model of teacher professional knowledge and skill including PCK results of the thinking from the PCK summit* (Gess-Newsome, 2015, p. 31)

### 2.2. Science teaching orientations (STOs)

In this section, I review literature related to STOs. I will begin by providing a brief account of the origins of STOs in the literature. From there, I will focus on the discussion of STOs in the literature by concentrating on the categorisations of STOs; I will conclude this section by looking at the studies that have examined the interaction between STOs and either PCK or TPK domains. Mostly, my review will focus on science education literature on STOs. In this, I will be highlighting the research methodology, participants of the study, analytical tools, the tools

for data collection as well as the findings of the studies. As in the sections above, I will also highlight the gaps and how they helped in the conceptualisation of this research study.

### 2.2.1. Origins of science teaching orientations

Anderson & Smith (1987) introduced the notion of STOs in science education in the early 80s to move away from the dominant "process-product" research (as described above). They conducted a study: "Planning and Teaching Intermediate Science (PTIS)" (Smith & Anderson, 1984) that ran for two years while they observed two groups of fifth-grade teachers as they taught science. The two groups of teachers used different versions of the improved curriculum while teaching the *Communities Unit*. The researchers noted that there were differences in terms of how the teachers implemented the curriculum within each curriculum group. They further investigated the differences in the way the teachers taught the lessons in order to have a comprehensive understanding of the issue. In their 1987 publication, the authors introduced the term "teachers' orientations toward science teaching and learning" to explain the differences they had earlier observed in terms of the approaches the teachers used when teaching the unit. They claimed the observed differences were a result of the teachers' STOs that they defined as "general patterns of thought and behaviour related to science teaching and learning" (p. 99). They also elaborated their definition of STOs by describing four different categories of STOs: *activity-driven teaching, didactic teaching, discovery teaching, and conceptual-change teaching*. I describe these together with those identified by Magnusson et al. (1999) in Table 2-3.

Grossman (1990) extended the understanding of the notion to other subject disciplines. In her book, *the making of a teacher: Teacher knowledge and Teacher Education* (1990), she renamed "teaching orientations" to "conceptions of purposes for teaching a subject" that is not specific to a particular discipline. In her model of teacher knowledge, Grossman stressed these conceptions of purpose for teaching a subject because they interact with various teacher knowledge domains which, in turn, impact teachers' practices. She noted that teaching orientations reveal themselves whenever teachers are formulating their goals for teaching a subject matter. What this means is that, while teachers are planning to teach, they, consciously or unconsciously, include aspects of their beliefs in these goals (see Chapter 3). Unlike Anderson & Smith (1987), Grossman (1990) presented a slightly different definition of the

notion of STOs as "knowledge and beliefs about the purpose of teaching a subject at different grade levels" (p. 8). While Anderson and Smith's definition discussed the general patterns of thought and behaviour which, in my view, seems to be ambiguous, Grossman's definition appears to be more precise in the sense that the definition shows that these teaching orientations are those beliefs that describe the ***goals and purposes*** of teaching a subject matter at a particular level.

Grossman (1990) further claims that teaching orientations are critical in that they act as a teacher's "conceptual maps for instruction decision making" (p. 86), which relates to the understanding of the role of teaching orientations in the teaching and learning process. This phrase explains that teaching orientation forms a jigsaw puzzle in which teachers fit their ideas concerning: what materials to use during instruction, what objectives to include, what assignments to give students, and how to evaluate students' achievement. Grossman (1990) describes the central role of teaching orientations as follows:

> *"Although beginning teachers may lack the managerial skills necessary to implement their plans successfully, their beliefs about the goals for teaching their subjects become a form of conceptual map for instructional decision making, serving as the basis for judgments about textbooks, classroom objectives, assignments, and evaluation of students" (p. 86).*

Magnusson et al. (1999) preferred to use the phrases "orientation towards science teaching and learning" (see Figure 2-2), "teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level" or "a general way of viewing or conceptualising science teaching" (see Anderson & Smith, 1987) focusing particularly on science education instead of Grossman's generic "conceptions of purposes for teaching a subject matter". Although they returned Grossman's views, Magnusson et al. (1999), related the concept to science teaching, making it discipline-specific.

Apart from the four STOs described by Anderson and Smith (1987), the authors further identified five other STOs which totalled nine STOs as described in Table 2-3. The dual nature of the definition of STOs and its implications are considered in section 2.2.3 below.

### 2.2.2. The categorisation of science teaching orientations

In reviewing the science education literature on teacher knowledge – STOs, Magnusson et al. (1999), as well as Anderson & Smith (1987), identified STOs that are: *process, academic rigour, didactic, conceptual change, activity-driven, discovery, project-based science, inquiry and guided inquiry*. These are described Table 2-3 together with the primary goal for each STO. The authors mentioned above stress that it is not a particular activity that a teacher uses that determines the STOs, but it is how the activity *meets the teachers' goals and purposes of teaching science*, as Magnusson et al. (1999) explain:

> *"… it is not the use of a particular strategy but the purpose of employing it that distinguishes a teacher's orientation to teaching science. For example, teachers with a discovery, conceptual change, or guided inquiry orientation might each choose to have students investigate series and parallel circuits, but their planning and enactment of teaching relative to that goal would differ. The teacher with a "discovery" orientation might begin by giving his students batteries, bulbs, and wires, and proceed by having them follow their ideas as the students find out what they can make happen with the materials" (p. 97).*

## Table 2-3: Science teaching orientations described in literature

| Orientation | Goal of the teaching | Characteristic of orientation |
|---|---|---|
| **Process** | Help students develop "science process skills." | The teacher introduces students to the thinking processes employed by scientists to acquire new knowledge. Students engage in activities to develop a thinking process and integrated thinking skills. |
| **Academic rigour (Lantz & Kass 1987)** | Represent a particular body of knowledge | Students are challenged with difficult problems and activities. Laboratory work and demonstrations are used to verify science concepts by demonstrating the relationship between particular concepts and phenomena. |
| **Didactic** | Transmit the facts of science | The teacher presents information, generally through lecture or discussion, and questions directed to students are to hold them accountable for knowing the facts produced by science. |
| **Conceptual change (Roth, Anderson & Smith, 1987)** | Facilitate the development of scientific knowledge by confronting students with contexts to explain and challenge their naive conceptions. | Students are pressed for their views about the world and consider the adequacy of alternative explanations. The teacher facilitates discussion and debate necessary to establish valid knowledge claims. |
| **Activity Driven (Anderson & Smith, 1987)** | Have students be active with materials; "hands-on" experiences. | Students participate in "hands-on" activities used for verification or discovery. The chosen activities may not be conceptually coherent if teachers do not understand the purpose of particular activities and, as a consequence, omit or inappropriately modify critical aspects of them. |
| **Discovery (Karplus, 1963)** | Provide opportunities for students on their own to discover targeted science concepts | Student-centred. Students explore the natural world following their interests and discover patterns of how the world works during their explorations. |
| **Project-based science (Ruopp et al., 1993; Marx et al., 1994)** | Involve students in investigating solutions to authentic problems. | Project-centred. Teacher and student activity centres on a "driving" question that organises concepts and principles and drives activities within a topic of study. Through investigation, students develop a series of artefacts (products) that reflect their emerging understandings. |
| **Inquiry (Tarnir, 1983)** | Represent science as inquiry | Investigation-centred. The teacher supports students in defining and investigating problems, drawing conclusions, and assessing the validity of knowledge from their conclusions. |
| **Guided inquiry (Magnusson & Palinesar, 1995)** | Constitute a community of learners whose members share responsibility for understanding the physical world, particularly concerning using the tools of science. | Learning community-centred. The teacher and students participate in defining and investigating problems, determining patterns, inventing and testing explanations, and evaluating the utility and validity of their data and the adequacy of their conclusions. The teacher scaffolds students' efforts to use the material and intellectual tools of science, toward their independent use of them. |

**Source:** *Nature, sources, and development of pedagogical content knowledge for science teaching*

(Magnusson et al., 1999, pp. 100–101).

Friedrichsen (2002) examined Magnusson et al. (999) STOs categories. She grouped the nine STOs into two general categories: teacher-centred STOs and STOs based on reform efforts and associated curriculum projects. In the first category, she included didactic and academic rigour as the two teaching orientations that fall within the category. The latter was further sub-divided into STOs based on the reform efforts of the 1960s, which included: *process, activity-driven and discovery learning*. The other category contained STOs based on what she called "contemporary curriculum reforms". In this category, STOs such as project-based was found to fall within this category. Apart from the nine categories described in Table 2-3, this shows another permutation of how researchers have conceptualised the notion of STOs.

### 2.2.3. Further research on STOs

There is little evidence about STOs in the literature. As indicated in Table 2-3, the first column shows the citations of studies where the category of STOs was found. However, some have no citations. To bridge this gap, Friedrichsen & Dana (2005) conducted a study with the purpose of understanding the nature as well as probable sources of STOs to generate a substantive level theory regarding STOs. The researchers observed the teachers during instructions and tasked them to do a card-sorting activity that complemented the interviews. The card-sorting task was done to elicit the tacit nature of STOs as the scenarios were prepared related to the nine STOs described above. Grounded theory and inductive data analysis led the authors to the construct what they termed "substantive-level theory" (Figure 2-9) that showed the complicated nature of STOs. The model shows that STOs are influenced by contextual factors such as time constraints, beliefs about teaching and learning of science. While beliefs about teaching and learning of science are presented as a contextual factor, in this case, it is one of the critical dimensions of STOs in other studies discussed below. Regarding the sources of STOs, the authors concluded that participants' classroom contexts, teachers' prior work experience, PD, as well as time constraints, influence their STOs. Concerning the nature of STOs, the authors used the terms "peripheral" and "central" STOs to illustrate their complex nature. Central STOs dominate and drive instruction, unlike peripheral STOs.

A study by Volkmann et al. (2005) provides further insights concerning STOs. This study, through the lens of STOs, investigated how a professor, teaching assistants, as well as students,

experience inquiry-based instructions to document the challenges college professors have when teaching physics to elementary teachers. They used classroom observations as a data collection technique for six weeks on the topic of electricity. Data analysis revealed that the professor, as well as the teaching assistant, had conflicts regarding instruction. While the professor held multiple STOs (didactic, discovery, and inquiry), the teaching assistant mainly demonstrated didactic STOs while students held discovery STOs. They concluded that STOs held by the participants influenced the decisions made during instruction. Necessarily, these two studies (Friedrichsen et al & Dana and Volkman) confirm the existence of STOs in practice and that teachers' experience, PD, and time constraints appear to influence their STOs significantly. The studies also demonstrate that STOs are complicated in that a teacher may hold multiple STOs where some are central and others peripheral. The fact that a teacher may hold multiple STOs appears to be a source of conflict teachers face during instruction. What should also be noted is that in the studies discussed above, STOs were defined according to the Magnusson et al. (1999) definition, and not the Friedrichsen et al. (2011) definition.

In view of the ambiguities, which I briefly raised in section 2.2.1, Friedrichsen et al. (2011) re-examined the notion of STOs. In their review, the authors first traced the origins of STOs by focusing on how published studies describe the notion. They placed particular emphasis on the way Magnusson et al. (1999) defined STOs because many studies extensively use the Magnusson et al. (1999) description of PCK and STOs as a theoretical framework. They concluded that Magnusson et al. (1999)'s notion of STOs is problematic on the following bases:

1. *STOs are used in different or unclear ways since there are various definitions of the notion;*
2. *There is an unclear relationship between the STOs and the other PCK components;*
3. *Teachers cannot merely be assigned to one of the nine categories of Magnusson et al. (1999) orientations; and*
4. *Studies ignore the overarching function of this component.*

As a way to bring clarity to the notion of STOs, the authors proposed several changes. For example, to address the issue of ambiguities that came as a result of point number one above, the authors suggested that STOs be defined as a set of interrelated beliefs having the following dimensions:

1. *Goals and purposes of science teaching*
2. *Beliefs about the Nature of Science (NoS)*
3. *Beliefs about the teaching and learning of science*

Regarding the issue raised in point number two, the authors' call for more empirical studies that examine the relationship between STOs and other PCK components since, at this point, STOs were understood to be part of PCK. My second research question (see Chapter 1) responds to this call; however, STOs are taken as a separate notion from PCK.

Furthermore, the authors challenge the usefulness of categorising science teachers' STOs into one of the nine categories proposed by Magnusson et al. (1999). They claim that, instead of categorising teachers based on the nine STOs, researchers should as an alternative investigate STOs from a multi-dimensional perspective as outlined above because it recognises the complex nature of STOs (Friedrichsen et al., 2011). My first research question considers this since, in the analysis, I did not categorise the teachers into the nine STOs. In the paragraphs below, I am going to review literature based on Friedrichsen et al.'s proposition of STOs.

Considering that STOs are personal constructs and hence might not be limited to the descriptions given above, Avraamidou (2013) used Friedrichsen et al. (2011) proposition to investigate pre-service teachers' STOs and experiences that impacted on their development through multiple data collection tools, such as drawings, interviews, reflective assignments, among others. The three-dimensional space narrative structure revealed that participants' experiences influenced some of their STOs. This finding is similar to the studies of Friedrichsen & Dana (2005) reported above. Specifically, the teachers cited course work experiences, such as inquiry-based investigations, contemporary theoretical discussions, outdoor field study, and the characteristics of the instructors they had for their university course work as influencing their STOs. This means that prior experiences are sources of teachers' STOs. Although the study used Friedrichsen et al.'s (2011) proposition, it only focused on the two dimensions of teaching orientations: beliefs about the goals and purposes of science teaching as well as beliefs about teaching and learning of science.

Boesdorfer & Lorsbach (2014) investigated one chemistry teacher's practice through the lens of her STOs. The researchers used classroom observations, interviews and some class documents to collect data. This study used Friedrichsen et al. (2011) description of STOs.

However, unlike investigating the interaction between STOs and TPK domains, the authors were interested in only the two dimensions of STOs other than NoS. From their data, the authors concluded that STOs can explain teachers' practices. In a related study Boesdorfer (2015), carried out a comparative case study with two chemistry teachers that examined the relationship between the teachers' choice of the representations (*tools that a teacher uses to help students understand concepts*) used in their practice and their STOs on the topic of atomic structure and the periodic table, which the teachers deemed difficult (Boesdorfer, 2015). For this study, Boesdorfer (2015) re-examined her dissertation data with a different theoretical lens. Similarly, she reported that STOs influence teachers' decision-making processes as teachers' representations were reflective of their STOs. For example, Louise, who described herself as a coach or mentor, when asked to describe herself as a teacher, mainly used teacher-centred methods of teaching as she saw herself as more knowledgeable and hence should impart knowledge to the learners. Furthermore, she reported that the two teachers in her study held multiple STOs. What this suggests is that STOs could be used to explain the decisions that teachers make during practice. For instance, if a teacher believes that his role during instruction is to transmit knowledge to the learners, teachers' teaching strategies would be characterised by teacher-centred methods of teaching. Likewise, STOs could explain why some teachers find it hard to implement lessons learnt from PD programs.

The findings of these two studies highlight the fact that teachers have multiple STOs. This finding sets it apart from several other studies that grouped teachers (participants) into one of the different categories of STOs. Even though the second study indicates how STOs interact with teacher knowledge, it was only limited to teachers' representations on a particular topic. My study is an attempt to elucidate the interaction between STO and TPK domains with experienced science teachers on a topic of their choice.

Kind (2016) conducted a study which also tested Friedrichsen et al. (2011) theoretical position about STOs as a component of PCK. Even though the study adopted Friedrichsen et al.'s position, the researcher, used Magnusson et al.'s (1999) categorisation of STOs. Similar to other studies above, Kind (2016) focused only on two dimensions: *beliefs about teaching and learning of science* and *beliefs about NoS*. She gathered data using content vignettes and questionnaires from 237 pre-service teachers. Content analysis of data supported: *didactic, academic rigour, conceptual change, activity-driven* and *inquiry* STOs the teachers held. In

light of the findings, she compressed the nine STOs into five STOs, as shown in Figure 2-8. She also proposed presenting STOs on a continuum (Figure 2-8) that shows their level of influence on students' learning. She considered the rest of the STOs as curriculum knowledge. This study shows the influence STOs have on teachers' practices. As shown in Figure 2-8, while teacher-centred (activity-driven, etc.) STOs appear to cause poor quality instruction, hence poor students' learning, reform-based STOs (conceptual change and inquiry), on the other hand, yield productive instructional practices. This study clearly links STOs to students' learning which other studies did not address.


**Figure 2-8: Proposed continuum for pre-service science teachers' teaching orientations**

To test Friedrichsen et al. (2011) proposition, Faikhamta (2013) conducted a study to understand the extent to which a PD course based on NoS affects teachers' understanding of the NoS as well as their STOs related to NoS. Using pre- and post-questionnaires on the nature of science, field notes as well as teachers' weekly journals, the researcher collected data from 25 in-service science teachers. While the researcher used deductive analysis to code questionnaire data to *informed, partially informed* and *naive categories*, the inductive analysis of other data forms revealed how teachers had engaged with the course. Before the course, a majority of the teachers held naïve views about NoS, especially with the following aspects: definition of science, scientific inquiry, and differences between laws and theories. After the course, data showed that the teachers had developed an understanding regarding their beliefs about NoS as well as their STOs related to NoS. Demirdöğen & Uzuntiryaki-Kondakçı (2016) also obtained similar findings in a study whose focus was on understanding the development of STOs over time. They reported that teachers who held naive STOs about NoS appeared to have reformed STOs about NoS. These studies show that, with the right conditions, teachers can develop their STOs just like any TPK domain. This supports the idea that teachers' experiences or exposure shapes their STOs. The limitation of these studies is that they only

focused on one dimension of STOs, i.e., NoS. This is an indication that, once the notion of STOs is fully understood, they will inform the design of both pre-service teacher training and PD programs.

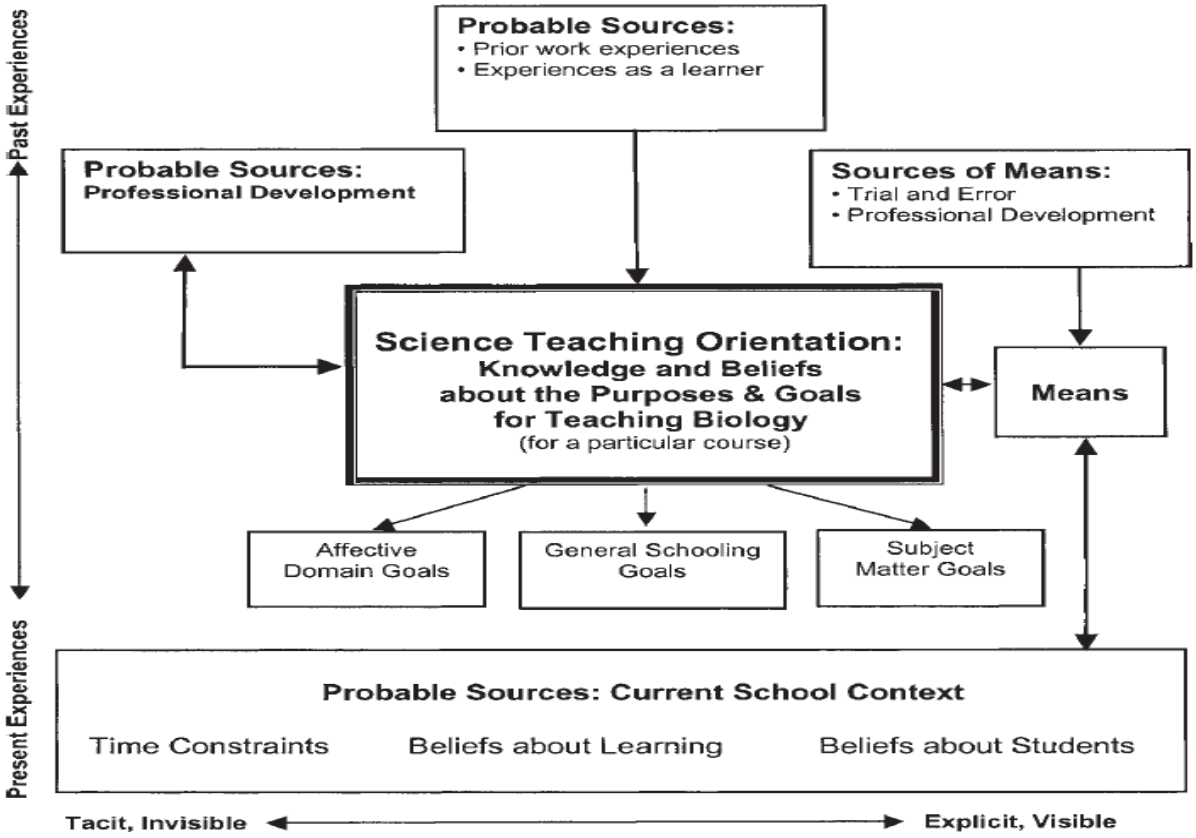


**Figure 2-9: Substantive level theory of science teaching orientations**

In a recent study where they sought to reconceptualise the notion of PCK in a Design and Technology (D&G) course, Doyle, Seery, Gumaelius, Canty, & Hartell (2018) revisited the concept of PCK by reviewing the literature surrounding the conceptualisation of the consensus model of PCK. They discuss the various aspects of the consensus model by considering every layer of the model, particularly the overall importance of the amplifiers and filters in determining the nature of the teachers' practices. They agree with the fact that teachers' beliefs (in this study, STOs were referred to as teachers' beliefs) have a significant impact on enacted practices. They substantiated these claims by proposing a model (Figure 2-10) for practices which linked the interaction of teachers' beliefs with various TPK, which, in this study, included all the relevant professional knowledge that teachers use during their practices. Drawing from Gess-Newsome (2015), the authors present TPK as professional knowledge that

includes TPK domains such as that of Gess-Newsome (2015), TSPK as well as PCK as shown in Figure 2-10. Overlapping ellipses represent the form of interaction between beliefs and knowledge. Hence from the figure, Friedrichsen et al. (2011) STO dimensions are seen interacting with all three TPK domains, i.e., TSPK, TPK domains and PCK, resulting in enacted practices that researchers observed in the classroom. The research presented by these authors is a departure from the consensus model propositions as all TPK domains have been compressed into one (knowledge as shown in Figure 2-10). Hence, they argue that STOs interact with all this knowledge despite the consensus model showing that STOs interact only with PCK and TSPK. These ideas helped in the conceptualisation and implementation of this study regarding TPK.

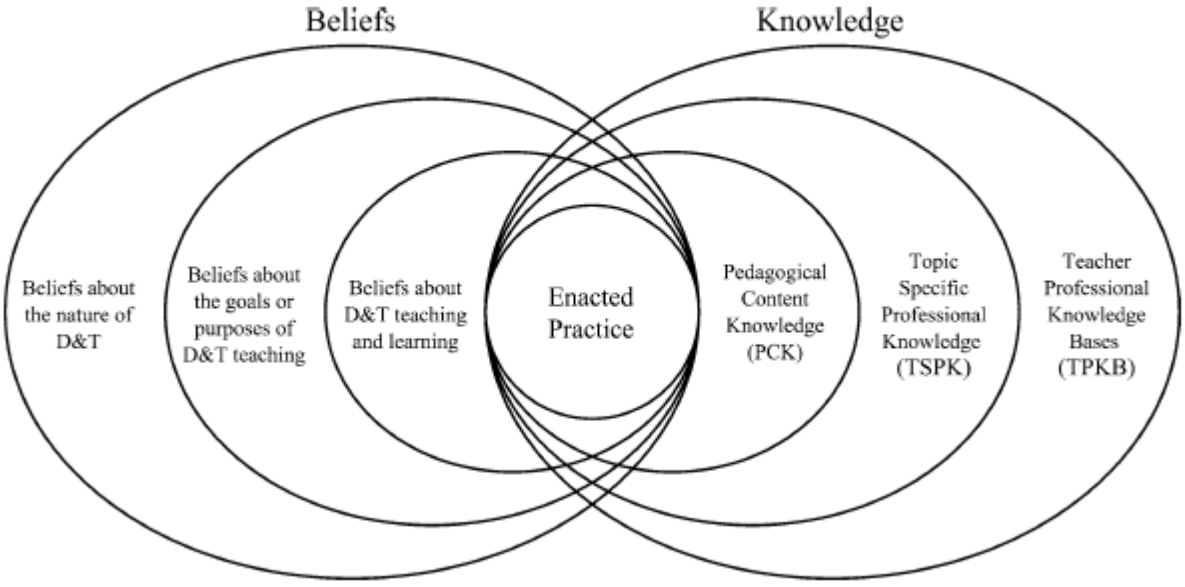


**Figure 2-10: Theoretical model of enacted practices, teachers' beliefs and teachers' knowledge**

**Source:** Doyle et al. (2018).

### 2.2.4. Interaction of science teaching orientations with PCK domains

Even though there have been studies that examined the notion of STOs as well as TPK, there is a limited number of studies that have examined the interaction between STOs and PCK as well as teachers' TPK. Furthermore, even those studies that have looked at this relationship have relied on the Magnusson et al.'s (1999) model of PCK and their definition of STOs. These

studies reveal exciting insights concerning the relationship between STOs and other teacher knowledge domains. Hence, this section reviews studies that have examined the interaction between STOs and PCK components.

Park & Chen (2012) carried out a study to map the integration of the components of PCK with biology teachers. This study focused on making the integration of PCK components more visible and accessible using PCK maps. They achieved this by using what they called PCK maps that show how frequently the components had interacted with one another. Data sources for the study were semi-structured interviews, students' work samples, instructional materials, lesson plans and classroom observations. They conducted this study with four biology teachers on the topics of photosynthesis and heredity. Their data were analysed using in-depth analysis, an enumerative approach and constant comparison to map out how the PCK components integrated. At the end of the analysis, the authors proposed five themes that emerged from the data. First, the nature of the integration among the components of PCK was idiosyncratic and topic-specific. Second, knowledge of student understanding and knowledge of instructional strategies and representations were the central components in the integration. Third, knowledge of science curriculum and knowledge of assessment of science learning indicated the most limited connection with other components of PCK. Fourth, knowledge of assessment of science learning was more frequently connected with the knowledge of student understanding and knowledge of instructional strategies than it was connected with the other components of PCK. Lastly, in a result linked to this study, they reported that didactic STOs inhibited the connection of knowledge of instructional strategies and representations with the other components of PCK and directed it. Aydin & Boz (2013) drew similar conclusions in a study that focused on exploring the nature of integration among PCK components with two experienced chemistry teachers. However, they further reported that, of all the PCK components, *teachers' knowledge of the learner* and that of *instructional strategies*, including their sub-domains, were more central in the integration. As expected, and of relevance to this study, the authors reinforced the overarching role of STOs by reporting that STOs shaped instructional decisions of the teachers. For example, they highlighted how STOs helped one of the teachers to address students' misconceptions about cells. Students held the view that the "anode is always on the left side of the cell". In the process of trying to address this misconception, the teacher's didactic teaching orientations influenced his decisions regarding the instruction strategy that he used to address the misconception which the students held as he used traditional methods of

teaching where he talked while the students listened.

Even though these two studies used different data collection procedures as well as analysis, the findings were similar. Further, these two studies make it clear that that STOs influence teachers practices. In addition, arriving at a similar conclusion while using different approaches seems to suggest the need for using several methods when studying STOs. The last finding of Park & Chen (2012), shows that didactic STOs result in poor quality instruction as claimed by Kind (2016). Park & Chen (2012) study is one of the first few studies that aimed at addressing the STOs-TPK interaction gap. However, it focused on providing evidence for only the didactic STOs.

Padilla & Van Driel (2011) explored the nature of PCK exhibited by college professors. This study was slightly different from the rest in that it involved college professors as participants rather than high school or primary school teachers. The researchers focused on examining the relationship between PCK components with six college professors who were teaching quantum chemistry. They adopted the Magnusson et al. (1999) model of PCK to define the components they were interested in. They used the interview method of collecting data from the six college professors. They combined both qualitative and quantitative approaches to analysing their data. The results showed that there were relationships between specific STOs and knowledge components of PCK. For example, quantitative analysis revealed that didactic and academic rigour STOs were predominant and were often linked with knowledge of instructional strategies. Specifically, the college professors combined didactic teaching with the problem-solving approach as, in their view, the teaching of quantum mechanics presents difficulties for the students.

In a more ambitious study and using the Friedrichsen definition of STOs in its entirety (considering all the three dimensions of STOs), Demirdöğen (2016) examined the relationship between STOs and other PCK domains with eight pre-service science teachers. She employed a variety of data generation tools that included interviews, CoRes (see Appendix M. CoRe sample used), classroom observations and a questionnaire about NoS. She used deductive analysis to analyse teachers' views about NoS, beliefs about teaching and learning and beliefs about the goals and purpose of science teaching. To determine the nature of the interaction, she used an inductive analysis approach of the CoRes as well as classroom observations to

determine the interactions between teaching orientations and PCK knowledge components. Her analysis revealed three significant assertions. First, the teacher's purpose for science teaching determines the PCK component(s) with which it interacts. Second, a teacher's beliefs about the NoS do not directly interact with his/her PCK, unless those beliefs relate directly to the purposes of teaching science. Lastly, beliefs about science teaching and learning mostly interact with knowledge of instructional strategies. She discussed these three assertions in terms of their implications for future research in science education as well as teacher education. This is one of the first few studies that investigated the interaction between STOs and PCK domains. However, her focus was on pre-service teachers. Since pre-service teachers have an undeveloped PCK (Cochran et al., 1993), I was thus compelled to revisit the problem, the interaction between STOs and TPK domains, with experienced, in-service teachers with a developed PCK.

Similarly, Kiran (2016) investigated the interaction of STO with PCK components using two experienced science teachers teaching the unit of mixtures. In this study, she used classroom observations, interviews, as well as field notes to collect data from the teachers. She adopted Friedrichsen et al. (2011) propositions of STO and collected data in all the three dimensions of STO. Results indicate that STO influences the PCK components. For instance, she reported that teachers' beliefs about the goals or purposes of science teaching interacted with knowledge of learner and knowledge of assessment, the most unlike knowledge of the curriculum.

There are studies that have investigated the interactions between STOs and PCK components. These studies have revealed insights about the nature of STOs, as well as how these STOs interact with the various knowledge components of PCK. Despite what others have previously investigated, the notion of STOs regarding its nature, conceptualisation as well as their interaction with various knowledge components, my study was slightly different from these previous studies based on the following points:

1. *I considered STOs as a separate domain from PCK, unlike other studies which considered STOs as part of PCK.*
2. *Friedrichsen et al.'s (2011) propositions about STOs were adopted and fully utilised in this study. I collected data on the three dimensions of STOs.*
3. *I conducted the study with experienced teachers whose PCK was considered to have fully developed over time regarding their more extensive experience when*

*it comes to teaching and learning of science.*

4. *Apart from considering STOs as a separate notion from PCK, I also used a conceptual framework which is a product of ideas from Gess-Newsome (2015), Doyle et al. (2018) and other researchers to guide the design as well as the implementation of the study hence the data analysis. As a result, the two studies have different theoretical positions.*
5. *While Kiran's (2016) study focused on investigating the interaction between STOs on a specific topic/unit, in this study teachers, were not limited to a specific topic or unit. Teachers were free to pick a topic of their choice, which they were more familiar with and felt free to teach.*

Hence this study is different in both conceptualisation and methodological approaches. Above all, the studies reviewed in this section helped in the conceptualisation of this research project.

### 2.3. Conceptual framework

So far, I have reviewed the literature on STOs, PCK as well as TPK. I now discuss three theoretical positions that informed the conceptualisation as well as the implementation of this study: STOs as defined by Friedrichsen et al. (2011), the consensus model by Gess-Newsome (2015) and the theoretical model of enacted practice, teachers' beliefs and knowledge by Doyle et al. (2018). Friedrichsen et al. (2011) offered these insights in their review of the notion of STOs. I have already discussed STOs, according to Magnusson et al. (1999) in section 2.2 of this chapter. The dual nature of Magnusson et al. (1999) definition has always confused researchers in science education. Friedrichsen et al. (2011) argue that the Magnusson et al. (1999) view of STOs offers multiple definitions and hence lacks clarity. Friedrichsen et al. (2011) went even further to state that, even though Magnusson et al. (1999) had indicated that teachers could hold multiple orientations depending on the topic or grade level they teach, many researchers simply assigned teachers into one of the nine STOs. Friedrichsen et al. (2011) argue that this tendency of grouping teachers into one of the nine categories overlooks the complex nature of teaching orientations.

In the process of trying to offer some clarity, Friedrichsen et al. (2011) claimed and defined STOs as a "set of interrelated beliefs having the following dimensions: *goals and purposes of science teaching, views about the nature of science, and beliefs about science teaching and*

*learning.*" This description was central to the conceptualisation and implementation of this study in the following ways: first, it enabled me to study a broad range of teachers' STOs. From there, I was able to understand the extent of STOs influence on the enactment of TPK during instruction. This is because the definition is not only comprehensive but also multidimensional in the sense that it refers to different aspects about teachers' beliefs (*goals and purposes of science teaching, views of science, beliefs about science teaching and learning*) and how these beliefs influence teachers' practices. At the same time, it allowed me to accord STOs the complexity they deserve. Secondly, the dimensions are precise, unlike the Magnusson et al.'s (1999) definition as presented above. Furthermore, there are various tools in the literature that have been developed and validated by other researchers which could be used to explore these dimensions. Lastly, there is empirical evidence that supports Friedrichsen et al. (2011) applicability in research studies (for example see Demirdöğen & Uzuntiryaki-Kondakçı, 2016; Kiran, 2016). Consequently, the instruments to elicit these dimensions were constructed and aligned to these three dimensions, that is, interviews on teachers' beliefs about teaching and learning of science, interviews on teachers' beliefs about purpose and goals of teaching science as well as the questionnaire on teachers' views about the nature of science were constructed to align with these three dimensions.

TPK is taken to mean all those knowledge domains, such as teacher professional knowledge bases and topic-specific knowledge domains, that are integrated to produce PCK that is enacted in the classroom to bring about successful learning. TPK, in this case, includes all those knowledge domains identified by Gess-Newsome (2015). Similarly, TSPK includes all those domains suggested within the consensus model. However, a closer look at these TSPK domains shows that they are a further explication of the TPK domains. Even Gess-Newsome (2015) claims that the description of TSPK and TPK domains are similar. It is for this reason that, in this study, TSPK was subsumed into the broader perspective of TPK domains. Hence the reasoning to examine the interaction between STOs and TPK domains.

Furthermore, even though the consensus model shows that STOs only interact with TSPK, recent conceptualisations of PCK show that STOs interact with a broad spectrum (Figure 2-10) of teacher knowledge. In Doyle et al. (2018)'s study, TPK includes all knowledge that teachers have at their disposal from where they draw insights. This includes TPK domains, TSPK as well as PCK, as already highlighted. However, for my study, I opted to examine the interaction

between STOs and TPK domains as defined by Gess-Newsome (2015). Hence, in this study, these knowledge domains include all the five knowledge domains identified and defined by the consensus model (first layer of Figure 2-7) discussed in Table 2-2 which include *curriculum knowledge, assessment knowledge, knowledge of pedagogy, knowledge of students* and *content knowledge*. These knowledge domains subsume TSPK domains. Since these knowledge domains are canonical and public (Gess-Newsome, 2015), the assumption that I made in this study was that all teachers who took part in the study have well developed knowledge domains considering their experience, having undergone formal teacher education programmes as well as their exposure to various PD workshops.

In the consensus model, PCK is defined as "the knowledge of, reasoning behind, and planning for teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes" (Gess-Newsome, 2015, p. 36). This means that, for each topic, teachers have a topic-specific PCK for handling it. This model links everything that a teacher does to students' outcomes and where the contribution of the topic-specific nature of PCK is appreciated. However, the focus of the present study was on understanding the nature of the interaction between STOs and TPK domains, which informs teachers' PCK enacted in the classroom. As a result, I isolated aspects of the model that I felt were important. Hence, teachers were not limited to a particular topic.

I consider the enacted PCK integrative, which means that, during instruction, a teacher incorporates various TPK domains to build a PCK manifested in the classroom during instruction. As a result, teachers were free to write their CoRes (discussed in detail in the methodology section) on any particular topic of their choice. The idea was to have an in-depth understanding of how STOs interact with TPK domains, i.e. how STO filters TPK domains to bring about PCK. As already highlighted above, this study was guided by Friedrichsen et al. (2011) definition of STOs. A closer examination of the definition shows that it defines teachers' STOs at a subject level rather than the topic level. For example, the dimensions: *goals and purposes of science teaching, views of science, beliefs about science teaching, and learning* all refer to beliefs concerning science as a discipline rather than a topic. This reasoning compelled me to focus on a subject discipline rather than a specific topic hence the reasoning to ask teachers to write their CoRes on a topic of their choice.

## 2.4. Summary

In this chapter, I have reviewed the literature that is related to this study. I have shown trends regarding the notion of teacher professional knowledge and how research has advanced in this field. Apart from that, I also showed how recent research had moved from the general consideration of TPK to the discussion of how TPK is manifested in the classroom. I showed that, while TPK is critical, it is PCK that is manifested in the classroom. Hence, I argued that issues surrounding PCK have a bearing on the design of any research study in this field. For instance, PCK is tacit; hence, there is a need to use a variety of data generation tools with the aim of triangulation.

In this chapter, I also discussed the notion of science teaching orientations. I started by looking at the origins of the notion which came before PCK. Then I looked at the various research studies regarding the categories of science teaching orientations. I highlighted briefly the current theoretical position of teaching orientations which views the notion as complex, having three dimensions. From there, I presented a conceptual framework that guided the implementation and analysis of the study. The conceptual framework is a synthesis of the literature on the current understanding of PCK and teaching orientations. Having discussed these issues, I now proceed to discuss the research methodology for this study.

# CHAPTER 3. METHODOLOGY

*In this chapter, I outline and present a justification for the research design of the study that I conducted. This research study aimed at examining the interaction between STOs and TPK domains and used qualitative research methods to have an in-depth understanding of the phenomenon at hand. This chapter discusses the rationale behind the decisions that I made regarding this study while not losing its focus. After that is a discussion of the research paradigm that was used for this study, a description of the instruments used for data collection as well as the process that I followed in the adaption of these instruments. I also explain how different data were collected and issues of trustworthiness were considered. I conclude with a reflection of ethical issues and limitations of the present study.*

## 3.1. Introduction and overview

In her book, *The foundations of social research: Meaning and perspective in the research process*, Crotty (1998, pp. 2–3) advances an argument which suggests that any social researcher should start the research process by thinking about and answering four questions that she defines as the "basic elements" of any research process. These questions are outlined below:

1. *What* methods *do we propose to use?*
2. *What* methodology *governs our choice of methods?*
3. *What is our theoretical perspective?*
4. *What* epistemology *informs our perspective?*

These questions form an essential step in the process of knowledge development for any study in social research. The first question is concerned with the techniques as well as procedures to be used to gather data and consequently, the data analysis. The second question examines the course of action, the design process, as well as the reasons for using particular methods in the study. The third question deals with the philosophical stance or paradigm that informs the overall design of the study. Lastly, the fourth question deals with the theory of knowledge generation entrenched in the theoretical perspective of the adopted research paradigm. Therefore, in order to conduct valid research, it is essential to address these questions. In this chapter, I discuss the philosophical assumptions as well as design strategies that underpin this research study. While reviewing underlying philosophical assumptions about research, I

present the interpretive research paradigm as a theoretical perspective for this study. Also in this chapter, I discuss the research methodologies and design used in the study, including strategies, instruments, data collection and analysis methods. This includes the justification for each of the data collection methods that I used in this study. Finally, in order to ensure the trustworthiness of the research, appropriate criteria for qualitative research are discussed, and several methods that include member checks, peer reviews, crystallisation and triangulation are presented.

Various data gathering tools and methods were used to collect data from the participants. These included questionnaires on the NoS, classroom observations, interviews, as well as Content Representations (CoRes).

### 3.2. Theories adopted in this research study

Researchers base their work on certain philosophical assumptions or paradigms depending on the nature of reality that is under investigation. Considering the discussion, I presented in both Chapters 1 and 2 about the nature of reality that I set out to investigate in this study, I adopted the interpretive research paradigm to underpin this study. Interpretivists hold that human beings are 'social actors'. This means that human beings interpret what they see or perceive in a particular way and their behaviour is normally reflective of this interpretation (Saunders et al., 2009). Furthermore, interpretivists posits the following:

1. Reality is a social construction reinforced through interactions
2. Interaction between may potentially force those being studied to behave in aa different way rather than they would if they were not being observed.
3. The aim of research within this paradigm is to understand the multiple constructions of meaning and knowledge.
4. Explanations of the social world might be affected by the observations being made Observations might be affected by the
5. Traditionally rely on qualitative methods of data collection such as interviews, document review as well as observations and hence points to the fact that research is about the interaction between the researcher and participants.

To achieve the objective in this study, I interacted with teachers through interviews, classroom

observations as well as through an analysis of the documents they prepared. These interactions had the potential to influence the outcome of reality. Another assumption was that the way the teacher interacted with the learners had the potential to change the direction of the lessons regardless of what the teachers originally planned. Hence the assumption of the possibility of multiple realities in terms of these participating teachers' STOs interacted with their TPK domains while preparing and delivering the lessons was critical. Therefore, with these assumptions in mind, it was logical to locate this study within this paradigm.

### 3.3. Research design

I conducted this study from the qualitative research design point of view considering the nature of reality I was interested in. In particular, I used a case-study research method design to gain in-depth insights into the experiences of teachers regarding the teachers' STOs interaction with TPK domains. Woodside (2010) defines a case study as "an inquiry that focuses on describing, understanding, predicting, and controlling the individual (i.e., process, animal, person, household, organisation, group, industry, culture, or nationality)" (p. 1). This definition of a case study aligns with this study, which was an inquiry to understand how teachers' STOs interact with TPK domains. Additionally, the definition is comprehensive and broad and is not limited to the study of contemporary phenomena which are inseparable from their contexts; it also applies to any other phenomena as long the researcher defines the case unit clearly.

Traditionally, case studies offer many advantages over other research designs. One such advantage is that they encourage the use of a variety of data collection methods. For instance, Woodside (2010) claims that case study research methods promote a deep understanding of the "actors, interactions, sentiments, and behaviours occurring for a specific process through time" ( p. 6). According to Woodside (2010), this in-depth understanding can be achieved through the use of multiple methods of data collection that typically include observing participants in their environment, interviews and the analysis of documents prepared by the participants. My study was about understanding the interaction between STOs and TPK domains, which is elusive and tacit hence the multiple realities that may be obtained. I was thus compelled to use a variety of data collection methods such as classroom observations, semi-structured interviews, questionnaires, and teacher tasks (documents) – Content Representations (CoRes). Since I combined several data collection methods, I had an opportunity to collect a rich data

set that provided a complete picture of the issue under investigation.

Case studies are used to answer questions that seek an in-depth understanding of an issue (Yin, 2011). The main research question for my study was to understand the interaction between the STOs and TPK domains. This is captured by the second research question of this study which seeks an in-depth understanding of the issue under investigation. Yin (2011) states that case study designs are best suited when a researcher cannot manipulate the behaviour of those involved in the research process. I was particularly interested in studying the teachers in their natural settings to have an in-depth understanding of how teachers articulate their teaching processes. I used this reasoning to allowed teachers to create their CoRes on a topic of their choice.

Merriam & Merriam (2009, p. 40) describe a case study as "an in-depth description and analysis of a social unit". This detailed description aims at understanding a phenomenon under investigation. The social unit in this study was a group of five experienced science teachers from schools in Zomba urban area. These teachers have been teaching science for more than five years in various schools in Zomba. Merriam & Merriam (2009) further claim that a case study is a bounded system. This means that a researcher makes clear statements regarding the boundaries of the research focus. The case may be bounded by time, place or activity (Babbie, 2010). Teachers who took part in this study met this requirement. These teachers participate in same SMASSE programs that are organised for a specified period. The teachers were also bounded by the fact that they teach PS at the secondary school level.

There have been several criticisms concerning case study research designs based on the following: they lack rigour, the inability of research results to be generalised, and the fact that case studies are time-consuming (Yin, 2009). However, Yin (2009) further explains that the lack of rigour is a result of some researchers being unable to address their influence in the research process. The author suggests that all work, as well as evidence, should be reported in a fair manner to ensure that the research study's outcomes are valid and trustworthy. Regarding the issue of a lack of generalisation of research findings for case study designs, Yin (2009) claims that issues to do with external validity do not necessarily concern case study research designs as they do not aim at generating laws but the development of theory. Woodside (2010) adds that a case study research design aims to have a deeper understanding of the issue under

investigation and generate theories. Similarly, my study was not aimed at generalising the findings but to gain an in-depth understanding of the issue at hand.

### 3.4. Ethics issues

Any credible research study that deals with human beings as its source of data guarantee participants' rights, which entails strict adherence to ethical principles. This implies that a researcher has the responsibility of making sure that the views of the participants are protected and taken into consideration.

When conducting social research, there are four crucial aspects of research ethics. These are informed consent, potential harm to participants, deception and privacy. In this study, I adhered to the following ethical pillars: privacy, anonymity, confidentiality, informed consent and the right to withdraw from the research study.

#### 3.4.1. Informed consent

Obtaining permission to interview or observe participants is not in itself adequate. Participants deserve to know precisely what they are being asked to do. Hence, the participant needs to give informed consent which is a statement that clearly explains the nature of the study, the purpose of the study, duration of the study, risks involved and a guarantee of anonymity and the confidentiality of the participants' views (Neuman, 2014). To gain participants' permission to take part in the study, I assured them of confidentiality and anonymity (Cohen et al., 2007). All participants were briefed on the objectives of the study, both verbally and through written documents (for example, see Appendix E. Information Sheet to the teachers). I also assured them that participation was voluntary and that they were free to withdraw from the study at any time.

#### 3.4.2. Privacy

The fact that teachers' beliefs about goals and purpose of science teaching, beliefs about views of nature of science and beliefs about science teaching and learning were required for the study meant that their privacy was compromised as the participants revealed intimate details about

how they view a particular phenomenon (Neuman, 2014). No matter how sensitive the research data is, the researcher needs to protect participants' rights to privacy by ensuring anonymity and confidentiality (Neuman, 2014) as explained below:

#### *2.8.2.1.* Anonymity

Anonymity means that the participants in the study remain unknown. This includes the features that could identify a participant, including location and name (Neuman, 2014). To ensure that this was achieved, I made sure that all identifying features were removed in cases where observation data was videotaped. Pseudonyms, as well as codes (as shown in Table 3-1) for participants, were used to make sure that participants remained anonymous.

#### *2.8.2.2.* Confidentiality

Neuman (2014) states that

> *"ethical protection for those who are studied by holding research data in confidence or keeping them secret from the public; not releasing information in a way that permits linking specific individuals to specific responses; researchers do this by presenting data only in an aggregate form (e.g., percentages, means)" (p. 155).*

In this study, both confidentiality and anonymity were adhered to and the values of the participants were respected.

### 3.4.3. Right to withdraw

Studies that involve human participants should ensure that participants are informed of their right to withdraw at any time of the study if they wish to (Neuman, 2014). This means that participants cannot be forced to take part in a study. When I was conducting this research study, I had full knowledge of this as one of the fundamental rights of the participants. Initially, I planned to have six participants in the study. However, after explaining the objective of the study, one participant was reluctant to take part and therefore he was free to withdraw from the study at the onset.

### 3.5. Researcher and positionality

I am a teacher educator in the School of education at Chancellor College. This is one of the few institutions that train teachers in Malawi to teach at secondary school. As a teacher educator, I teach undergraduate methodology courses for teaching Physics subject at secondary school. The focus of these methodology courses is on enhancing the pre-service teachers' knowledge about teaching. As already highlighted in chapter 1 and 2, teacher knowledge consists of, but not limited to, *content knowledge, knowledge about the students, curriculum knowledge, assessment knowledge as well as pedagogical knowledge*. While I expect that these teachers will utilise this knowledge during instruction, mostly this does not happen. As a result, I have always wanted to have an understanding of how and why this happens even with experienced teachers.

While reading through the various studies on teacher knowledge and classroom practice, I came across a study by Magnusson et al. (1999) which pointed to the possible interaction between teachers beliefs and teacher knowledge during instruction. Around the same time, I also applied for a PhD study at the University of Witwatersrand. It is during this time that, with the help of other professionals on teacher knowledge, I conceptualised this study to understand how STOs interact with teacher professional knowledge. My mind has always been about having an understanding of the interaction between the STOs and TPK domains. It is therefore possible that my high expectations about this study and the fact that I am a member of the faulty from an institution where most of the participants were sampled from, could potentially have influenced my interaction with both the participants and data analysis as well as interpretation. It is with this understanding that I had employed several ways of collecting data rather than relying on one particular method. The understanding is that data collected from all these sources will be used to triangulate the findings. Insights from professionals were also used to confirm the evidence.

### 3.6. Sampling

Polit & Beck (2010) state that selecting a sample from a wider population is a crucial stage for any research study. A sample is defined as a smaller group or subset of the population from where the researcher generates data (Cohen et al., 2007; Polit & Beck, 2010) that is representative of the wider population. Hence, the sampling strategy needed to allow me to

obtain quality and credible data from the sample. I conducted my study with five experienced secondary school teachers purposively sampled from three different schools within Zomba Urban Education District (ZUED). Cohen et al. (2007) describe purposive sampling as a non-probability sampling technique where participants are selected based on "their judgement of their typicality or possession of the particular characteristics being sought". In this way, a researcher builds a sample that would enable him/her to answer the research questions or achieve the objective of the study (Saunders et al., 2009).

Even though purposive sampling is mostly not representative of the actual population, Cohen et al. (2007) explain that the goal of purposive sampling is to have access to more knowledgeable people, i.e., those people who have in-depth knowledge about an issue under investigation due to their professionalism, role, power and/or experience. So in this study, the experience of the teachers mattered.

I started the study by identifying appropriate participants who were both qualified to teach science and are more experienced in teaching Physical Science (PS) at the secondary school level. First, the teachers to take part in the study must have been teaching PS for at least four years. The assumption in this was that, by the end of four years, teachers were more familiar with the content and how they teach it using various representations. My second assumption comes from the idea that highly experienced teachers are more knowledgeable and hence would offer more insights for the study. Furthermore, Cochran et al. (1993) show that pre-service teachers have undeveloped PCK. Hence, it was for this reason that I targeted experienced teachers. Table 3-1 presents a summary of the characteristics of the five teachers who took part in the study.

**Table 3-1: Participants' Profile**

| Code | Gender | Qualification | Major/Minor | Teaching Subject at the time of study | Experience | Form /level | School teaching |
|---|---|---|---|---|---|---|---|
| **KA** | M | Diploma | PHY/MAT | PHY | 6 | Form 1 | 1 |
| **MP** | M | Degree | CHE/BIO | CHE | 12 | Form 2 | 3 |
| **NG** | M | Degree | PHY/CHE | PHY | 4 | Form 4 | 3 |
| **PH** | M | Degree | HE/BIO | PHY | 6 | Form 4 | 2 |
| **TH** | M | Diploma | PHY/MAT | CHE | 10 | Form 3 | 2 |

**M: Male, HE: Home Economics, PHY: Physics, CHE: Chemistry, BIO: Biology, MAT: Mathematics, form 1 and 2 – Junior Section of secondary school education, form 3 and 4 – Senior section of secondary school education.**

From Table 3-1 above, PH is not qualified to teach PS as he majored in Home Economics. However, his Home Economics courses required him to take Chemistry and Physics courses for the first two years. According to the structure of Physics and Chemistry courses at the university he attended, this was enough content knowledge required to teach PS at secondary school successfully. Hence, he was selected to take part in the study. KA is qualified up to diploma level. He majored in PS and minored in mathematics. Hence, he is qualified to teach both mathematics and PS. However, since his graduation, he has mainly taught PS for the past six years. The same applies to TH, however, they teach at different schools. NG started teaching PS six years ago when he graduated from Domasi College of Education with a diploma in education majoring in Physics and Mathematics. He then went back to upgrade to a degree and eventually proceeded to do a Master of Science (MSc) degree in environmental sciences on a part-time basis. MP has been teaching PS for a long time, and he is the most experienced of all the teachers. He started at diploma level then upgraded to degree level at a later stage. During his degree, he majored in biology and minored in chemistry. Since then he has mostly been teaching PS with some biology classes.

### 3.6.1. Schools sampled

Five teachers from three different schools participated in this research study. Two of these schools were Conventional Secondary Schools (CSS), and one was a Community Day Secondary School (CDSS). For the CSSs, one is a district boarding secondary school, while the other is a district day secondary school. CSSs are better resourced than CDSSs in terms of the quality of teachers, teaching materials, and infrastructure for learning, such as laboratories. For instance, the two CSSs had laboratories with running water and power sockets and well-stocked libraries. Table 3-2 provides a description of these schools from which the teachers were sampled.

**Table 3-2: Description of the schools from which teachers were sampled**

| School | Secondary school type | Description | Duration of a single lesson |
|---|---|---|---|
| School 1 | District boarding school | • Has laboratories<br>• Has boarding facilities | 40 minutes |
| School 2 | Community Day Secondary School (CDSS) | • No labs<br>• No boarding facilities<br>• Double shift school[1]<br>• Students commute from home | 30 minutes |
| School 3 | District day school | • Has laboratories<br>• No boarding facilities<br>• Double shift school<br>• Students commute from home | 30 minutes |

[1] schools which have different set of pupils in the mornings and afternoons, but the same number of lesson hours as pupils in single-session schools, and different teachers for each session. Double-shift schools in Malawi normally have 30 minute lessons than the normal 40 minutes for most non double shift schools.

## 3.7. Data generations

### 3.7.1. Phases of data collection

For this study, data generation happened in four phases. The first phase was to get an understanding of the teachers' STOs. So I conducted interviews on teachers' beliefs about teaching and learning, and about the goals and purpose of science teaching. For the last dimension of STOs, I administered a questionnaire on NoS to capture teachers' views about NoS. In this phase, the aim was to make myself more familiar with the participants' STOs. The second phase, which ran concurrently with the third phase, was mainly about how teachers think about and prepare their lessons. During this phase, I asked each of the participating teachers to prepare a CoRe (see **Appendix M. CoRe sample used**) for every lesson that I observed (two for each teacher) to show how the teachers think about teaching a particular topic. It also showed how the teachers envisage teaching that particular lesson. Through this process, I was able to generate data that would eventually allow me to understand the influence of STOs on the enactment of TPK domains. In the third phase, soon after the teachers had prepared their CoRes, I followed up with classroom observation. Classroom observation was used to complement the CoRes that the teachers had prepared. Lastly, I followed up with post-observation interviews. The whole data generation process is shown in Figure 3-1. Table 3-3 shows a summary of the data generation methods that I used.

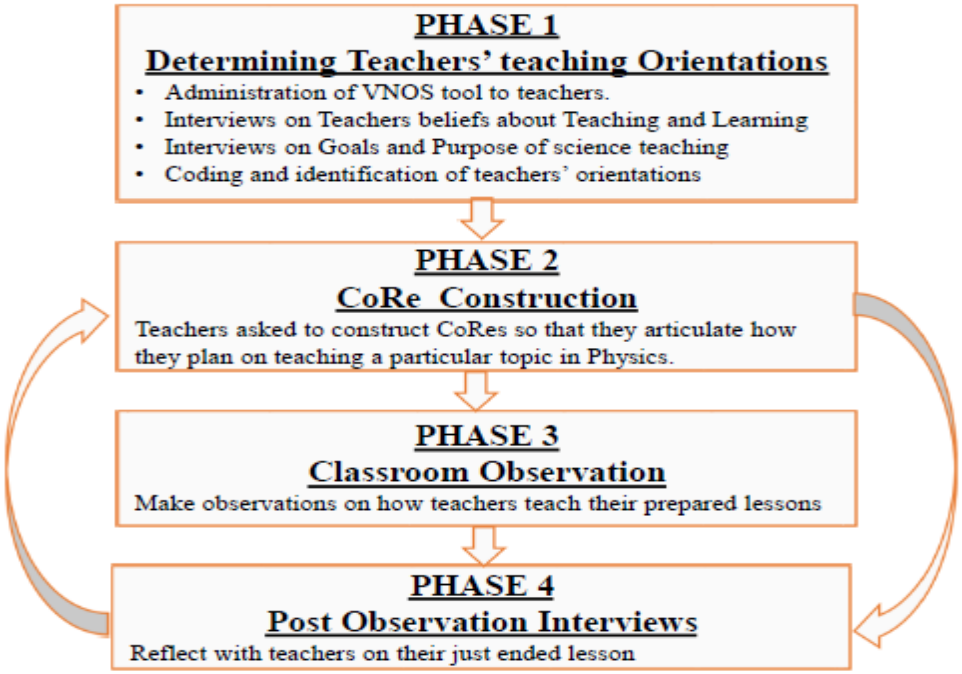


**Figure 3-1: Data collection process**

**Table 3-3: Nature of data collected**

| Teacher | Interviews | Time (hrs) | CoRe | Classroom Observation | Post-Observation Interviews | Time (Min) |
|---|---|---|---|---|---|---|
| **KA** | 1 long interview | 2 | 2 | 2 | 2 short interview | 30 |
| **MP** | 1 long interview | 2.25 | 2 | 2 | 1 short interview | 20 |
| **NG** | 1 long interview | 2.23 | 2 | 2 | 2 short interview | 20 |
| **TH** | 1 long interview | 2 | 2 | 2 | | |
| **PH** | 1 long interview | 1.5 | 2 | 2 | 1 short interview | 15 |

### 3.7.2. Semi-structured interviews

To capture the two dimensions of STOs (*beliefs about teaching and learning of science* and *beliefs about goals and purposes of science*), I used qualitative interviews that are a powerful tool for accessing the human mind (Cohen et al., 2007). Case study research designs advise the

use of interviews. As Cohen et al. (2007) explain, the interview is "a flexible tool for data collection, enabling multi-sensory channels to be used: verbal, non-verbal, spoken and heard." They allow the interviewer to collect first-hand in-depth information about an issue being investigated. These interviews allowed me to collect not only their ideas but also the visual cues as the teachers expressed their ideas on a topical issue. Mertens (2010) maintains that interviews enable the researcher to have a full understanding of someone's experiences or the way they understand their world around them. As a result, interviews allowed the researcher to probe teachers' views about teaching and learning of science as well as their beliefs about goals and purposes of science teaching.

To ensure that I thoroughly explored the area I was interested in, I used semi-structured interviews in this phase on goals and purposes of science teaching and beliefs about teaching and learning of science dimensions of STOs. The interview schedules were adapted from Demirdöğen (2016) and Luft & Roehrig (2007) respectively. The two different interview schedules each has seven questions in total that covered a wide range of issues concerning the various beliefs teachers have about the goals and purposes of science as well as their beliefs about teaching and learning of science (see, Appendix L. Goals and purposes of science teaching interview schedule and Appendix O. Beliefs about teaching and learning interview Schedule**)**. All the questions from both authors were used because I felt that the questions captured all the important aspects that I needed to interrogate. Semi-structured interviews offer many advantages over other interview types. Polit & Beck (2010) explain that "semi-structured, also known as focused interviews, are used when researchers have a list of topics or broad questions that must be addressed in an interview". In this case, I had several broad questions that were to be addressed by the teachers. Another reason that compelled me to use this type of interview was the fact that that these kinds of interviews allows for flexibility. Even though semi-structured interview address critical areas through deliberate prompts, the interviewer is at liberty to diverge and pursue an idea or response further. This allows for discovery or elaboration from the participants. The aim of conducting interviews with the teachers was to get first-hand information from the participants regarding their beliefs about teaching and learning of science and well as their beliefs about the goals and purpose of science teaching.

After classroom observations, I also conducted interviews with the teachers. These were brief

unstructured interviews to gain further insights regarding the events that had unfolded during instruction. I was interested in getting clarification from the teachers on why they had decided to do something. Their reasoning allowed me to gauge how their beliefs about science had interacted with TPK. During this phase, I did not use any interview guide as the questions that I asked depended entirely on the occurrences during the lesson; hence, each teacher was asked different questions depending on how the lesson had proceeded. Due to their busy schedules, I was not able to conduct these interviews with all the teachers but I managed to interview four teachers about at least one of the lessons they had delivered. These interviews helped me to achieve a deeper understanding of teachers' justifications of the decisions they made during instruction. I asked the teachers to explain some of the aspects of their teaching that I had observed during the lesson. This gave teachers a chance to elaborate and clarify their decisions made while teaching. This data was analysed and provided some insights on how STOs interact with teachers' TPK domains.

Despite being one of the best ways of accessing participants' views about an issue, interviews have some weaknesses. For example, Cohen et al. (2007) show that a significant weakness of interviews is that they are more prone to subjectivity and bias on the part of the researcher that can affect the validity and integrity of the whole research process. To mitigate this effect, I spent long hours with teachers during the data collection process. On the part of "investigator effect", I made sure that I created a conducive environment that enhanced our social interaction and where they were free to talk about the issue at hand. I also assured the teachers that whatever we talked about was confidential that gave them the confidence to talk freely without worrying about how their data will be used.

All interviews took place at the participants' schools. Extended interviews lasted between 90 to 135 minutes while short interviews lasted between 15 to 30 minutes (see Table 3-3). I sought teachers' permission to audiotape all the interviews.

### 3.7.3. Content Representations (CoRes)

To capture the teachers' thoughts about how they planned their teaching and learning processes, I used CoRes (see Appendix M. CoRe sample used). According to Nilsson & Loughran (2012, p. 702), a CoRe

> *"is designed to elicit participant teachers' knowledge of teaching a particular science concept/topic and as such is a methodological tool used for capturing PCK that has been successfully applied across diverse contexts by a range of science education researchers."*

Since teachers do not have a readily available "language" to articulate their PCK, apart from classroom observations, I was also compelled to use CoRes to gain an understanding of how teachers' STOs interact with TPK domains. Hence, I was able to address the second research question.

CoRes were first described and used by Loughran et al. (2004) to find ways for teachers to articulate and document their PCK. The use of CoRes enables researchers to find out what a teacher thinks about when teaching a particular topic or concept. The belief is that, once a teacher completes this task, a researcher can discern the teacher's thinking process about a topic or concept and how they envisage teaching it. In its basic form, a CoRe has columns denoting "big ideas" on a particular topic. Researchers probe these ideas through various prompts, which are on the left axis.

CoRes are not easy to construct for someone who is not familiar with them (Demirdöğen, 2016). As a result, I oriented the teachers on how to construct a CoRe. During this orientation, I used CoRe examples from Loughran (2012), constructed for the topic of electricity, to orient the teachers. Since these were experienced teachers, it only took a day to explain the basics of the CoRe. Once the teachers were familiar with CoRe construction, they used the knowledge to construct their CoRes on a topic they were going to teach. Data from the CoRes was used to answer research question number 2. I could have used the teachers' lesson plans to gather this data, however, the design of the CoRes goes beyond what a lesson plan captures. For instance, while a lesson plan captures the teachers' rationale as well as objectives of teaching a particular topic, it does not address other equally important aspects of the teacher's planning process. This includes things such as assessment of the lesson, concept representations, procedures of engaging students in the teaching and learning process and their justification that are not captured by lesson plans (see attached CoRe in Appendix M. CoRe sample used).

Because I was interested in how teachers' STOs interact with TPK, I did not limit teachers' CoRes on a particular topic as other studies reviewed in Chapter 2 for reasons articulated in the theoretical framework section of Chapter 2. Each teacher had to write two CoRes at the end of

the study on any topic of their choice. This translates to a total of ten CoRes from the teachers which I collected. Teachers prepared their CoRes before the delivery of the lesson except for two teachers who prepared their CoRes after the lessons. This is because the two teachers said they were busy and could not prepare their CoRes on time.

### 3.7.4. Views on Nature of Science Questionnaire

Teachers' beliefs about NoS is the third dimension of STOs, according to Friedrichsen et al. (2011). To capture data regarding this dimension, I relied on an open-ended questionnaire which I administered to all the participating teachers. Sekaran & Bougie (2016) define a questionnaire as "a pre-formulated written set of questions to which respondents record their answers, usually within rather closely defined alternatives" (p. 142). The authors describe two kinds of questionnaires; however, the one that is usually associated with qualitative studies is the open-ended type where participants are free to answer the questions in any way.

Cohen et al. (2007) explain the advantages of using an open-ended questionnaire. First, they argue that the open-ended questionnaire gives participants the freedom to give an account of views as they are not limited to what they can talk about on an issue. This also helps them to justify their responses with evidence. They further argue that open-ended questionnaires enable the participants to explain their responses in detail. Secondly, the authors show that open-ended questionnaires are suitable for investigating issues that are complex since respondents are allowed to give their responses freely. Naturally, NoS is a complex area in science education (Khishfe & Abd-El-Khalick, 2002b) which is why I used the open-ended questionnaire to achieve the task. Furthermore, considering that I had already spent a considerable amount of time interviewing the teachers, I decided to give the teachers more privacy when talking about their views on NoS.

On the other hand, open-ended questionnaires have been criticised on the basis that they may yield irrelevant data (Cohen et al., 2007). Woodside (2010) further adds that questionnaires pose as "foreign elements" in the participants' social settings, they are limited to only those who take part in the study and may also sometimes yield results that are irrelevant to the topic of study. However, since I was interested in exploring teachers' views about the nature of science, I decided to use the open-ended questionnaire that allowed respondents to answer the questions on a complex topic in the way they felt comfortable (Cohen et al., 2007). One

advantage of using questionnaires is that they are less expensive and are not time-consuming compared to other data generation methods (Cohen et al., 2007; Sekaran & Bougie, 2016).

To avoid the issue of bias in the questionnaire (Woodside, 2010), I used the Views on Nature of Science (VNoS) questionnaire (see Appendix N. Views on Nature of science Questionnaire (VNOS)**)**. I developed the items on this questionnaire from various tools available in the literature that had been rigorously tested and validated. These tools that assess teachers, as well as learners' views about nature of science, included Views on Nature of Science (VNoS) forms A, B, C and Views on Scientific Inquiry-Primary version (VOSI-P). The creators of the tools used a rigorous process to develop them. They also report that they dedicated much time to developing these items as they had to review them several times to ensure a credible tool that elicits teachers' views about the nature of science. The creators further report that the validity of the tools was tested through the administration of the tool to several teachers with different groups of teachers and comparing their responses to that of the authors' own questioning process. They reported the following on the credibility of the tool:

> *"Because of its open-ended nature, the VNoS differs from traditional paper and pencil instruments. Whereas face and content validity of the various versions of the instrument have been determined repeatedly, its principal source of validity evidence stems from the follow-up interviews. During these interviews, it is possible to directly check respondents' understandings of each item, as well as the researchers' interpretation of these responses" (Lederman et al., 2002, p. 517).*

Thus, the tool was considered credible and appropriate for the intended purpose of investigating teachers' views about the nature of science. Consequently, I designed the questionnaire items in such a way that the items were aligned to the basic tenets: *nature of scientific knowledge, scientific theories and laws, science and creativity, scientific method as well as social-cultural aspects of science* (see Table 3-8) about the nature of science, which are the aspects that are envisaged by the science curriculum in Malawi. I administered the questionnaire to every teacher at his/her convenience. Before participants could respond to the questionnaire, I explained the aim of the questionnaire and emphasised that it is not about assessing their competencies but to learn about their beliefs about the nature of science from their responses. I also asked for informed consent from the participants of the study. All the teachers took the questionnaire and answered at their convenient time. Since the research lasted for the whole

term, some teachers asked to submit their filled questionnaire at the end of the term which I accepted.

### 3.7.5. Classroom Observations

Case study research designs are supposed to take place in a natural setting (Yin, 2011); hence, observation is an essential source of data. For this study, I conducted several lesson observations (see Table 3-4) to complement the CoRes. As already highlighted in the literature review section, TPK, which translates to PCK, is tacit, elusive and challenging to capture which is why I also decided to use classroom observations to complement other data collection sources. Cohen et al. (2007) argue that observation "offers an investigator the opportunity to gather 'live' data from naturally occurring social situations" (p. 396). Since the researcher observes and generates data from a natural context, the data generated, therefore, is more valid or authentic than would have been possible using inferential methods (Cohen et al., 2007).

Baxter & Lederman (1999) observe that PCK is an internal construct hence teachers' do not have a readily available language to articulate it. Cohen et al. (2007) further elaborate this by claiming that what people say might differ from what they do and how they do it. Hence, observation takes care of this particular gap during a research study. The authors also point out that observation provides an opportunity for the researcher to generate data about an aspect that might have unconsciously been missed out during interviews. Hence observational data allows the researcher to generate data about the physical, human interaction and programme setting (Cohen et al., 2007). Through classroom observations, I was able to gather data that would have otherwise been difficult to gather using other methods described above.

Complementing CoRes data with observational data, I was able to answer the second research question for this study, i.e., to what extent do STOs influence the enactment of TPK domains. During classroom observations, I was particularly interested in the teachers' use of representations, their decisions and all their plans which they made during instruction and any other thing that reflected their teaching orientations. I videotaped all the lessons that I observed after I sought permission to do so. I used video recording since it offers the researcher an opportunity to revisit the video data and reflect more on the behaviours the teachers displayed in the classroom (Sherin, 2003). Every CoRe that the teacher prepared was followed with classroom observation. This translates to 10 lesson observations which were all recorded. Table

3-4 summarises the duration. Class/form each teacher was teaching, and the topic of the lesson that I observed for each teacher. The teachers were teaching different topics in both senior and junior classes.

**Table 3-4: Summary on lesson observations made**

| Teacher | Lesson 1 | Duration | Form | Lesson 2 | Duration | Form |
|---|---|---|---|---|---|---|
| **KA** | Energy | 40 minutes | 1 | Electric current | 80 minutes | 1 |
| **MP** | Specific heat capacity | 30 minutes | 2 | Machines | 60 minutes | 2 |
| **NG** | Magnetism | 60 minutes | 4 | Electricity, magnetism and electric induction | 60 minutes | 4 |
| **TH** | Pressure in liquids | 30 minutes | 3 | Chemical reactions | 30 minutes | 3 |
| **PH** | Electricity – electrical energy and power | 30 minutes | 4 | Electricity – electromagnetic induction | 30 minutes | 4 |

Saunders et al. (2009) describe problems related to the use of observation as a way of data generation. The authors argue that this method has a threat of the researcher's bias as it is difficult for the researcher to detach him/herself from the research process. To overcome the issue of reliability, I verified all the data collected by asking the participants to have a look at the data to ensure that my interpretation regarding what I observed is an exact representation of how teachers view that particular instance.

### 3.8. Data analysis

In this section, I describe how I analysed the data that I generated using the various methods described above. Ritchie & Lewis (2003) explain in detail how to analyse qualitative data. They present two ways on how to handle qualitative data: *data management* and *making sense of the data through a description or explanation of the data*. I had large volumes of data for this study, hence, I used Nvivo 12 software to manage all interview, classroom observation, questionnaire and CoRes data.

Firstly, all audio and classroom observation data were transcribed verbatim into text. To

expedite the transcription process, I transferred all the audio and video recordings onto a laptop computer where I used a flexible software to play and replay sections during transcription. I listened to the segments several times to make sure I got them right before moving to the next segment. This also applied to other video recordings. I would watch the video segments several times to get it right. During transcription, I also recorded any insights that I had. These notes proved useful during the interpretation of the data. Once all the data were prepared and cleaned, I imported the files into Nvivo 12 software for deductive as well as inductive data analysis.

### 3.9. Inductive data analysis

Inductive data analysis involves discovering patterns, themes and categories that emanate from the data (Patton, 2002). To achieve this, I developed a coding scheme, as shown in Table 3-5, by relying on the literature on TPK, especially that of Gess-Newsome (2015). Each STOs dimension was examined based on how it interacted with the sub-domain (described in section 2.1.5 and shown in Table 2-2) of the TPK knowledge domains. To achieve this, I used both classroom observations, post-observation interviews and CoRes when determining the interaction between STOs and TPK sub-domains. An episode was taken to have interacted with the TPK sub-domain if the teacher expressed a view or belief not only during the interview but that was also observed during a classroom observation. For instance, if the teacher thought that using analogies was an excellent way to increase students' understanding and used it in the class, it was concluded that there was an interaction between the teacher's beliefs about science teaching and learning which is sub-component of STOs and knowledge of topic-specific representations which is sub-component of knowledge of instructional strategies.

**Table 3-5: Coding Scheme – the interaction between teaching orientations and TPK**

| | Teaching Orientations Dimensions | | |
|---|---|---|---|
| **TPK Domains** | **Beliefs about the goals and purpose of science teaching** | **Views about the nature of science** | **Beliefs about teaching and learning of science** |
| **Pedagogical knowledge** | If a teacher attempts to teach the various goals and purposes of science teaching, for instance, everyday coping, scientific skills development etc. using the various teaching and learning strategies such as cooperative learning techniques, lecture method, or the use of topic-specific instructional strategies for instance activities, instructional strategies indicate an interaction between goals and purpose of science teaching and pedagogical knowledge. | If a teacher considers using an instructional strategy – explicitly or implicitly – that supports his/her beliefs about the nature of science, this is considered as an interaction of the nature of science and pedagogical knowledge. | If the teacher uses instructional strategies that reflect his/her beliefs about teaching and learning of science – for instance using various methods of teaching to support differentiation, using various ways of managing the classroom, different ways of engaging the learners – this is considered as an interaction between teaching and learning of science and pedagogical knowledge. |
| **Assessment knowledge** | If a teacher plans to asses' students by incorporating goals and purpose of science teaching aspects at the end of the lesson or through homework, that indicates an interaction between goals and purpose of science teaching and knowledge of assessment. For instance, a teacher may ask students to describe how electricity is useful in our everyday life. | If a teacher uses assessment strategies that reflect his/her ideas about the nature of science, that is considered as an interaction between the nature of science and assessment knowledge. For instance, a teacher may ask students to describe the nature of scientific knowledge or ask students to think of an experiment they can carry out to illustrate the behaviour of something. | If the teacher assesses his/her students in such a way that his/her beliefs about teaching and learning of science are reflected in the assessment, it was taken as an interaction between teaching and learning of science and assessment knowledge. |
| **Knowledge of students** | If a teacher attempts to teach a goal and purpose of science teaching for instance by using students' pre-requisite knowledge, this indicates and interaction | If a teacher considers students' misconceptions about the nature of science in the teaching and learning process, that shows an interaction between | If the teacher considers students' difficulties as well as students' misconceptions in the teaching and learning process. If this is considered either in the |

| | | | |
|---|---|---|---|
| | between knowledge of students and goals and purposes of science teaching. | the nature of science and knowledge of the students. | CoRes or observed during instruction, this is considered as an interaction between teaching and learning of science and knowledge of students. For instance, a teacher my correct students' wrong answers during the lesson by asking students further questions in order to help the students to arrive at the correct answer. |
| **Knowledge of curriculum** | If a teacher plans to teach his students by exclusively planning content that reflects the goals and purposes of science, for example, by the end of the lesson students should be able to describe the role of electricity in our everyday life, or students should be able to describe a how they can gadget they could use to detect rains. These indicated an interaction between goals and purposes of science teaching and knowledge of the curriculum | If a teacher considers curriculum related to the nature of science, for instance, clearly formulating objectives that relate to aspects about the nature of science in the teaching and learning process, either explicitly or implicitly, this shows an interaction between nature of science and knowledge of the curriculum. | If the teacher reflects his beliefs about teaching and learning of science in the concerning the curriculum such as formulation of the objectives, or structure of the curriculum, or shows linkages to other topics either through the formulation of explicit objectives concerning that or implicitly observed during instruction, that is considered as an interaction between teaching and learning of science and knowledge of the curriculum |
| **Content knowledge** | If a teacher attempts to teach a particular goal of science and relate it to other subject discipline, or relate it other knowledge domains, that indicates an interaction of content knowledge and goals and purposes of science teaching | If a teacher structures his/her content in such a way that he/she considered how the content is connected to the nature of science that shows an interaction between the nature of science and content knowledge. | If a teacher plans to teach science content that reflects his beliefs about teaching and learning of science such as considering the practices in science for the generation of scientific knowledge, considering the core ideas in science, as well as cross-cutting issues either in their CoRes or implicitly observed during instruction, this was taken as the interaction between teaching and learning of science and content knowledge. |

### 3.9.1. Analysis of CoRes

Content Representations tasks were analysed using an inductive data analysis approach. During this phase and applying Table 3-5, I read the CoRes repeatedly to identify the themes emerging that show the interaction between STOs and TPK domains.

### 3.9.2. Analysis of Questionnaire on NoS

Data obtained through the questionnaire were deductively analysed. Predetermined codes were used to categorise the teachers' responses from the questionnaire as described in section 3.10.

## 3.10. Deductive analysis dimensions

Interview transcripts, as well as questionnaires, were deductively analysed. Deductive data analysis involves discovering patterns, themes and categories that emanate from the data and eventually categorising them into pre-determined themes and categories (Patton, 2002). Patton (2002) argues that this approach to data analysis works best if themes, identified from the literature, are used to categorise the data. All the transcriptions from the audio data were read and re-read to identify categories from the data that emerged. I then coded these categories against the predetermined themes or categories identified from the literature. To facilitate the deductive analysis process, I converted the transcripts into Word format, cleaned them, and imported the Word document text files into Nvivo 12 software. Audio interviews were imported separately for each teacher. Thus I had five cleaned interview audio transcripts that I had imported into the software. The same process was applied to classroom observations. Since I observed two lessons for each teacher, I imported 10 separate files into the software for lesson observation. For lesson observations, I used inductive data analysis approach.

### 3.10.1. Goals and purpose of science teaching

Data for this dimension of teaching orientation was analysed using the concept of curriculum emphasis proposed by Roberts (1982, 2015). Roberts examined several documents regarding the teaching and learning of science, such as textbooks, high-profile classroom materials, as well as curriculum policy statements from North America and England from the 1900s. He

realised that the documents had a set of messages that suggested why a particular unit or topic was offered at a particular level. These groups of information or messages were called "curriculum emphases". According to Roberts, a curriculum emphasis is:

> *[a] coherent set of messages to the student* about *science (rather than* within *science). Such messages constitute objectives which go beyond learning the facts, principles, laws, and theories of the subject matter itself – objectives which provide answers to the student question: "Why am I learning this?" The answer to that question differs significantly for the Burns text and the PSSC text just noted (Roberts, 1982, p. 245).*

From his analysis of the documents, he identified seven curriculum emphases, which I describe in Table 3-6. In this study, these curriculum emphases were taken as *goals and purposes of science teaching* – which is one of the dimensions of STOs, according to Friedrichsen et al. (2011). This is because these curriculum emphases describe a coherent set of messages concerning the teaching and learning of science which the new science curriculum advances. For instance, for each topic in the new curriculum, there is an objective that empowers teachers to relate the concepts/content to everyday life. This is what the everyday coping curriculum emphasis captures. Hence, I decided to use this categorisation scheme to code interview data on the goals and purpose of science teaching. An interview extract was coded as *everyday coping* if a teacher had expressed that the reason for teaching science is to help learners understand and relate the teaching and learning of science to everyday occurrences. For instance, a teacher may give an example to help learners to understand how electricity is applicable in everyday life. Similarly, an extract was coded as a *solid foundation* if a teacher had expressed that the purpose of science teaching is to prepare students for future science courses. I preferred to use this as a coding scheme as it is already well organised and captures the various goals for teaching science teachers may have. Furthermore, most of these goals and purposes of science teaching described by Roberts capture the underlying set of messages endowed in the Malawian science curriculum. This provided an easy way for me to organise the teachers' views concerning what they believe to be the goals and purposes of science teaching.

## Table 3-6: Description of curriculum emphasis

| | Curriculum Emphasis | Description |
|---|---|---|
| **1.** | Everyday Coping (Everyday Application) | The main idea here is using science to understand both technology and everyday occurrences. For example, physics topics can be oriented to show how various standard home devices, such as a lamp or a television set, function and can be maintained. |
| **2.** | Structure of Science | Understand how science functions as an intellectual enterprise in its growth and development. This emphasis stresses the importance of evidence and the role of "scientific method" as an analogy, hypothesis, experiment, characteristics of scientific concepts and, to a certain extent, the historical evolution of scientific ideas. The ideas from the academic discipline, philosophy of science, are closely associated with this emphasis because it also investigates the relationship of evidence and theory, adequacy of a model to explain phenomena, self-correcting features to promote the growth of science, and matters relating to the way scientific knowledge is developed. |
| **3.** | Science, Technology, and Decisions (STS; Science, Technology, and Society) | This curriculum emphasis brings out the interrelatedness of scientific explanation, technological planning, problem-solving, and practical importance to society. For example, scientific knowledge and technical know-how should guide the decision on the route of an oil pipeline. Here socio-scientific decision making is seen as a process. |
| **4.** | Scientific Skill Development | Developing sophisticated competence in conceptual and manipulative skills that are basic to all science, collectively labelled “scientific process”, which are the keys to arriving at a reliable “product”, or idea in science. This emphasis concentrates on the means of “science inquiry” including variations of inductive and deductive reasoning. |
| **5.** | Correct Explanation | This entails understanding one’s way of explaining events in terms of personal purpose, intellectual preoccupations, and cultural influences that form their context – exposing the conceptual underpinnings that influence scientists when they were in the process of developing explanations; a personal animation of the history of science – a constructivist view of learning. |
| **6.** | Solid Foundation | Science instruction should be organised to facilitate the students’ understanding of future science instruction. Viewing science as an accumulation of knowledge telling students the purpose of learning this year’s science is to get ready for next year's, and then the following year, and so on through graduate school. Stresses science as cumulative knowledge. |
| **7.** | Self as explainer | This is basically about understanding the self as an integral part of the learning of science |

### 3.10.2. Beliefs about science teaching and learning

This part is also one of the three dimensions of STOs, according to Friedrichsen et al. (2011) definition of STOs. To gather data on this dimension, I used the Teacher Beliefs Interview (TBI) that has seven critical open-ended questions, listed below, that probe teacher beliefs about the teaching and learning of science. This tool was developed by Luft & Roehrig (2007) in a study where they sought to capture teachers' beliefs about the teaching and learning of science. As can be seen from Table 3-7 as well as Appendix R. Beliefs about teaching and learning of science Coding Scheme., the TBI touches on several aspects concerning the teaching and learning of science, especially during teacher planning (such as *the source of teachers' content when they are planning about teaching*) as well as teachers' delivery of content (such as *the role of the teacher during instruction*).

I analysed this dimension of STOs using a categorisation scheme developed by the same authors; Luft & Roehrig (2007). Apart from the TBI interview schedule, the authors also developed a matching analytical tool for each of the seven questions, as shown in Table 3-7 which are further described in Appendix R. Beliefs about teaching and learning of science Coding Scheme. The categories are *traditional, instructive, transitional, responsive and reform-based*. The first two (*traditional and instructive*) are teacher-centred while the last two (*responsive and reform-based*) are student-focused while transitional signifies that the teachers' beliefs fall between teacher-centred and student-centred. I analysed data for this dimension by grouping the data into these five categories. Teachers' interview data on this dimension was compared against this coding scheme for each question. For instance, under methods of maximising students' learning, if a teacher expresses that he/she maximises students' learning by providing information in a structured manner, that was coded as "traditional" or teacher-centred category. It must be noted that the reliability of the TBI and its corresponding analysis framework has been established by various studies (e.g. Campbell, Abd-Hamid, & Chapman, 2010; Mavhunga, 2012) other than those of the authors who developed these instruments. This is the reason I opted to use this tool for this study.

**Table 3-7: Teacher Interview category description by Luft & Roehrig (2007)**

| Category | Traditional (teacher-centred) | Instructive (teacher-centred) | Transitional | Responsive (student-centred) | Reform-based (student-centred) |
|---|---|---|---|---|---|
| **Ways of maximising students' learning** | The teacher provides information in a structured environment | Teacher monitors students' actions or behaviour during instruction | The teacher creates a classroom environment that involves the students | Teacher designs the classroom environment to enable the students to interact with each other and their knowledge | Teacher depends upon students to design an environment that allows for individualised learning |
| **Role of the teacher** | Focus on information and structure | Focus on providing experiences | Focus on student/teacher relationships or students' understanding | Focus on collaboration between teacher and students | Focus on mediating students' prior knowledge and knowledge of the discipline |
| **Know when the students understand** | When they receive the information | When they can reiterate or demonstrate what has been presented | When they give an explanation or response that is related to the presented information | When they can utilise the presented knowledge | When they can apply knowledge in a novel setting or construct something that is related to the knowledge |
| **What to teach and what not to teach** | Decision guided by the adopted curriculum or other school factors | The decision is based on teacher focus or direction | The decision on which some modification is based on students' feedback | The decision is based on students' feedback and other possible factors | The decision is based on students' focus and guiding documents (e.g. research standards) |
| **When to move on to a new topic** | Directed by the teacher | Directed by the teacher based on primary students' understanding of the facts and concepts | Teacher decision based on students' feedback or the ability of the teacher | The decision is based on students' feedback that potentially involves revisiting the concepts | The decision is based upon an on-going evaluation and considers student abilities to demonstrate understanding |

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|---|---|---|---|---|---|
| | | | | | in different ways. May involve the modification of lessons |
| **Students' best ways of learning science** | From the teacher | By mimicking the teacher | By using procedures or guidelines | By encountering and interpreting phenomena | By eliciting, encountering, and constructing their ideas about phenomena. |
| **Knowing when learning occurs** | Determined by the action of students during instruction. Emphasis is on order and attention as related to the student | Determined through measures given by the teacher. Emphasis on the correctness of the student response to the measure. | Teachers determine this through subjective conclusions about the student. | Students interact with their peers or the teacher about the topic. Responses are limited or preliminary. | Students initiate significant interactions with one another and the teacher about the topic. |

### 3.10.3. Beliefs about the views about the nature of science

In the literature review section, I showed that one of the dimensions of teaching orientation deals with views of nature of science (NoS) that show how teachers view science. NoS is a critical component of students' understanding of science yet it lacks a clear definition. There have been many efforts to provide a comprehensive definition of NoS (Khine, 2012; Norman G. Lederman, 1999; Osborne et al., 2003) that "typically refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (Lederman, 2007, p. 833). It strives to find answers to the following questions: What is science? How do we conduct science? What is the nature of scientific knowledge? How does society perceive science? How science operates throughout history? What are the characteristics of scientists? Who are scientists? How do scientists work? (McCommas & Olson, 1998). By asking participants to reason through some of the questions, a researcher is able to discern an understanding of participants' views/beliefs about the nature of science. Some consensus has been reached in terms of characteristics/aspects to look at when describing NoS (Khine, 2012). Khine (2012) outlines the basic tenets for describing NoS in Table 3-8 below.

**Table 3-8: Basic tenets about the nature of science**

| Basic NoS tenet | Description of the basic tenet |
|---|---|
| **Scientific Method** | No single scientific method exists |
| **Scientific Knowledge** | Scientific knowledge is tentative |
| | Scientific knowledge relies on empirical evidence |
| | Scientific knowledge is subjective (Theory-laden) |
| | Observation and inferences are used to discern scientific knowledge |
| **Scientific Theories** | Scientific theories and laws serve different purposes |
| **Creativity** | Human creativity plays a critical role in framing or studying science |
| **Social and Cultural Aspects** | Science is socially and culturally embedded |

This dimension of teaching orientations was analysed using a categorisation scheme that is widely used in NoS studies (Kishfe & Abd-El-Khalick, 2002; Lederman et al., 2002) which is the reason I adopted this coding scheme for my study. I analysed the questionnaire data and categorised it into three categories: *naïve*, *transitional* and *informed*. A teacher's view about

the nature of science was categorised as naïve if it demonstrated a misconception or the explanation regarding the NoS aspect was incorrect. Similarly, if a teacher's view about the nature of science was correct but demonstrated a deficient explanation or failed to give an example from the history of science to justify the answer, I categorised it as transitional. On the other hand, if the answer to the question was correct, I categorised a response as informed if the teacher gave a suitable example from the history of science to justify the answer.

### 3.11. Research study trustworthiness

For quantitative research studies, internal validity, external validity and reliability are the measures determining the quality of the research and its findings (Long & Johnston, 2000). These measures are not applicable in qualitative studies that use the concept of research trustworthiness to measure the research quality. "How can an inquirer persuade his or her audiences (including self) that the findings of an inquiry are worth paying attention to, worth taking account of?" (Lincoln & Guba, 1985, p. 290). The answer is that research trustworthiness explains the credibility of qualitative research findings.

In line with this, Lincoln & Guba (1985) describe ways to ensure credibility. They describe a set of four constructs as described below:

**Credibility** refers to whether the participants' perceptions of the setting or events match up with the researcher's portrayal of them in the research report (Lodico et al., 2010). In other words, this explains how accurately the researcher has represented participants' views in the research report. An extended stay in the field ensures that the data obtained and hence, its interpretation, is credible. I stayed in the field for the whole term interacting with the participants to gain an in-depth understanding of the context.

**Transferability** describes to what extent similar results can be found in other sites bearing the context described by the researcher (Lodico et al., 2010). To ensure this, I provided detailed descriptions regarding the context of the study, the assumptions that were considered during this study, as well as the profile of the participants for the study.

**Dependability** refers to the extent to which one can track the processes and procedures that

the researcher used to collect and interpret his/her findings to arrive at a conclusion (Lodico et al., 2010). To ensure that this research study is dependable, I have explained all the decisions that I made regarding the data generation tools used and data analysis approaches in sections of this report.

**Confirmability** is the extent to which the interpretations and recommendations are supported by the data and are coherent (Lincoln & Guba, 1985). The use of critical readers to examine the interpretation of research findings enhances the confirmability of the study. Hence, in this study, I involved critical readers to check and recheck the research stages, especially the data collection tools, data collection and analysis process.

Even though the above criteria have been criticised on the basis that they are similar to those of quantitative research methods, I used them to enhance the trustworthiness of the study. The table shows how these criteria compare to those of quantitative studies. Table 3-9 provides a summary of the strategies that I employed to ensure the criteria for assessing the quality of the study was met.

**Table 3-9: Summary of Criteria for meeting research trustworthiness**

| Qualitative term | Quantitative equivalent | Strategies for meeting the criteria |
|---|---|---|
| **Internal validity** | Credibility | Deeper engagement with the teachers in the field<br>• Use of peer debriefing<br>• Triangulation<br>• Member checks<br>• Time sampling |
| **External validity** | Transferability | Provide a thick description<br>• Purposive sampling |
| **Reliability** | Dependability | Create an audit trail<br>• Code-recode strategy<br>• Triangulation<br>• Peer examination |
| **Objectivity** | Conformability | Triangulation<br>• Practice reflexivity |

This table was adapted from Anfara, Brown, & Mangione, (2002, p. 30)

### 3.12. Summary

In this chapter, I presented my arguments regarding the decisions I made during this study. I have presented arguments for the adoption of the interpretive research paradigm to guide this research study. I explained the assumptions that I had made concerning the nature of knowledge that I was interested in which eventually led to the adoption of the paradigm. I outlined the research design for this study by highlighting the methods that I used to achieve my goals. I also evaluated the strengths and weaknesses of each method and the strategies that I followed to minimise the weaknesses of the methods used. I discussed the steps that I had taken to analyse the different kinds of data that I collected in this study. I used both deductive and inductive methods of data analysis to respond to the research questions I had set out to answer.

Considering that this was a qualitative study involving human beings, I also discussed the steps that I followed to ensure that ethical issues were followed, how I negotiated access to the research sites, how the participants' privacy will be protected and also how informed consent was obtained from the teachers. Having accomplished data generation successfully, I now present the findings of the study in the next chapter.

# CHAPTER 4. THE TEACHERS' SCIENCE TEACHING ORIENTATIONS (STOs)

## 4.0. Introduction

In the previous chapter, I presented the methodology that I used in this study and the rationale for adopting a particular research methodology. This study examined the interaction between teaching orientations and teacher professional knowledge by answering the following research questions:

1. What beliefs or teaching orientations about the nature of science; teaching and learning of science; goals and purposes of science teaching do Malawian Physical science teachers have?
2. To what extent do STOs influence the enactment of content knowledge, curricular knowledge, pedagogical knowledge, assessment knowledge, and knowledge of the students during instruction?
3. What insights can we draw from the understanding of these interactions?

In this chapter, I will answer the first research question: "What beliefs or teaching orientations about the nature of science; teaching and learning of science; goals and purposes of science teaching do Malawian Physical science teachers have?"

To achieve this, I have used data from both interviews and classroom observations. In Chapter 2, I showed, through a review of the literature, that STOs, according to Friedrichsen et al. (2011), are defined in terms of the three dimensions (*teachers' beliefs about the goals and purposes of science teaching; teachers' beliefs about teaching and learning of science; and teachers' views about the NoS*). The first research question captures these dimensions. Hence the presentation of findings in this chapter is aligned to these three dimensions.

The findings presented in this chapter are based on five experienced PS teachers who took part in this study. I used deductive analysis (Patton, 2002) to analyse interview as well as classroom observation transcripts to find quotes that align with the categories that were developed from the literature. For instance, I analysed teachers' goals and purposes of science teaching using the concept of curriculum emphasis by Roberts (1982,2015) as discussed in Chapter 3

Similarly, I analysed teachers' beliefs about teaching and learning of science using a categorisation scheme by Luft & Roehrig (2007). Lastly, I analysed beliefs about the NoS using a categorisation scheme proposed by Khishfe & Abd-El-Khalick (2002). Therefore, in the following sections, I present the actual findings and the insights drawn from the analysis of the interviews and classroom observations.

## 4.1. Findings on the three dimensions of teaching orientations

### 4.1.1. Teachers' beliefs about goals and purposes of science teaching

In Chapter 3, I argued that, for the purposes of this study, the curriculum emphases (such as *everyday coping, correct explanation*, etc.) developed by Roberts (1982;2015) were aligned to goals and purposes of science teaching. Hence, in this study, the curriculum emphases will be referred to as goals and purposes of science teaching.

Interview, as well as classroom observation data, revealed that the participating teachers collectively articulated about six goals and purposes of science teaching. These are *everyday coping, correct explanation, science, technology and decisions, scientific skills development, structure of science and solid foundation* as shown in Table 4-1. Within Table 4-1, I have further categorised teachers' beliefs into two: **ideal beliefs** – detected from interview transcripts as well as **beliefs in practice** – which are the teachers' beliefs detected from their practices, i.e., during instruction.

From the six goals and purposes, interview data seem to suggest that *everyday coping, science technology, and decisions,* as well *scientific skills development* were more dominant than the other goals as shown in Table 4-1. Dominance[2] refers to the fact that all five teachers made utterances that explicitly linked to these three goals and purposes of science teaching. Apart

[2] What should be noted however is the use of the term "dominance" in this thesis especially in Chapters 4 and 6. In Chapter 4, I use the term dominance to mean those goals that were frequently expressed by the teachers in their discussion about the various beliefs. While in Chapter 6, my use of the term dominance relates to how goals and purposes controlled the lesson both during instruction and planning. So dominance in Chapter 6 means: to what extent did each goal influence the various decisions the teachers made?

from this, three teachers also made utterances that aligned with *correct explanation*. The least mentioned among the goals and purpose of science teaching was that of *solid foundation* as only one teacher made explicit links to it as shown in Table 4-1.

On the other hand, data from classroom observations suggest a contrary pattern as there were considerable variations amongst the teachers during instruction. Everyday coping was not dominant, as observed during the interviews. Even though this is not yet confirmed, at this stage, this seems to suggest that the formulation of goals and purposes of science teaching is dependent on the nature and structure of the topic (see Chapter 7).

**Table 4-1: Teachers' beliefs about goals and purpose of science teaching**

| Belief type | KA | MP | TH | PH | NG |
|---|---|---|---|---|---|
| **Ideal belief** | Everyday coping | Everyday coping | Everyday coping | Everyday coping | Everyday coping |
| | Correct explanation | Correct explanation | Solid foundation | | Correct explanation |
| | Science, technology, decisions | Science, technology, decisions | Science, technology, decisions | Science, technology, decisions | Science, technology, decisions |
| | Scientific skills development | Scientific skills development | Scientific skills development | Scientific skills development | Scientific skills development |
| | Structure of science | | | | |
| | Solid foundation | | | | |
| **Beliefs in practice** | Everyday coping | Everyday coping | Everyday coping | Correct explanation | Scientific skills development |
| | Solid foundation | Correct explanation | Correct explanation | Solid foundation | Correct explanation |
| | Structure of science | Solid foundation | | | |

#### *4.1.1.1.* Everyday coping

For each of these teachers, clearly, science is a subject that offers students a chance to cope effectively in their environments. The teachers gave different reasons for this, which included: *the ability to explain everyday phenomena, the ability to utilise scientific knowledge and skills*

*acquired for their own survival*, among others. For example, the quotation below is a typical example of those categorised under everyday coping. When asked to explain what he considers to be the goal and purpose of science teaching, Mr KA explained it in the following way:

> *The purpose? [purpose of science education,* yes – interrupts the interviewer – yeah that's in general – the general purpose of science education] … Yeah, the general purpose of science education is that one you want to instil skills to the students so that these students *when they acquire these skills, talk of knowledge, they utilise it in their everyday life [KA, School 1, Interview Transcript]*.

Similarly, Mr TH claimed that teaching and learning of science helps learners to have an understanding of their surroundings. He explained about the applicability of scientific knowledge to everyday life by citing simple everyday life phenomena that can be explained using scientific knowledge, as shown in the quote below:

> "*… For example, at home, there is the application of science, it's when they are cooking, there is a lot of science there. Yeah so, even as an individual, walking you know from one place to the other, there is a lot of application of science. And the commodities that being produced nowadays, there is a lot of science in there. Yeah, so we cannot run away from that. Yeah, those are just a few examples*" *[TH School 2, Interview Transcript]*.

These extracts provide evidence of teachers' orientations regarding the *everyday coping* goal of science teaching. Further, the comments suggest that science teaching is connected to our everyday lives therefore, these teachers consider that science teaching is not an isolated aspect divorced from everyday life, but something which directly relates and is applicable in explaining aspects about people's surroundings.

Despite being one of the most recurring themes during interviews, it was, however, not frequently referenced during instruction as shown in Table 4-1. This suggests a misalignment of teachers' views and their practices, which I interrogate further in Chapter 7. However, a few lessons depicted everyday coping. The transcript below shows a typical example of an *everyday coping* goal manifestation during instruction:

| | | | | |
|---|---|---|---|---|
| 1 | - | Teacher | : | Can you tell us any situations [*from our everyday life*] that show us that there is pressure in liquids? |
| 2 | - | Student | : | Because liquid particles exert force in all directions. |

| | | | | |
|---|---|---|---|---|
| 3 | - | Teacher | : | Now how can we … make this idea to be understood very well? … Suppose we have got a plastic bag and then we fill that with water, all right, and then you pierce a sharp material on that plastic bag. Is the water going to come out? |
| 4 | - | Student[s] | : | The water will come out. |
| 5 | - | Teacher | : | Why? |
| 6 | - | Student | : | [Total silence from the students] |

[TH, School 2, Classroom Observation]

"*Everyday life examples help to make the concepts to be easily understood by the learners*", the teacher commented during post-observation interviews. Hence, from the above extract, the teacher wanted the students to give examples from everyday life that demonstrate the existence of pressure in liquids, as shown in excerpt 1. After noticing that students failed to give convincing examples on their own, he further asked them a hypothetical question that students were more familiar with about *water held in a plastic bag* as it relates to everyday life. Trying to build on their experiences of the phenomenon, he asked the students to predict what would happen when someone pierces the plastic bag holding water, as shown in excerpt 3. The expectation is that, since liquid pressure acts in all directions, water would then come out of the bag through the hole. Hence, from their experience with this phenomenon, all students answered that the water would come out just because liquid pressure acts in all directions. This is a typical example of the demonstration of *everyday coping* from the teachers during instruction.

Similarly, another teacher (MP) teaching about power and machines also tended to give examples to illustrate how the concept of machines manifests in everyday life. He wrote a list of simple machines on the board and explained how each one of them worked. He also used mathematics and explanations to demonstrate why these examples, listed on the board, are called machines.

Everyday coping i.e. the using everyday examples during lessons is not coming as a surprise especially on some topics, such as power and machines as illustrated above, which are strongly linked to the application side of scientific knowledge. The new curriculum emphasises on the

need for teachers to link their teaching to everyday life. I discuss more of this in Chapter 7.

#### *4.1.1.2. Science, technology and decisions*

*Science, technology and decisions* was one of the goals that were dominant in the sense that it was frequently mentioned by the teachers during interviews. As discussed in Chapter 3, this aspect is concerned with using scientific knowledge to make decisions as well as developing products that help humans to live and survive in their environment. Teachers who took part in this study believe that teaching and learning of science help students to make decisions concerning their lives as well as their environment. For instance, arguing on the general well-being of a person and the aspect of decision making, one teacher claimed that, through proper exposure to science, one could make sound decisions regarding how to take care of one's environment as suggested by the quote below:

> "*What I can also add is that the world is changing. You talk of environmental changes so, another purpose is making sure that, as the students are living in our society, they know different impacts there, say, what science can do, what science can generate, what solutions can science provide to different challenges which we face as a nation*?" *[KA, School 1, Interview Transcript]*.

The teacher, in this case, raised fundamental questions concerning science. Questions like "what is science?", "what can science do?" etc. that, once fully understood, would not only help students understand science concepts but also understand how to apply these concepts correctly and eventually make sound decisions concerning their lives and environments.

Regarding technology, participating teachers were cognizant of the fact that the teaching of science instils knowledge and skills in the students which they can use to develop products to solve problems they are facing. Interview data suggest that all five teachers were seeking ways of ensuring that students are aware of what they are learning and how they can apply scientific knowledge in their everyday lives. Mr PH argued that teaching and learning of science equip students with various skills which "*when they go out there … scientifically, they should at least be part and parcel of developing the country*". This is because the teaching of science for these students helps to instil "… *creative and innovation – innovative minds in the learners*" [PH]. He cited China as an example that has benefited a lot from teaching and learning of science as

he explains below:

> *… sometimes they may say, we are just teaching them science, but they have to know we are teaching them science and then they can produce something real as in what our friends are doing [in China]. It's not just a matter of showing them, but it is used somewhere else and … sometimes, for example, as you can even tell them, like about how these other products are produced, talk of fertiliser, how it is manufactured, talk about these other tablets [medicine] how they are produced – it's all science. So, if they know that they will say 'come* on, are *these tablets, they have manufactured scientifically' [product of scientific knowledge], they will have an interest in science [Mr. PH, School 2, Interview Transcript].*

One teacher expressed how satisfied he becomes when he sees his students developing different products which they use to solve the problems they are facing. He said this acts as a feedback to him. He explained that despite being limited in terms of curricular objectives where "*learners should learn what the curriculum wants them to learn, … achieve …*" [NG], the "upper limit", as he calls it, is unlimited. This is where you tend to see how creative and innovative the students are. He explained it in the following way:

> *I become thrilled when learners come back, 'sir, you taught us this, now we have used this idea to produce this item'. I become pleased, and I follow those, those productions from the learners … they have done some materials which are in the lab, the materials [things] which I could not think that they can produce, but they produce the materials just because, to me, it was like a feedback, to say 'ok you taught us this now we have produced this'. So, to me, that's ok and for a learner to say 'ok I have produced this thing from the knowledge I had', to me, what it applies is that, ok, it means this learner understood what I taught yea and then can apply because to reach an application-level, it means that you have theoretically understood the concept [NG, School 3, Interview Transcript].*

Surprisingly, not all lessons that I observed illuminated this goal. This suggests a gap between teachers' beliefs about goals and teachers' actual practices. Further, this may also mean that not all teachers' goals and purposes manifest in one single lesson. Different topics address different goals and purposes of science teaching. I explore this in Chapter 6 where I discuss the issue of "peripheral and central" goals and purposes of science teaching.

#### *4.1.1.3. Scientific skills development*

Scientific skills development was also one of the goals and purposes that all five teachers referred to when they explained the purposes of science teaching during interviews. Interview data revealed that these teachers believe that science helps the students to develop critical science skills that would allow them to function successfully in environments that demand science. They gave a range of skills which include practical skills such as measurements, problem-solving skills, critical thinking skills, as well as analytical skills so that these skills "*coupled with scientific knowledge can be applied somewhere …*" [MP]. For instance, with analytical skills, "*they can analyse a particular situation, or break things into different components …*" [PH]. This gives them a chance for a multi-perspective approach to the problem, at the same time, it enables them to have a comprehensive understanding of the concepts in science.

Further, the teachers believe that students will utilise scientific knowledge to solve problems they face as science is linked to the development of the nation, as Mr PH explains:

> *"*Komaso *[but also] like for Malawi, science is attached to national development because eee they believe* kuti *[that] if you have learnt science, aaaaa your understanding of mmm you have that inquisitive mind, those skills that you get when you are learning science. You gain those skills. A curious mind, critical thinking, and analytical perspective in doing things which will be a necessary thing for national development. Yeah. [MP, School 2, Interview Transcript].*

Apart from gaining critical practical skills, one of the teachers also linked the idea of the development of scientific skills to individualised learning. He claimed that once these learners have acquired necessary scientific skills such as problem solving and research skills, they will be able to learn independently. The teacher may sometimes give the learners a task. Then, these learners go into the library to look for information on their own to complete the tasks assigned. This enhances self-learning as he explains below:

> *"… the students are able then to gain practical skills, which is also practical knowledge. They can follow, given a task where they can understand. Talk of experiments right, yeah they can conduct investigations on their own, of course, upon supervision. They can do the actual experiments there, which is hands-on. They are also able to respond to questions*

*after learning. And another thing, after teaching students there, they also acquire research skills because, in some cases, where we have had instances whereby you give a task to the students to go and research using books in the library and they can come back and also report on their findings. So that skill they do acquire those kinds of skills" [KA, School 1, Interview Transcript]*.

From the above quote, the teacher claims that, once the students have acquired practical skills, they can conduct experiments on their own with minimal supervision from their teacher. This, according to the teacher, enhances students' self-efficacy – a critical ingredient when it comes to learning science. Secondly, the teacher might assign students an "independent study". They are able to achieve these things once they have proper scientific skills. This goal was also evident during instructions from some of the teachers. For instance, in both lessons that I observed for Mr MP, the emphasis was on the development of "sound" manipulative mathematical skills as shown below:

| | | | | |
|---|---|---|---|---|
| 1 | - | Teacher | : | Today we are going to do some calculations on how these things are calculated … we are talking of the amount of energy required – so how do we calculate these things? [specific heat capacity] |
| 2 | - | Student | : | $c = Q/m*\Delta T$ |
| 3 | - | Teacher | : | [Writes a problem on the board] |
| 4 | - | Student | : | *Listen and answer questions from the teacher* |
| 5 | - | Teacher | : | [*reads the problem loudly to the students*] 8000J of heat is supplied to raise the temperature of 5kg metal from 10K to 50K. To calculate the specific heat capacity of the metal, we need to find the specific heat capacity of the metal. |
| 6 | - | Student[s] | : | [*Listen and answer questions from the teacher*] $c = Q/m*\Delta T$ |
| 7 | - | Teacher | : | **The first thing is to look at the numbers from the figures that are there**. |
| 8 | - | Student[s] | : | *Listen and answer questions from the teacher* |
| 9 | - | Teacher | : | Now let's go to our question – the question is demanding the calculation of specific heat capacity which we said it is represented by *c*. |

10 - Student[s] : *Listen and answer questions from the teacher*

11 - Teacher : Can you punch in the figures and come up with the specific heat capacity for this metal?

[MP School 3, Classroom Observation]

From the transcript above, in excerpt 1, soon after revisiting students' prior knowledge, the teacher informed the learners of the objective of the lesson, which was to perform calculations on specific heat capacity. Hence, he asked the learners the formula for calculating the specific heat capacity. One of the students correctly answered in excerpt 2. In excerpt 7 (bold emphasis) he tells the students how to start to solve problems of that nature. If they are given these kinds of problems, the first thing is to list whatever they have been given (*variables*) and compare it to the formula. Once they have done that, they then check for the missing variable[s] which they need to find, as can be seen, especially in excerpt 7 where the teacher seems to be making sure that students have acquired the desired mathematical skills for solving problems, not only on this topic but for all other problems for this subject. "*You know, we need to help these learners master problem solving in physics, hence I have the duty to tell them the tricks of doing that*", he answered when I asked why he emphasised on that so many times. This was evident on his CoRe where he stated that the aim of the lesson was to enhance learners' mathematical abilities/skills. This pattern was also observed when he was teaching about power and machines where he was seen coaching the students so that they are competent in solving physics problems. This means that teachers ensure that their teaching of science helps learners to develop these skills.

#### *4.1.1.4. Correct explanation*

"The teaching and learning of science should be conducted so that students master the basic concepts in science, such as theories, laws, etc." [MP]. By learning about the various theories, laws, facts and principles, students will have an understanding of how things work. These teachers feel that science, therefore, should help students to provide correct explanations concerning phenomena. A typical quote that was coded under this category is shown below:

> *"... after acquiring science, students should now be able to appreciate, in one way or the other, the importance of the knowledge they have gained ... they should be able to use it.*

*If there was something that they did not know, they should be able at least to know how to describe it or to explain it. If they were failing to manipulate something, for example, if it is an apparatus of some kind or a piece of equipment, they did not know how to handle … by the end of the lesson, they should be able [to do] it. For example, if we talk of a microscope, they can see it at first, and if you ask them 'how does it work?', maybe they cannot tell. But after teaching, they should be able to explain how it works and they should be able to operate, know how to do the course adjustments, fine adjustments, mounting some of these slides and the like, be able to focus some kind of a specimen, then, if they are able to do that comfortably, we're saying students have learned [MP, School 3, Interview Transcript].*

In the above quote, the teacher says that students should be able to use scientific knowledge to explain or describe the things they were not able to do before the lesson. He cites a few examples of how he expects this knowledge to be translated into practice, for example, in the case of a microscope, students should be able to say what a microscope is, how a microspore works, etc. During instruction, a pattern was observed as the teachers helped students to understand the *correct explanation*. For example, Mr MP often used questions and answers to test how students understood or remembered some of the previous concepts. If he noticed that some students were failing, he devoted time to drawing diagrams on the board to illustrate what he was saying. Once he did this, students were able to appreciate how things worked.

#### *4.1.1.5. Solid foundation*

Only two teachers mentioned a solid foundation goal during the interviews (TH, KA). This might imply teachers' lack of orientation and emphasis attached to this goal. This finding is worrying especially considering that one of the primary goals of science teaching, particularly at this level, is to prepare learners for advanced science courses and hence should be a default goal and purpose of science teaching. For instance, during the interviews, Mr KA explained that science teaching should aim at preparing students for future science courses. He said one of the reasons he teaches science is that he wants to see the students "*grow in science because wherever they go, they will apply that science*". This teacher thinks, not only of the secondary school cycle but of where the students will be after secondary school. He said:

*"We talk about different courses in colleges, whereby these courses also require the Physics/Chemistry which we are talking about. It's like we are teaching science so that we*

*prepare these students so that they achieve their goals, they achieve their dreams and also instilling the pre-requisite knowledge there which is going to be used at a later stage after they finish secondary school" [KA, School 1, Interview Transcript].*

The above quote suggests that the teacher is aware that some of his students will go further with their studies and that secondary school education is only the beginning. Even though he is not sure which route these students will take, he is optimistic that, if these students choose to study science-related subjects, the lessons he offers will ensure a solid foundation for these courses "when they go further with science".

During instruction, elements of a *solid foundation* were observed in other teachers apart from Mr KA and TH as shown in Table 4-1. This pattern was observed in other goals as well and is explored in Chapter 7. For instance, Mr MP, teaching on specific heat capacity, used the lecture method to ground the students in the mathematical skills which he believes are necessary for their future science studies. When asked why he decided to adopt that pattern, he explained:

*"There was a need for clarity in some issues, and that area required a bit more of lecturing so that they should be at least clarification of some concept, for example, the force meter what are these, how do they work?" [MP, School 3, Post Observation Interviews]*

These comments suggest that the teaching of science at this [secondary school] level is not terminal. However, the question, "why other teachers did not reference this, especially during interviews?" needs to be further explored.

The goals and purposes of science teaching are reported according to the degree of perceived importance by the teachers. For instance, the goals and purposes (*everyday coping, science technology decisions*) related to the application of scientific knowledge were frequently referred to by the teachers during interviews. Goals and purposes that are generally believed to be equally important, such as the structure of science, were less frequently mentioned. A few plausible explanations for this are identified in Chapter 7.

### 4.1.2. Teachers' beliefs about teaching and learning of science

From Table 4-2, teachers' beliefs regarding teaching and learning of science varied even across the items on the TBI schedule. Furthermore, the variations were also noted between teachers'

ideals (inferred from interview data) and their practical beliefs (deduced from classroom observation data). The presentation of findings in this section is aligned to the interview schedule items shown in Table 4-2. Using Luft & Roehrig (2007) beliefs categorisation schedule, I categorised teachers' beliefs about teaching and learning of science into *traditional, instructive, transitional, responsive* and *reform-based* beliefs as described in Chapter 3. While traditional and instructive beliefs categories are "teacher-centred", responsive as well as reform-based beliefs are "student-centred". This leaves transitional beliefs in between teacher-centred and student-centred. They signify that the teacher is showing some traits of transitioning from teacher-centred to student-focused. Below I present the findings for this dimension.

#### *4.1.2.1. Ways of maximising students' learning*

On this aspect, there were few variations amongst the teachers as can be seen from Table 4-2. Four teachers held transitional beliefs in both cases (*ideal and practical beliefs*). As a way of maximising students' learning in the classroom, these teachers were of the view that this may be achieved when classroom instruction is tailored to the needs of the learners through the use of different instructional strategies. They believed that the blending of instructional strategies, such as lecture method, cooperative learning, etc., results in an instructional approach that caters for the needs of each student in the classroom. The quote below is a typical example of those that were coded under this category:

> *Teaching strategies should be of a variety because you are dealing with a range of learners, they learn differently, and they also have different paces of getting things [*understanding*], so if you vary your methods [*teaching strategies*], then you are able, at least, to incorporate all the students or most of the learners [PH, School 2, Interview Transcript].*

Apart from the use of a variety of methods of instruction, Mr KA mentioned the issue of language. Since most of the students have difficulties in understanding the English language, he claims that maximum students' learning may be achieved through the use of suitably simplified language during instruction. This will ensure that language is not a barrier to the learning of science. The idea of simplifying the language makes science concepts accessible to the students in a language that students can understand. To achieve this during instruction, the

teacher would make sure that his pace of speaking was moderate – he could repeat some words/phrases to make sure that students understand what he is talking about and use the vernacular (*known as code-switching*) language especially when defining new concepts.

The teachers' practices were reflective of their ideal beliefs during instruction concerning this aspect. Teachers' instructions were differentiated to suit the needs of the students. The execution of their plans also indicated their common beliefs concerning this aspect. For instance, Mr NG used a variety of teaching strategies during instruction as a way of ensuring that every student was involved in the learning process. When he taught the behaviour of resistance in a circuit, he divided the students into groups to do practical work and later used a question and answer technique to engage the learners (see Chapter 5). Eventually, he used the lecture method to complement this. On the other hand, only one teacher who held transitional beliefs during interviews had traditional beliefs during instruction. This represents a misalignment of his ideal beliefs and his practices (see Chapter 7).

**Table 4-2: Summary of teachers' beliefs on teaching and learning of science from interviews as well as classroom observation data**

| | Teacher | | | | | |
|---|---|---|---|---|---|---|
| **Interview Items** | KA | MP | TH | PH | NG | **Belief type** |
| **Maximising students' learning** | Transitional | Transitional | Transitional | Transitional | Transitional | **Ideal belief** |
| | Transitional | Transitional | Transitional | Instructive | Transitional | **Practical belief** |
| **Role of the teacher** | Transitional | Reform-Based | Traditional | Transitional | Responsive | **Ideal belief** |
| | Transitional | Traditional | Transitional | Traditional | Transitional | **Practical belief** |
| **Knowing students' understanding** | Traditional | Instructive | Responsive | Reform-Based | Reform-Based | **Ideal belief** |
| | Instructive | Instructive | Instructive | Instructive | Transitional | **Practical belief** |
| **Knowing what to and what not to teach** | Transitional | Traditional | Traditional | Traditional | Traditional | **Ideal belief** |
| | Traditional | Traditional | Traditional | Traditional | Traditional | **Practical belief** |
| **When to move to the next topic** | Instructive | Instructive | Instructive | Traditional | Instructive | **Ideal belief** |
| | Traditional | Instructive | Instructive | Traditional | Instructive | **Practical belief** |
| **Students best ways of learning science** | Instructive | Transitional | Transitional | Transitional | Transitional | **Ideal belief** |
| | Traditional | Traditional | Transitional | Transitional | Transitional | **Practical belief** |
| **Occurrence of learning in the classroom** | Transitional | Instructive | Instructive | Instructive | Instructive | **Ideal belief** |
| | Instructive | Traditional | Instructive | Traditional | Instructive | **Practical belief** |

#### *4.1.2.2. Role of the teacher*

Interview data suggest that all teachers, except one, assume a facilitatory role during science instruction. As a facilitator, a teacher aids the instruction process by carefully designing science

learning experiences where students take charge of their learning. One of the teachers who had reform-based beliefs, while acknowledging that sometimes he assumes the role of a "traditional teacher", explained that he believes in giving students a platform where they can be "doing much of the 'issues' and, as a teacher, trying to guide them …". This gives the learners autonomy to take charge of their own learning as he explains below:

> *"Science, for it at least to be acquired fully, there is a need for these learners to be given a chance to air out their views, do some kinds of mistakes, probe some questions on them, direct and guide them what they should do but it should be them doing the issue of discovering the new knowledge that is there. If it's the kind of skills that they are trying to acquire, they should be more or less like through discoveries. So in so doing, it should not be you the teacher working as if you are dishing out the information, but they should try to find out more about that. So if you are doing such kind of teaching, teaching that similar then you are now probably graduated into a facilitator in that learning" [MP, School 3, Interview Transcript]*.

Similarly, while confirming the facilitatory role of a teacher, Mr NG briefly mentioned how he performs this role. He claimed that, while in class, he makes sure that he creates a "conducive environment" for his learners, by preparing enough instructional material for the students to use during instruction. These include the use of activities for the students, organising practical work for the students as well as asking probing questions that help the learners to arrive at a "conceptual understanding". These are "interactive ways" of learning science. He believes that learning is a "two-way interaction" between the teacher aiding instruction and the students responding as well as asking questions in the process. He deliberately makes learning a two-way interaction so that:

> *"I … get their ideas. I am saying* kuti *[that] … they need to provide their ideas so that, in the end, if they have challenges, they can ask me questions, and I help them. I get a lot of ideas in that particular class, so after getting all those ideas, in the end, we will consolidate those ideas. After merging, we will come out of the room with one thing" [NG, School 3, Interview Transcript]*.

The above quotes show that these teachers have a sophisticated understanding of how modern classrooms ought to be managed that is indicative of student-centred teaching orientations. Even though teachers had sophisticated beliefs on this, their ideal and practical beliefs differed

significantly. These inconsistencies demonstrate a long-standing issue of discrepancy between teachers' beliefs and practices. Several reasons for this observation are explored in Chapter 7.

#### *4.1.2.3. Knowing students understanding*

For this aspect, there were extensive and significant variations between teachers' ideal as well as practical beliefs. Three teachers held student-centred beliefs during interviews. However, the same teachers demonstrated teacher-centred beliefs during instruction, except for one who had transitional beliefs. The rest held teacher-centred beliefs in both cases. For the three teachers, it was a general view that, during instruction, they would know whether students understood when they subjected their students to a variety of assessments. The following are some of the quotes from the teachers:

> *"Yea, they should be able to answer questions basing on my objectives, but also they should be able to give me practical situations of the ideas later, or they can be giving me examples of the cases where we can apply this idea in the day-to-day life. And then, what rings in me is that they have understood the concept of trying to marry it to the situation" [NG, School 3, Interview Transcript].*

> *"Yeah, you see that they have acquired whatever you wanted them to if they can show the desired skills that we wanted them to have. For example, if I am teaching presentation skills when we give them a graph, can you draw can you come up with a chart of resistance against voltage or current against voltage. If they can come up with that, then we can tell … or when we say they can analyse a particular situation or they can apply a specific concept, you can give them. When you are teaching plastics or polymers kuti [that] if how can you manage plastic wastes in your environment or in your communities – so when they are able to come up with that, then you are able to [know] that they have grasped what you wanted them to so, in short assessments huh yeah through evaluations" [PH, School 2, Interview Transcript].*

> *"For me, understanding means they have taken that thing into them. Are students able to explain, ok? They can even explain to others that this is what we have learnt. They can be able to apply it in real life that we learnt this, and then we can use it on this. And that is the way I understand by the word understand" [TH, School 2, Interview Transcript].*

From the above quotes, the emphasis of these teachers was that they use different ways of

determining students' understanding. All the teachers mentioned students giving answers which are aligned to the objectives of the lesson. Apart from that, it is also clear from the quotes that these teachers want their students to be able to explain the applicability of the knowledge they have just acquired to everyday contexts. For instance, Mr NG, who held reform-based beliefs, said during interviews, "*I use question and answer technique to determine to what extent the students understand what I am teaching*". Not only is the teacher interested in how students respond, according to the objectives, but he is also interested in how students relate the content of the lesson to their everyday lives referring to the application of the content. Similar to Mr NG, Mr PH, who also held reform-based beliefs, provided elaboration by describing typical examples on both objective levels as well as the practical level as in the extract above.

Despite articulating these and apparently holding student-centred beliefs during interviews, the teachers demonstrated teacher-centred beliefs during instruction that showed a misalignment of beliefs. For instance, Mr PH, who taught electrical energy, only asked the students "*do you have any questions so far?*" to check their understanding. Not only is this limited in terms of gauging students' understanding, but it is also too general. With the absence of response[s] from the students, the teacher interpreted that as a sign that students understood. He then gave students an exercise that followed the same pattern as the example he worked on with the students.

| | | | | |
|---|---|---|---|---|
| 1 | - | Teacher | : | Do you have any questions? |
| 2 | - | Students | : | *Silence* |
| 3 | - | Teacher | : | So if there are no questions, you will show that by answering this question |
| 4 | - | Students | : | *Students copy down the exercise in their books* |
| 5 | - | Teacher | : | So remember these equations are three, this one, this one and this one [teacher pointing to the three equations on the board]. |

[PH, School 2, Classroom Observation]

After explaining the concept of electrical energy to the students and doing an example on how to calculate electrical energy, the teacher wanted to check students' understanding. He asked the question in excerpt 1. There was total silence. The teacher interpreted that to mean that the

students understood what he was teaching so, in excerpt 3 he said, "you will show that…", "that" means understanding, in this case. However, the exercise was similar to the example which he had just done. This was a strict alignment of assessment to objectives of the lesson.

Other teachers held teacher-centred beliefs regarding this aspect in both cases. These teachers' sentiments suggest that they use assessments exclusively aligned with the objectives of the lessons. The teachers did not even want to create a room where the students would apply what they have learnt. For instance, the following quote is a typical example of those coded under this category:

> *"In every lesson, we have got objectives, and as a teacher when you are teaching there, you know that these are my objectives and, at the end of the lesson, there is a conclusion and this conclusion, in some days, it can be questions which you are going to ask before you [end] the class. After giving these questions, if the students can respond, you are at least assured that they have understood. Or an exercise you give a task, and you mark – if the students are getting it right then, you know that the students have understood depending on the percentage" [KA, School 1, Interview Transcript].*

Similarly, in this aspect, beliefs about knowing students' understanding, there is an apparent misalignment of teacher beliefs about teaching and learning of science with their practices. There are several reasons for this misalignment (see Chapter 7).

#### *4.1.2.4. Knowing what to teach and what not to teach*

For this aspect, there were minimal variations amongst the teachers. Except for one teacher who held transitional beliefs during interviews, all teachers held traditional, teacher-centred beliefs in both cases. During interviews, most teachers expressed that their decisions concerning this aspect are guided by what the curriculum prescribes at a particular stage. Even though they acknowledged having freedom where the "sequence may be changed" [MP] depending on weather, seasons and time, they still argued that they could not change the scope and there is very little room for them to teach things outside the curriculum. For instance, Mr NG noted:

> *"As I said, I am obliged what to teach. It is taken from the syllabus. I have no choice. Unless it's a thing which is related to my syllabus. So I follow the syllabus, I make sure I*

*have to teach what is in the syllabus. But if there is something learners have asked and is something which could be beneficial relating to the syllabus, then I teach [it]" [NG, School 3, Interview Transcript]*.

For fear of confusing the learners, one teacher acknowledged that sometimes he/she might change the scope of the curriculum by teaching things not prescribed in the syllabus, however, he/she concedes that this does not happen frequently:

*"It [*the syllabus*] controls the scope as to how deep you are supposed to go with that topic. And the other thing is that the syllabus tells us precisely what we are supposed to teach. We cannot go outside that one. You cannot bring in something because sometimes we may bring confusion to the learners. So that syllabus, you know, helps a lot and even the textbooks themselves" [TH, School 2, Interview Transcript]*.

This teacher, just like the rest of the teachers, argued that the curriculum "controls" the scope, that is, it spells out how deep and how broad the content should be at a particular level. He continued to say that, even though they cannot change the scope of the curriculum, they sometimes teach things outside the scope. However, this is not as frequent as one would expect as he had only done this once in the past three years when he was teaching the topic of radioactivity:

*"Yeah, I did that because, in other textbooks, it's there so maybe they [students] may come across it in the library so there is what this beta plus so they may ask you that question and because I taught them in advance that this is not of your level but in case you may come across it. So we discussed that one" [TH, School 2, Interview Transcript]*.

These traditional beliefs manifested themselves during instruction. The teachers simply took all the objectives they had intended to achieve from the curriculum with no further modification or additions (see chapter 7 where I discuss this). For instance, Mr NG, while introducing the topic of magnetism, listed all the topics' objectives on the chalkboard from the syllabus students are supposed to achieve. He then said:

*"What I have written on the board here are the objectives you need to be guided on when you are looking at this topic, magnetism. So if you go read concerning this part, these*

*should be your basis for this topic, magnetism, at MSCE[3] level, if you say you have studied magnetism, ready for exams, then you should be answerable to these ones (*pointing at the topic objectives on the board*). [*reads the objectives loudly to the students*] ... So these ones are some of the benchmarks guiding us as we are going along with this topic – magnetism" [NG, School 2, Observation Transcript]*.

Even though this tendency of relying on the curriculum as well as giving students all the objectives enhances teacher-student accountability, at the same time, it impedes teachers' creativity in terms of embedding other equally essential objectives such as NoS objectives.

Mr KA also showed transitional beliefs during interviews:

*"First of all, ... you are looking at the level of the learners. Because you are the one who is interacting with the students so, after looking at the instruction, materials, and the content, you do assess, saying 'will the students there understand this at this level?' Because, in the books where they may arrange the topics to order but looking at the level there, sometimes it needs time. So that the students are mature enough when they have been exposed to a number of topics so that you can come up with this one – so actually for you to decide where you are looking at the abilities of the learners" [KA, School 1, Interview Transcript]*.

From the quote above, the teacher isolated several factors, such as time, level, and the ability of the learners, as fundamental factors when it comes to determining what to or not to teach. He suggested that, even though there is a scope in the curriculum or textbooks, these will not make sense if they do not match with the level of the learners. Hence, when preparing for lessons, he checks if the content fits the level of the learners. If not, he does bridging courses which would enable the learners to be at the level he wants. This is a complete departure from other teachers who only rely on what the curriculum prescribes. At the same time, it was surprising to have this kind of articulation from a teacher who only holds a diploma in education. Usually, the expectation is that diploma holders have less developed PCK than degree holders since, traditionally, there is less content in diploma programmes than degree

[3] Malawi School Certificate of Education (MSCE). This is the award given to a student who has successfully passed the examinations marking the end of senior secondary school education

programmes. However, during instruction, the teacher seemed to follow the traditional approach described above exclusively.

#### *4.1.2.5 When to move on to the new topic*

For this aspect, all teachers held teacher-centred beliefs, with varying degrees. Teachers' sentiments strongly suggest that moving to a new topic is mostly based on teachers' judgement once students have attained a basic understanding of the concepts they are learning. The quote below is a typical example of teachers' beliefs:

> *"Moving to a new topic is based much on how students have understood the previous topic that you were teaching because, as I already said, that the syllabus might be sequenced in such continuity. So, if you go ahead and yet they have not heard the previous issues, they will not understand that. So, first of all, you need at least to teach so that they understand it fully. After that, it's when you can go to the next topic because, if you rush to go that topic, then they will have problems because they have failed to understand these things, they will not also capture" [MP, School 3, Interview Transcript].*

Similarly, during instruction, it was evident that moving on to a new topic was based on the decisions of the teacher who noted when students achieved a minimal understanding of the objectives of the lessons. None of the teachers observed in this study gave an end of topic tests to check to what extent the students understood the lessons within the topic. They relied on questions which they asked during instruction as a way of determining whether students have understood or not.

One teacher, who had traditional beliefs during interviews, acknowledged that there are several factors which he considers, such as students' feedback, as well as time constraints. On the part of students' feedback, the teacher was of the view that teaching and learning proceeds from clearly formulated lesson objectives after getting feedback from the students. Once *"... the objectives have been achieved ... then you proceed ...*" to the next topic/concept. However, he pointed out that time constraints sometimes forced him to move on to the new topic without necessarily checking whether students have understood or not as he argues in the quote below:

> *"... our teaching here is determined by several factors, like time. For example, the form fours have got a target they are going to write national examinations. So, by national*

*examinations, we have the syllabus, because the national examinations will cover the whole syllabus whether you have finished or not, but they will still cover everything, so there is a time factor that will also help you to move to another topic. You can teach that one, you have seen that some students that are behind you can go back and just try to do remedial activities. But sometimes you see that, if I do that, I am losing time. The moment you repeat a certain particular topic, then it means you are automatically off your schemes, so time factor also helps us to move forward" [PH, School 2, Interview Transcript].*

This teacher argues that moving to a new topic is dependent on several factors. However, he seems to place much emphasis on time. Since he is teaching the senior class whose students are about to sit for national examinations, he claims that, once he finishes the topic, he quickly moves on to the new topic. This is to ensure that he uses the time resource efficiently. This was also evident during instruction.

#### *4.1.2.6. Students best ways of learning*

For this aspect, there were variations observed. Four teachers held transitional beliefs during interviews. While three out of the four maintained their transitional beliefs during instruction, one teacher displayed traditional beliefs during instruction. The other teacher held teacher-centred beliefs in both cases. Interview data revealed that most teachers were well versed in participatory approaches to teaching science where the teacher engages students in the teaching and learning process. "*Students learn science best when they are being involved … learner involvement maximises learning in order to acquire the knowledge successfully*" [MP]. Mr NG, who believes that students learn best by "doing", explained the problems associated with relying on the lecture method of teaching:

*"Of course, they learn better by doing because I tried someday, I mean there was this particular term, I had to use, when I just started working, I was using the lecture method. So I could lecture, lecture, lecture and then go out but now, assessing the results at the end, were not good for me because the learners, I think the learners had challenges to absorb [understand]. But once I started to combine the thing [teaching methods], teach them how to do it and then they should actually do the things, then the results were boosted up" [NG, School 3, Interview Transcript].*

The above quote illuminates the fact that, through experience and students' feedback, teachers'

orientations are continuously being developed, for the better, in this case. Modern strategies of teaching demand that students are actively engaged in the teaching and learning process as it is believed that this ensures enhanced retention rates for concepts.

Most teachers' transitional beliefs were evident during instruction. This was evidenced by the use of instructional strategies that engaged students. Mr TH knew the importance of engaging students' minds. He used the probing question technique, as shown in the extract below:

| | | |
|---|---|---|
| Teacher | : | Is there pressure in liquid? |
| Student [s] | : | [most of them] yes |
| Teacher | : | How do you know that there is pressure in liquid? |
| Student [s] | : | [*After a long period of silence and no answer from the students*] |
| Teacher | : | *so we should say that there is no pressure in liquids, huh?* |
| Students | : | [most of them] No |
| Teacher | : | Suppose you have a bottle, with three holes at different heights (shows the diagram of the bottle drawn on the board to the student). Describe what would happen and why? |

[TH, School 2, Classroom Observation Transcript].

In the transcript above, the teacher tried to engage the students using question and answer techniques. The questions, as seen, are related to everyday life. He believes that, through such an engagement, learners learn content that they can relate to their everyday lives and that this stimulates the learners' interests. After that, the teacher posted a chart on the board, which provided a summary of what he has talked about so far concerning pressure in liquids. Specifically, the chart had points about the three facts of pressure in liquids.

One teacher held teacher-centred beliefs in both cases. When asked how he thinks students learn science best, he explained:

*"My students, to say the fact, my students learn best when I am explaining and also doing the thing they do learn best. Yeah, explaining and doing the thing there. Or explaining and they are also doing the thing. On that one, I can give an example saying I am teaching Archimedes principle – you state it, you give them the materials there so that they do on their own there. Yeah, they do learn better" [KA, School 1, Interview Transcript]*.

The above quote suggests that the teacher thinks his students learn science best when he explains [lectures] while the students are copying him in the process. He went further by giving an example of what he meant by "explaining and doing".

#### *4.1.2.7. The occurrence of learning in the classroom*

Four teachers held teacher-centred beliefs (instructive) when asked about this aspect during interviews. Furthermore, their teacher-centred beliefs were also evident during instruction. Only one teacher held transitional beliefs during interviews while showing traits of teacher-centred beliefs during instruction. For the four teachers who held instructive beliefs, their quotes suggest that they base their decision on whether students give correct answers to the questions. Hence, by closely monitoring what the students are doing in class, they evaluate the learning in the class. For instance, one teacher said the following:

*"Of course, I usually take note of that when they are following up on the steps. When learners are doing the steps logically, for example, I can go to a class, maybe it is a practical session, then they have done step one, step two but they are failing to do step three. Then I know, ok if you are at step three then you have done step one and step two, which means for step one and two it's ok for them. Moreover, there if there is a need, I can assist in step three, which means they will carry on to other steps" [NG, School 3, Interview Transcript]*.

Closely monitoring students' actions in the classroom is also one of the ways of determining whether students understand or not. What the students are doing in class gives a teacher insights regarding instruction:

*"Oh so, when they are following the activities that we are also doing, when they have achieved the objectives of the lessons, or when they are achieving the objectives of the lesson. Because per lesson, you have objectives. By the end of this, students must be able to do this and that or to acquire this and that, so if those things you see that they are*

*acquired, then you know that learning has taken place" [PH, School 2, Interview Transcript]*.

One teacher held transitional beliefs during interviews. He argued that, apart from being attentive in class, he also becomes aware of students' understanding of the content when they can ask questions that either seek further clarification of the presented content.

*"... when the students are listening attentively, and also when the students are asking questions in the process of teaching and learning. These questions can be like, 'sir I did not get the point there, how does that happen? How does this work? How does it relate to this ...?' Such kind of questions I do know that these students are with me and learning is taking place. They are not just passive there, they are listening to the teacher, but when they are asking questions, either they are not getting the concepts or wanting to learn more about that idea. Then you say learning is taking place. Moreover, some there maybe they are reasoning in their own way, you know that learning is taking place" [KA, School 1, Interview Transcript]*.

This is entirely different from the rest. Asking questions about a presented subject gives the impression that the learners attentively followed the topic under discussion. While the more experienced teachers held instructive beliefs, this teacher further articulated how students' understanding can be assessed. However, during instruction, all the teachers demonstrated teacher-centred beliefs concerning this aspect. All the teachers relied on asking simple basic questions towards the end of the lesson. Once students answer the questions correctly, the teachers would then dismiss the lesson.

### 4.1.3. Teachers' views about the nature of science (NoS)

Participants' views about the nature of science were gathered through a questionnaire – Views of Nature of Science Form C (VNoS-C) developed from various sources, as discussed in Chapter 3. As already highlighted in the data analysis section in Chapter 3, the questionnaire comprised several aspects/tenets concerning the NoS which are: *the scientific method, the tentativeness of scientific knowledge, observation, creativity and inferences, scientific theories and socially and culturally embedded nature of science*. Table 4-3 shows a summary of the teachers' beliefs about NoS, which were grouped into three categories: *naïve, transitional* as well as *informed* as described in Chapter 3.

Teachers' CoRes as well as classroom observation data also shows that these teachers did not explicitly include objectives concerning any of the aspects of NoS. When asked why they did not explicitly include the nature of science objectives in their lesson during Post Observation Interview (POI), teachers' responses suggested that NoS is treated as a standalone topic in the curriculum. They claimed to have already offered that topic when they taught Physics/Chemistry to form one learners hence did not see a reason to repeat objectives concerning this aspect in the following topics they teach, as shown in the quote below:

> *"I think my objectives were matching the topic at that particular time. I don't know what you wanted on the nature of science. The nature of science was already covered in the first weeks of the term one in form one. So that's why I did not include it during that period (*when I was collecting data*)" [KA, School 1, POI].*

The first part of the quote suggests that he had trouble understanding why I had asked him about incorporating NoS in the lessons I observed. He wondered why I wanted him to include NoS objectives in the lessons I observed, as shown in the underlined sentence. He further said that they had already covered NoS in the first term of form one. The teachers' comments seem to highlight a limited PCK for NoS which I discuss in detail in Chapter 7. Effective NoS practices demand that teachers explicitly embed aspects of NoS in their subsequent science lessons. However, this is not the case with these teachers. This highlights some of the gaps concerning NoS that exists in the new science curriculum as discussed in chapter 7. He nevertheless maintained that he had already covered NoS in form one, he, therefore, saw no reason to reteach some of the aspects concerning NoS. He treated the nature of science as a standalone topic.

On the other hand, Mr NG equated NoS to students conducting experiments. He believes that when students carry out an experiment, it entails teaching about NoS. Furthermore, similar to the other teachers, he also stated that he had already covered such issues in form one where students are taught about the various tenets to do with NoS.

> *"If I recall precisely, I think I did take that into account, especially on the investigative part as a science applies the systematic investigative approach. I think I gave them an assignment which had a direct follow up (application) on our class discussion" [NG, School 3, POI].*

When I asked him why he did not make that explicit, he explained:

> *"I was banking on our prior discussion with the students, kukhala Ngati munatipeza titayamba kale topiki imene ija (it appears we had already covered that topic in form one). So the assignment was but a continuation of what they already had, moreover, it gets covered in Physics, Chemistry, Biology, and Agriculture. The topic is called a scientific investigation. It is taught at the beginning of the term in form one. So all the searchable assignments which come forthwith are supposed to follow a similar presentation. Even anawo amadziwa (those students know that) Ukangowapasa (if you just give them) activity they actually know how to present it systematically."*

In the highlighted section of the quote above, the teacher's sentiments seem to suggest that his ideas about the NoS are only limited to the aspect of "scientific method" which students have to follow. He continues to say that, once students are given such activities, they have to follow the scientific method precisely even when they are presenting their findings. Even though this was not the aim of the study, this finding points to the teachers' understanding/interpretation concerning the treatment of NoS during instruction. Ultimately this suggests the teachers' limited PCK for NoS, which I discuss in detail in Chapter 7.

**Table 4-3: Teachers' Beliefs about NoS**

| | Teacher[s] | | | | |
|---|---|---|---|---|---|
| **NoS tenet** | **KA** | **MP** | **TH** | **PH** | **NG** |
| ***What science is and how science differs from other disciplines*** | Transitional | Naïve | Transitional | Informed | Transitional |
| ***Scientific knowledge is tentative*** | Informed | Informed | Naïve | Informed | Naïve |
| ***Scientific knowledge, observation, inferences, and creativity*** | Naïve | Transitional | Naïve | Informed | Naïve |
| ***Scientific theories and laws*** | Naïve | Informed | Naïve | Informed | Naïve |
| ***Science is socially and culturally embedded*** | Naïve | Transitional | Naïve | Transitional | Naïve |

#### *4.1.3.1. Definition of science and how science differs from other disciplines*

Regarding this aspect, three teachers (KA, TH, NG) held transitional beliefs. They defined science as a discipline that involves a systematic study of things of the natural world. However, they did not clarify when asked: "how science differs from other disciplines of inquiry". This is a surprising finding considering that the teachers are more experienced and well qualified; hence, they should have been particularly conversant in what science as a subject is and how it differs from other disciplines of inquiry. For instance, Mr KA described science in the following way:

> *"Science is the systematic study of things which include natural forces through observations and experimentations" [KA, School 1, Questionnaire]*

Similarly, Mr NG's description of science was limited to what science is in terms of how the process of doing science is conducted:

> *"Science is the study of natural phenomena. It studies the natural activities, how they occur, and how they are related in our everyday life. Unlike other disciplines of inquiry, science is practical. It's easy to appreciate and be involved in the natural process" [NG, School 3, Questionnaire]*.

Despite Mr NG mentioning that science differs from other disciplines of inquiry, he did not unpack what he meant by the fact that science differs from other disciplines since science is "practical". He instead stated that, with science, it is easy to appreciate and be involved in the natural process. However, even in the social process, one is also intimately involved in the process of inquiry.

Mr MP, on the other hand, demonstrated naïve views regarding this tenet. Even though his definition of science as a discipline is correct, his description of how science differs from other disciplines of inquiry shows that he harbours misconceptions concerning the scientific method. In other words, he argues that the scientific method is the only method that results in the generation of scientific knowledge:

> *"This is a belief that truth or solutions to a problem can be found only through experiments. Science believes that any result or solution found through any method other than the scientific method is sceptical" [MP, School 3, Questionnaire]*.

From the above quote, the teacher argues that scientific experiments are instrumental in addressing scientific problems. What the teacher does not mention is that the experiment is just the final stage, where scientists test a theory or hypothesis. Furthermore, there are many examples from the history of science, which shows that there is no single method of doing science. Hence, this is an apparent misconception concerning science.

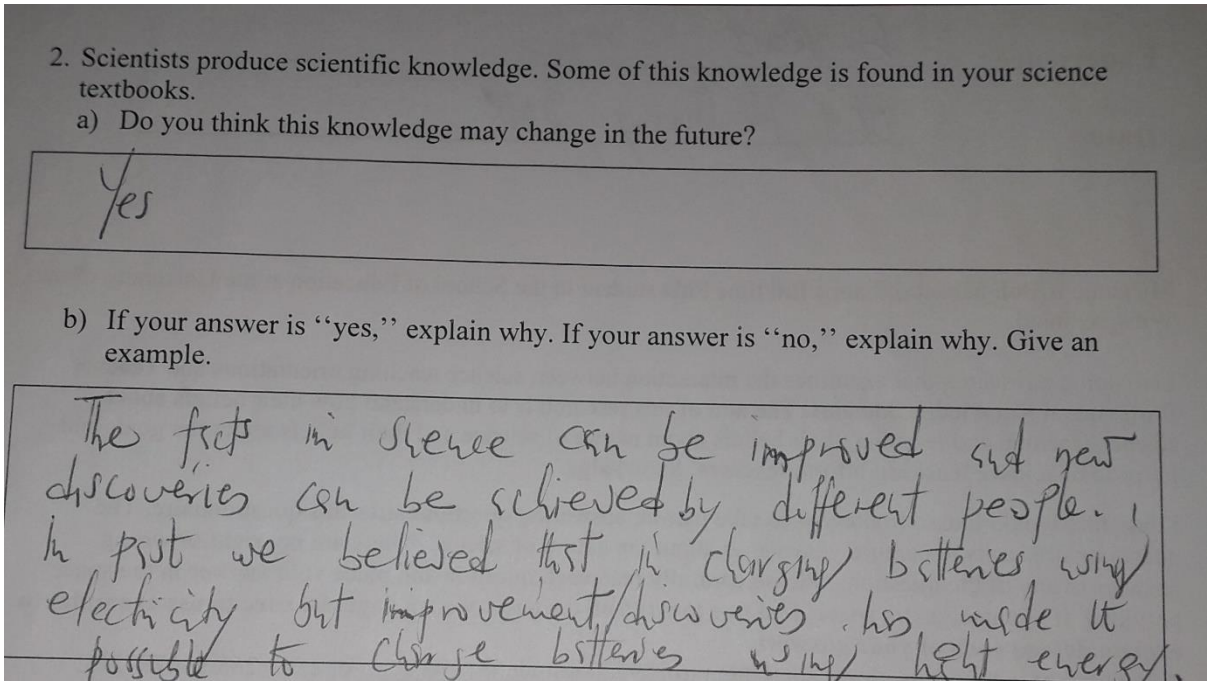
Mr PH demonstrated informed views about this tenet. Apart from correctly describing what science is, he clearly elaborated how science differs from other disciplines of inquiry despite the noticeable lack of creativity and imagination in his definition as captured below:

> *"Science is the discipline that deals with the systematic study of the things or phenomena in nature through observation and experiments. Science differs from the other subjects because it is based on empirical evidence, inquiry, by developing hypotheses which are tested several times" [PH, School 2, Questionnaire].*

The teacher also highlighted that the developed hypotheses have to be tested several times, probably to make sure that all other conditions are taken into consideration.

#### *4.1.3.2. Tentative nature of scientific knowledge*

While the above item concerning the definition of science provided a glimpse of teachers' views about science, the nature of scientific knowledge items, on the other hand, provided a contrary view. Data clearly show that all teachers regard scientific knowledge as tentative, apart from two teachers (TH, NG) who had naïve beliefs since they could not correctly justify their answers. Responding to the question: "Do you think scientific knowledge may change in the future?" They all said "Yes" signalling that they believe that scientific knowledge is dynamic. Furthermore, they were also able to give at least one example from either the history of science or from our everyday lives to support their claims. For instance, Mr KA explained that he believes scientific knowledge can be improved by discoveries about the natural setting. Furthermore, he supported his claims using an example from everyday life, as shown in Figure 4-1 of the extract.



2. Scientists produce scientific knowledge. Some of this knowledge is found in your science textbooks.
   a) Do you think this knowledge may change in the future?

Yes

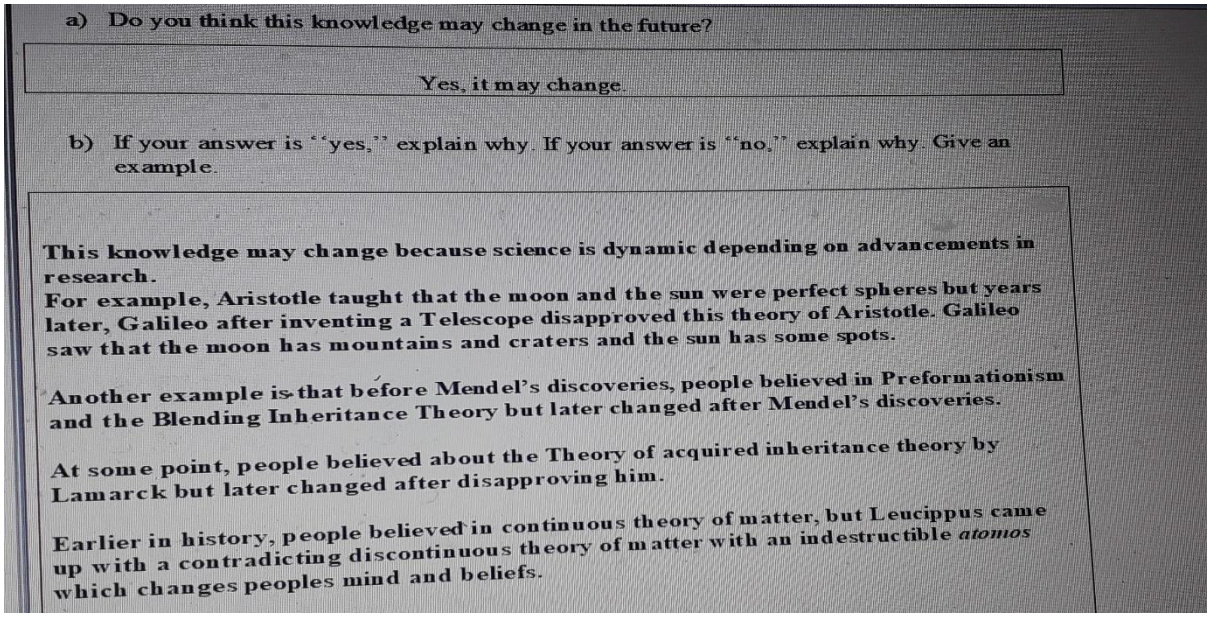
   b) If your answer is ''yes,'' explain why. If your answer is ''no,'' explain why. Give an example.

The facts in Science can be improved and new discoveries can be achieved by different people. In past we believed that in charging batteries using electricity but improvement/discoveries has made it possible to charge batteries using light energy.

**Figure 4-1: KA views on the nature of scientific knowledge**

In the above figure, the teacher supported his claim by giving an example from our everyday life (charging of battery) to substantiate his answer. Advancements in science necessitated the development of other ways of charging batteries. This, according to him, signifies the tentative nature of scientific knowledge.

Mr MP's beliefs about scientific knowledge were far more elaborate in the sense that he used more examples from Astronomy, Chemistry, Physics as well as Biology to substantiate his claims. Figure 4-2 shows the extract from the returned questionnaire.



a) Do you think this knowledge may change in the future?

Yes, it may change.

b) If your answer is "yes," explain why. If your answer is "no," explain why. Give an example.

This knowledge may change because science is dynamic depending on advancements in research.
For example, Aristotle taught that the moon and the sun were perfect spheres but years later, Galileo after inventing a Telescope disapproved this theory of Aristotle. Galileo saw that the moon has mountains and craters and the sun has some spots.

Another example is that before Mendel's discoveries, people believed in Preformationism and the Blending Inheritance Theory but later changed after Mendel's discoveries.

At some point, people believed about the Theory of acquired inheritance theory by Lamarck but later changed after disapproving him.

Earlier in history, people believed in continuous theory of matter, but Leucippus came up with a contradicting discontinuous theory of matter with an indestructible *atomos* which changes peoples mind and beliefs.

**Figure 4-2: MP's views on Scientific Knowledge**

Preferring to use a soft copy of the questionnaire, the teacher supported his views regarding the nature of scientific knowledge by using several examples from the history of science. By correctly describing the examples from a wide range of disciplines (Physics, Astronomy, Chemistry, Biology), the teacher not only demonstrated sophisticated beliefs concerning scientific knowledge but also how comprehensive his understanding of the tenet was. This is critical when it comes to giving evidence to the learners when covering such objectives in science lessons.

Other teachers held naïve beliefs about this tenet. Even though the teachers acknowledged that scientific knowledge is tentative, they did not give a convincing reason or examples to substantiate their claims. As a result, I did not code their reasoning.

#### *4.1.3.3. Observation, inferences, and creativity regarding science*

Regarding this aspect, there were huge variations amongst the teachers, unlike the tentativeness of scientific knowledge. One of the items on this subject was about the structure of the atom. Specifically, the question was: "how are scientists so sure about the structure of the atom even though they have never seen an atom?" This question required the participants to talk about the issue of observation, inferences as well as creativity on the part of the scientists. Three teachers (KA, TH, NG) held naïve beliefs concerning this question. They believed that scientists are

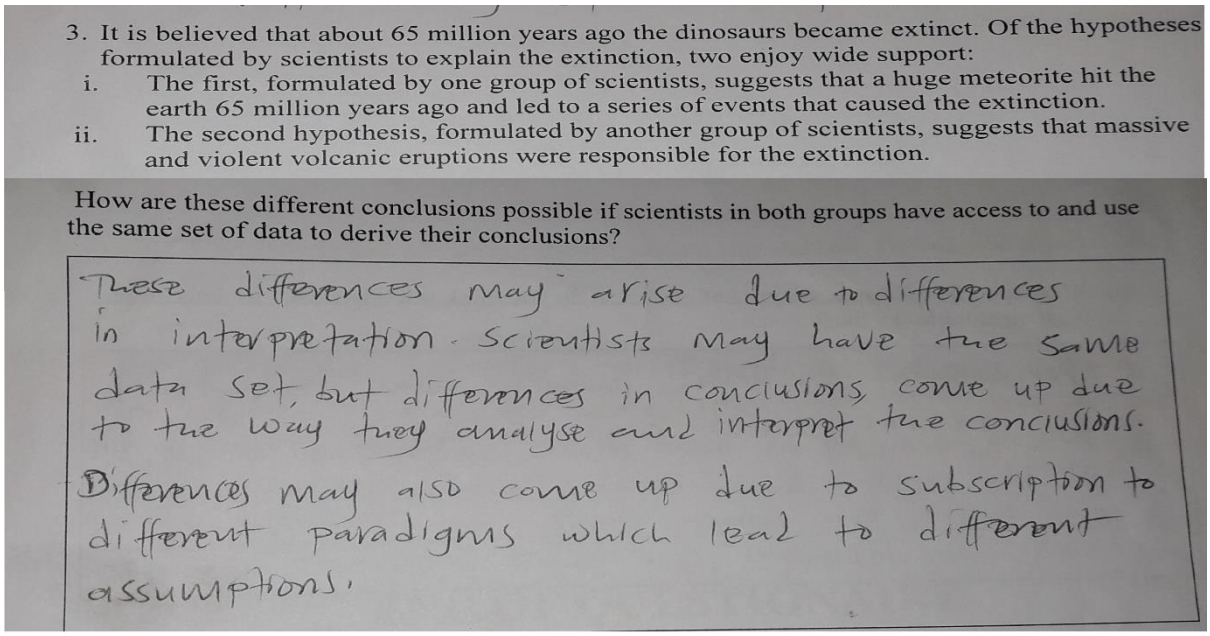
sure of the structure of the atom due to several experiments that were carried out repeatedly to confirm this. While the issue of "repeated experiments" is genuine, teachers, however, were not clear concerning the issue of creativity and inferences. Experimentation alone is not enough in science; scientists are creative people who make inferences to explain their observations. Because of their explanation, despite being accurate, I coded them as naïve. For instance, the excerpt below gives an example of those that I coded under the naïve category:

> *"It is difficult to tell precisely the position of the subatomic particles, e.g., electrons since they revolve around the nucleus at high speeds. However, for simplicity sake, since the electrons revolve around the nucleus, that is why they are represented in shells as in figure 1. The emphasis must be on the energy levels, as explained in quantum physics" [NG, School 3, Questionnaire]*.

In the above extract, the teacher's explanation concerning the structure of the atom shows that the teacher might be aware that the structure of the atom is not really like that. However, his explanation was not good enough to fall under "informed". On the other hand, Mr PH recounts the role of experiments that have helped scientists to uncover the structure of the atom:

> *"The scientists are certain about this structure of an atom through several experiments that they conducted. The results of these experiments showed the very same thing, the circular model with the nucleus. At the centre, which contains the two subatomic particles, the protons, and neutrons, while high energy electrons orbit outside the nucleus" [PH, School 2, Questionnaire]*.

The teacher claimed that, through repeated experiments on a phenomenon, scientists confirm the results they get. However, like the teacher above, the teacher did not know that experiments alone are not enough to explain the development of scientific knowledge. Scientists need to infer and use creativity to develop knowledge. Inference and creativity go beyond what these scientists observe. Surprisingly, in a similar item, his explanation demonstrated that he had informed beliefs about the issue. When asked why scientists come up with different theories from the same data set, he explained, as shown in Figure 4-3.


3. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support:

i. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction.

ii. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction.

How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

These differences may arise due to differences in interpretation. Scientists may have the same data set, but differences in conclusions come up due to the way they analyse and interpret the conclusions. Differences may also come up due to subscription to different paradigms which lead to different assumptions.

**Figure 4-3: PH views on Observation, Inferences and Creativity**

As can be seen from Figure 4-3, when the teacher was asked why different scientists come to different conclusions while using the same data set, his explanation suggests that scientists are bound to have different interpretations of the data. This extract highlights the issue of differences among scientists due to their subscription to different paradigms and their backgrounds. Here the teacher acknowledged the fact that, despite working on the same data set, they may interpret it differently because of personal preferences.

Mr MP had transitional beliefs concerning this tenet. His explanation concerning the structure of the atom was not convincing as he explains in the extract below:

> *"The theories on the structure of an atom tend to become complex with academic levels. It started with Dalton's Atomic theory, then the Rutherford Model of the atom followed by the Bohr Model and later the Charge-cloud Model. It keeps on changing depending on discoveries and explanations on atoms. So, it may be assumed that more and more discoveries on an atom will produce a further explanation of its structure. Currently, as scientists believe, the structure of an atom may be* tentative*" [MP, School 3, Questionnaire].*

In the above extract, rather than addressing the issue of creativity, as well as inferences

scientists, make, the teacher talks about how complex the idea of atom gets as one progresses. Even though this is true, however, he talks about the issue of inferences as well as creativity in an implicit way. Similarly, he acknowledges that, even though scientists might have the same data set, their conclusions might be different. However, his explanation of this was not comprehensive and hence categorised under transitional beliefs as shown:

> *"Science believes in empirical evidence, deductive and inductive reasoning. Two scientists can have one set of data, but the interpretation and reasoning attached to this data may differ, resulting in two different conclusions. The lack of some information may widen the gap between the conclusions reached. So the data must be valid; otherwise, so many conclusions can be drawn from one set of data" [MP, School 3, Questionnaire].*

#### *4.1.3.4. Scientific theories and laws*

Regarding the issue of scientific theories and laws, three teachers held naïve beliefs, while the other two had informed beliefs. This item required the teachers to state the difference between a scientific theory and a scientific law. Even though all the teachers agreed that the two are different, their articulation of their differences varied significantly. For instance, Mr NG showed that the two are different since:

> *"a theory is generalised thinking whose results may easily be appreciated, but it is not proven. On the other hand, a scientific law is proven generalised thinking, and its results can be determined precisely. For instance, the law of conservation of energy is actually proved, but the behaviourist theories are not proven" [NG, School 3, Questionnaire].*

From the extracts above, it is clear that the teacher harbours misconceptions regarding what theories are. He equates a scientific theory to the everyday usage of the term. He argues that a theory is an idea that demands proof. This is true in criminal investigations where an investigator develops a theory that he can prove but, in science, a theory explains the phenomenon while a law describes the phenomenon.

Mr MP held informed beliefs concerning this aspect. He acknowledged that a theory is different from a law. He illustrated this by advancing an argument that the development of scientific laws a simple activity. For instance, to develop the universal law of gravitation, Newton merely needed to make observations on the falling apple from the tree. On the other hand, a theory

needs rigorous testing as this constitutes explaining how things behave as they do. He explains this in this excerpt:

> *"The two are different. A theory cannot be validated by a simple activity while a scientific law can be validated by a simple activity and not necessarily an experiment. For example, a theory is a generalised statement established after valid investigations. It needs to be guided by steps for it to work. It is a thought about how something happened to exist. A theory is never absolute and can be disproved sometime in the future. On the other hand, a law is an established fact of how natural phenomena operate. It needs not to be guided by logical steps of an experiment. It [is], not a thought but rather a reality of how something happens or exists. For example, the kinetic theory of matter, one needs several steps to validate that a block of wood at rest contains particles that are in constant motion. However, the law of magnetism, one just needs to take two pieces of the magnet and demonstrate that like poles repel while unlike poles attract. So a theory needs an experiment to prove as it may be deniable while a law just needs an activity to demonstrate as it is undeniable" [MP, School 3, Questionnaire]*.

The above extract is illustrative of teachers' developed orientations concerning scientific theories and laws as the teacher has isolated a law from a theory. He has shown how the two differ in terms of how each is derived. This insinuates that more creativity is needed to generate a theory, unlike a law. This does not mean that one is more important than the other. They are equal but serve different purposes.

Mr PH also presented another well-articulated stance concerning the difference between theory and law:

> *"A scientific law is like a universal set of statements that have been proved and accepted worldwide while theories are just explanations of the natural phenomena based on the confirmed observation and experiments, for example, the kinetic theory of matter and the law of charges" [PH, School 2, Questionnaire]*.

The above excerpt is a demonstration of the teacher's advanced understanding concerning scientific theories and laws. Firstly, even though the teacher is unable to show that a scientific law describes a natural phenomenon, he has, however, correctly identified what a scientific theory does – "it explains the phenomenon". Secondly, the teacher has managed to give an example of a theory to illustrate his claim. These are emblematic extracts that were coded under

informed beliefs category.

#### *4.1.3.5. Social and cultural embeddedness of science*

In this aspect, two teachers had transitional beliefs, while the remaining three held naïve views. Responding to the question which asked them if they believe science to be universal, two teachers (MP, PH) demonstrated transitional beliefs. Their responses showed that they believed that context plays a huge role in scientific knowledge generation. For instance, the response by Mr MP typically shows how cultural practices and norms influence science in the following excerpt:

> *"Science is culturally embedded. For example, here in Malawi, poverty fuels the belief of witchcraft, and any strange occurrence is associated with witchcraft. As such, the spirit of investigation and experimentation is low such that the scientific knowledge is not put into practice as evidenced by despite so many professors. In agriculture, a vast amount of water in lake Malawi and fertile soils, Malawi still faces food insecurity and insufficiency. So, to many Malawians, a notion that science can be a solution to many problems being faced now is far from the truth. It is the same scientific knowledge that educated Malawians have, that has developed other nations, but it is failing to work here in Malawi. Therefore, social and cultural values influence much on the profitability of scientific knowledge" [MP, School 3, Questionnaire].*

In the above excerpt, the teacher gives an example of how cultural practices and beliefs influence the acceptance of the use of scientific methods and hence, the use of scientific knowledge. However, his argument centred on the use of scientific knowledge and methods. Responding to whether science is universal or not, Mr PH agreed with the idea that science is universal. He supported his answer by citing an example from astronomy. He argues that despite cultural differences, you can learn concepts, laws and theories wherever you are. However, a crucial issue of applicability of the laws and concepts did not come out clearly from the teacher hence it was categorised as transitional. He explains below:

> *"I believe that science is universal because it can be practised universally disregarding cultural, social, or political values. For example, although we do not have an astronomy centre base in Malawi for observing the universe in our schools and colleges, we still teach astrology. In short, there are some basic science concepts that are universal and need to*

*be learnt despite the cultural, philosophical, social, and intellectual backgrounds" [PH, School 3, Questionnaire].*

Three teachers held naïve views concerning this. Even though these three teachers agreed with the idea that science is universal, the support offered was not enough to substantiate their claims hence they were coded under naïve category.

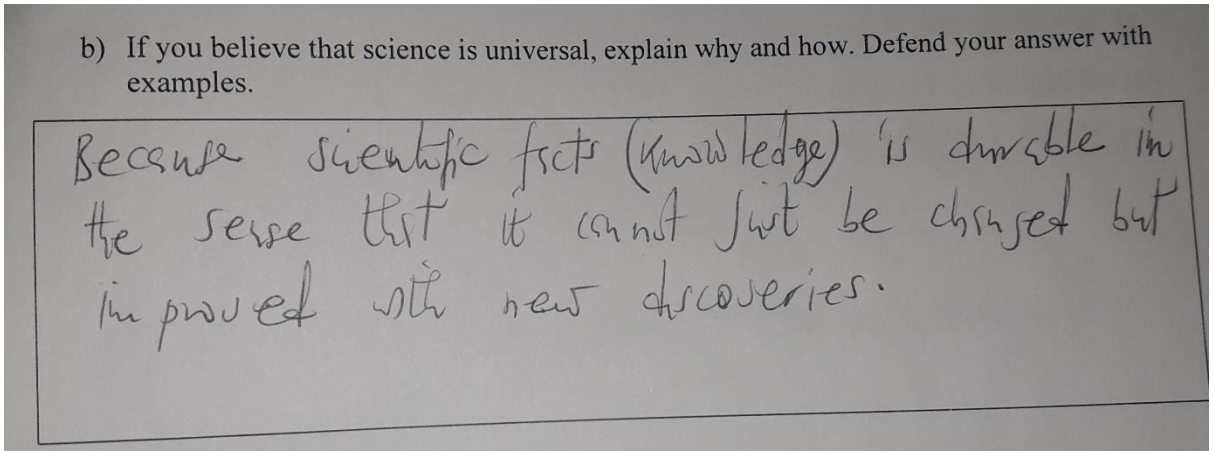



**Figure 4-4: KA views about Universal nature of science**

For each of these teachers, who held naïve views concerning this aspect, their views demonstrated that teachers lack understanding concerning the conduction of science since science is a human enterprise that cannot be divorced from human activity.

### 4.2. Summary

In this chapter, I presented findings concerning the first research question: "what teaching orientations concerning goals and purposes of science teaching, beliefs about teaching and learning of science as well as beliefs about the nature of science do Malawian teachers have?" Concerning the teachers' goals and purposes of science teaching, the teachers have different and multiple goals for science teaching which significantly impacted on how they structured their lessons. Concerning beliefs about teaching and learning of science, the teachers have sophisticated beliefs concerning aspects such as the role of the teacher as well as ways of maximising students' learning in the classroom. However, there were variations concerning their ideal beliefs and their beliefs emanating from classroom practice about teaching and

learning of science, that is, their ideal beliefs seem not to be reflective of their practices. Lastly, concerning teachers' views about the nature of science, data suggests that teachers have sophisticated beliefs about the nature of science. However, just like their beliefs about teaching and learning of science, their beliefs could not be translated into practice. Teachers cited several reasons for this which I illustrate in Chapter 7.

# CHAPTER 5. THE INTERACTION BETWEEN SCIENCE TEACHING ORIENTATIONS (STOs) AND TEACHER PROFESSIONAL KNOWLEDGE (TPK)

## 5.0. Introduction

In the previous chapter, I presented the findings concerning Malawian teachers' teaching orientations held by the five teachers who participated in this study. It was done to provide additional evidence concerning science teaching orientations according to Friedrichsen et al. (2011) framework.

In this chapter, I answer the second research question: "*To what extent do STOs influence the enactment of content knowledge, curricular knowledge, pedagogical knowledge, assessment knowledge, and knowledge of the students during instruction?"* To do this, I used data from classroom observations, post-observation interviews and CoRes. As shown in Chapter 2, teaching orientations, according to Friedrichsen et al. (2011), are defined in terms of three dimensions (*goals and purposes of science teaching, beliefs about teaching and learning of science* and *views about the nature of science*). Similarly, as in the previous chapter, I also align the presentation of the findings to these dimensions. I will start by presenting the interaction between the goals and purposes of science teaching with TPK domains and then I shall present findings on the interaction between teaching and learning of science and TPK domains. In both cases, during instruction as well as on their CoRes, teachers did not explicitly include any objectives concerning NoS. As a result, I did not observe any interactions between the NoS and TPK domains. Hence, I will not be presenting any findings concerning the interaction between the NoS and TPK domains.

In order to answer this research question, I used the inductive data analysis approach where I determined the interactions after an iterative process of interacting with the data several times. The second question is addressed by showing that STOs interact with TPK by influencing the various sub-domains of TPK either before (during lesson preparation as shown on the CoRes) or in the course of instruction (as determined though classroom observations – ongoing planning). Therefore, in the following sections, I highlight the influence STOs had on the various TPK sub-domains by giving specific examples.

## 5.1. Interaction between science teaching orientations and TPK domains

Inductive analysis of the classroom observations, CoRes, as well as post-observation interviews led to the following claims: Firstly, the *goals and purpose of science teaching interact with TPK domains*; secondly, *teachers' beliefs* about *teaching and learning of science interact with TPK domains*; lastly, teachers' *beliefs about the nature of science do not interact with TPK because the NoS topic is standalone where teachers teach about the NoS to the students*. I have summarised these interactions in Table 5-1 and Table 5-2 of this chapter where the + sign indicates the presence of an interaction. In the following sections, I present findings concerning the interaction between STOs and TPK aligned to the three dimensions of STOs according to Friedrichsen et al. (2011).

**Table 5-1: Summary of interaction between STO with TPK sub-domains**

| TPK Domains | TPK Sub-Domains | Goals and purposes of science teaching | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | KA | | | PH | | TH | | NG | | | | MP | | |
| | | Everyday coping | Solid foundation | Structure of science | Solid foundation | Correct explanation | Everyday coping | Correct explanation | Correct explanation | Solid foundation | Scientific skill development | Scientific skill development | Solid foundation | Correct explanation | Everyday coping |
| **Assessment Knowledge** | What to assess | | + | | + | | + | | + | + | + | + | + | | |
| | Reasons for assessment | | | | + | | | | | | | | | | |
| | Methods of assessment | | | | | + | + | | + | | + | + | | | |
| **Pedagogical Knowledge** | Classroom management | | | | | | | | | | | | | | |
| | Students' engagement | | | | | | | | | | | | | | |
| | Instruction strategies | | + | + | + | + | | + | + | + | + | + | + | + | |
| **Knowledge of Students** | Students' differences | | + | | | | | | | | | | + | | |
| | Pre-requisite knowledge | + | + | | + | + | + | | | | | | | + | + |
| | Misconceptions | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Curriculum Knowledge** | Goals & objectives | + | + | + | + | | + | + | | | + | | | + | + | + | + | + | |
| | Scope and sequence | | | | | | | | | | | | | | | | | | |
| | Curriculum coherence | | | | | | | | | | | | | | | | | | |
| | Linkage to other topics | + | | | | | | | | | | | | | | + | | | |
| **Content Knowledge** | Practices for scientific knowledge generation | | | | | | | | | | | | | | | | | | |
| | Core ideas (principles, theories) | + | + | + | + | | + | | | | + | | | | | + | | | |
| | Cross-cutting issues | + | | | | | | | | | | | | | | | | | |

### 5.1.1. Goals and purposes of science and TPK domains

Data show that teachers' goals and purposes of science teaching interact with various sub-domains of TPK. Therefore, the examples below show that the goals and purposes of science teaching influence the various decisions teachers make regarding their TPK when they are planning to teach or during instruction.

#### *5.1.1.1.* Goals and purposes of science vs curricular knowledge

In Chapter 2, through a review of the literature, I showed that curricular knowledge has sub-domains such as *goals and objectives of the curriculum, overall coherence of the curriculum* among others. Data indicate that various teachers' goals and purposes of science teaching interacted with these sub-domains. Despite these teachers having different goals and purposes of science teaching, the nature of the interaction between the goals and purposes and TPK sub-domains appeared to be uniform in the sense that teachers had interacted more with the *goals and objective* sub-domain of curricular knowledge (Table 5-1). This suggests a teacher training pattern from the institutions where the teachers studied where the teacher educators emphasised this sub-domain of *goals and objectives*. Apart from that, there were only two teachers (KA, MP) out of the five whose goals and purposes of science teaching also interacted with another sub-domain (*linkage to other topics*) of curricular knowledge. To illustrate these interactions, Mr KA, for example, had three goals and purposes of science teaching during instruction as shown in Table 4-1 in Chapter 4. These goals interacted with the teachers' curricular knowledge sub-domains as they influenced the pedagogical decisions the teacher made regarding this knowledge domain. For instance, his goals, *solid foundation*, as well as the *structure of science*, influenced his decision concerning the kind of objectives he had planned to achieve. On his CoRe, he indicated that, by the end of the lesson, students should be able to do the following:

1. Define the meaning of electric current;
2. Calculate the amount of electric current in a conductor as time elapses;
3. Construct series and parallel circuits given the tools;
4. Explain the effect of connecting bulbs in series and parallel in electric circuits [KA, School 1, CoRe].

From the above, the first and second objectives suggest that the teacher wanted his students to have an understanding of the concept of "electric current". During the post-observation interview, when asked why the objectives were arranged in such a way, the teacher explained that:

> *"it is important that students are first aware of the basic definition of the concepts. Then this is followed by some basic examples/calculations so that students have an understanding of the concepts for other related content that is going to come. Hence, this arrangement allows me, as a teacher, to move with the students from simpler objectives to complex. As you can see, the last two objectives are a bit more advanced than the first two…. So, in this case, the way the objectives have been presented in the curriculum, I find that there was no need to change or rearrange or add other objectives because they have already been suitably presented and they capture logically what is supposed to be covered, because were moving from simple to complex gradually" [KA, School 1, POI].*

He intended that they define the concept and later on he planned to do some calculations on the concept. This gave the impression that the teacher wants the students to have a *solid foundation* of the concept of electric current to ensure students' understanding of the concepts to prepare them for related content in the senior classes and even beyond the secondary school level. Similarly, during instruction, it was also evident how his *solid foundation* goal interacted with *linkage to other topics/disciplines* sub-domain while he was teaching about sources of energy. In trying to help students recall and relate the concepts, he asked the students if they could relate the term "geothermal" to geography as shown in the extract below:

| | | | | |
|---|---|---|---|---|
| 1 | - | Teacher | : | … under geothermal … but the term there is saying "geo" we know geology, geography? |
| 2 | - | Students | : | Yes |
| 3 | - | Teacher | : | In geography, there we talk about the earth's crust. Hope you have heard of it huh? |
| 4 | - | Students | : | Yes |
| 5 | - | Teacher | : | How about "thermal"? From the thermal expansion of solids topic? Do you remember this term? |

| | | | | |
|---|---|---|---|---|
| 6 | - | Students | : | Yes |
| 7 | - | Teacher | : | Ok. So what we are saying is that the earth's crust contains rocks but these rocks are very hot. Now when the water has been trapped in these rocks, we all know that when you are boiling water there is "this" thing which is produced …? |
| 8 | - | Students | : | Yes – Steam |
| 9 | - | Teacher | : | So the trapped water when boiled by these hot rocks produces steam, there is a production of very hot steam that comes out. Now this steam which is coming out is the one which is known as geothermal energy and can be used to drive turbines to produce electricity. Are we clear? |
| 10 | - | Students | : | Yes |
| 11 | - | Teacher | : | So geothermal is a term which means a kind of energy produced from the heat of the earth crust (*he now summarises what the term geothermal means*) |

[KA, School 1, Classroom Observation]

In trying to explain the concept of "geothermal" energy, the teacher asked students if they are familiar with the prefix "geo" from geography in excerpt 1. At this point, the teacher wanted to explain the concept of "geothermal" first by tracing the etymology of the word. As can be seen from the extract, the teacher was interested in the prefix "*geo*" – a Greek word which means "earth". Hence, this prefix combined with *thermal* which means "heat", to form "geothermal" would mean a kind of energy produced from the earth's crust (excerpt 11). The teacher was aware that his learners also take geography as a subject, and that they probably covered the definition of geography in the first term of form one when they did an introduction to geography. Relating concepts to other disciplines makes it apparent that the teacher wants to use a variety of tools at his disposal to improve students' understanding of the concepts as this is a cross-cutting issue. When I asked him during post-observation interviews to explain why he had explained the concepts he was teaching using the knowledge/ideas from geography, he said the following;

*"As a teacher, you have to utilise each and available resources at hand. I know students are aware of what '*geo*' mean in geography or geology … because in the first topic of geography, they learn what the geo in geography means" [KA, School 1, POI].*

This presents evidence that the teachers' *solid foundations* goal has interacted with this sub-domain. Not only did he relate the prefix of "geo" to this new concept (geothermal), but he also further explained the concept of geothermal in relation to concepts from geography concerning the structure of the earth's crust as shown in extract 3. He further complimented this by drawing the structure of the earth's crust on the board showing the different parts to aid students' understanding.

The third and fourth objectives, on the other hand, appear to be coming from the *structure of science* goal and purpose of science teaching. Contemporary methods of teaching science demand active involvement in the teaching and learning process. This involvement should be both hands-on and minds-on; hands-on in the sense that students should be allowed to interact with the materials in the process of learning. This enhances their handling of materials and the generation of scientific knowledge is accordingly enriched, for instance, objective number 3 above, *construct series and parallel circuits given the tools*. Through this objective, the teacher purposively ensured that students enhanced their manipulative skills (hands-on) once they had been given the apparatus. Through this, they would be able to interact with them by constructing different types of circuits. This kind of interaction is hands-on.

On the other hand, minds-on is the sense that students should be able to use their cognitive abilities to offer explanations for what they are observing or offer an explanation concerning a particular procedure. This is exemplified by objective number 4 above: *explain the effect of connecting bulbs in series and parallel in electric circuits*. To achieve this, the teacher engaged his learners on a (hands-on and minds-on) task through the use of practical work (*structure of science*). Hence, he included the third and fourth objectives where his students were required to construct both types of circuits (hands-on) and be able to conduct practical work and ultimately be able to explain (minds-on) the effect of connecting the bulbs in a series or parallel manner.

Likewise, Mr MP's goals and purposes of science teaching interacted with curricular knowledge. His *correct explanation* as well as *scientific skills development* goals interacted

with *goals and objectives* of the curriculum sub-domain. Regarding *correct explanations*, on his CoRe which he prepared on the topic of specific heat capacity, he planned to achieve the following objective with his learners, among other: "*describe the difference between heat and temperature*". This objective would ensure that students have an understanding of the concepts and hence were able to offer a correct explanation of the two concepts. Concerning *scientific skill development*, the teacher planned to inculcate mathematical skills in the learners. As a result, on his CoRe that he planned on power and machines, he indicated that, by the end of the lesson, students should be able to "*solve different problems related to the machines*". This was visible during instruction. He gave students various examples which he did together with the students. Towards the end of the lesson, he gave the students an exercise to do that demanded students' prowess in mathematical skills. He marked that exercise within the lesson. He emphasised the importance of changing the subject of the formula as well as having a mathematical calculator. The emphasis on changing the subject of the formula points to the facts that the teacher wanted to enhance students' scientific skills. This kind of interaction was also observed in the three remaining teachers.

Mr NG's scientific skills development goal interacted with *goals and objectives* sub-domain of curricular knowledge where he formulated an objective, "*investigate the behaviour of resistors in both series and parallel circuits*". This aligns with the teacher's comments (during interviews) where he claimed that, through the use of practical work, learners could gain the various scientific skills which are critical for scientific knowledge development. Even though there are several sub-domains of curricular knowledge as shown in the literature review chapter, findings of this study suggest that STOs interact more with *goals and objectives* sub-domain of curricular knowledge. These examples present evidence that goals and purposes of science teaching interact with the teachers' curricular knowledge although the interaction seems to be predominantly with specific knowledge sub-domains. This trend will probably continue to be like this until reasons for such are fully exploited. There was no interaction between goals and purposes of science and the curriculum coherence sub-domain as shown in Table 5-1. Perhaps this suggests that it is not possible to observe interactions in all the sub-domains in a few lessons and hence calls for a prolonged stay in the field.

#### *5.1.1.2.* Goals and purposes of science vs knowledge of the students

Teachers' goals and purposes of science teaching interacted with teachers' knowledge of the students as shown in Table 5-1. Even though the teachers had different goals and purposes of science teaching, the way these goals interacted with various sub-domains of this TPK domain were also similar, with minor differences. Data seem to suggest that students' *pre-requisite knowledge* as well as *students' differences* sub-domains interacted with goals and purposes of science teaching more than the other knowledge sub-domain in this category. This is indicative that teachers' plans or instructions are influenced by students' prior knowledge rather than their misconceptions regarding a particular concept. For instance, Mr KA's solid foundation goals and purposes of science teaching interacted with students' prior knowledge. This was exemplified when, on his CoRe about sources of energy, he planned to use questions and answers, brainstorming as well as discussions (pair work) methods to uncover students' existing ideas about the topic of the lesson. According to the teacher, asking about students' prior knowledge is important since "*we base the structure of our lessons depending on what the students already know*". These sentiments give the impression that the teacher acknowledges students' prior knowledge when it comes to teaching and learning of science and that this is the framework upon which the lesson is built. However, during instruction, the teacher tried to build his lesson on students' *previous lessons* rather than *students' prior knowledge*. Although what is learned from the previous lessons forms part of students' prior knowledge, it goes beyond what was covered in the previous lessons and includes what the students know outside the confines of the classroom, what the students learn informally related to the topic under discussion. This, therefore, suggests the teachers' limited understanding of the notion of prior knowledge. This pattern was also observed in all the other teachers when they introduced the lessons. Even though the teacher managed to build his lesson on students' prior knowledge, the teacher deviated from his original plans. Instead of implementing what he had planned on his CoRe, i.e., using question and answer, discussions and brainstorming to retrieve prior knowledge, the teacher only asked the learners to "define energy". This may point to the fact that the teacher wanted to gauge students' understanding of the previous lesson rather than retrieving learners' prior knowledge. This represents a misalignment of the teacher's views and practices (see Chapter 7).

Similarly, Mr MP demonstrated another dimension of the goals and purposes of science

teachings' interaction with the knowledge of students. His *everyday coping* goal of science interacted with students' prior knowledge sub-domain. During instruction, for example, while teaching about power and machines, the teacher asked questions and gave examples that related to students' prior knowledge. These questions or examples were about students' understanding of fundamental phenomena in their everyday lives. He believed that the use of examples, which learners are familiar with, gave them a chance to relate knowledge from what they already know to the unknown as he explained during post-observation interviews:

> *"Students are familiar with these things, but they do not know the principle behind their operation. So, asking them such questions acts as an eye-opener to see the application of the theory in everyday life. Secondly, failure arouses learners' interest towards the concepts such that their attention is captivated and their understanding is maximised" [MP, School 3, POI]*.

The extract below shows what occurred in the classroom during instruction:

| | | | | |
|---|---|---|---|---|
| 1 | - | Teacher | : | So let's look at the types of simple machines. So the first category is force multipliers […] This machine has the duty of multiplying this small load to become a significant force […] lift this massive load. For example, a **car jack** […] |
| 2 | - | Teacher | : | Can somebody try to describe how a car jack works? |
| 3 | - | Student | : | A car jack works by winding [*he demonstrates what he means by winding*] – so there it multiplies the force. |
| 4 | | Teacher | | Now you will see that you will use only one hand – just only one hand whether he is winding or trying to put it up or down. But what comes out of this using just one hand, you will see a car being lifted up. So you see that is why we say this car jack is multiplying the force that you are applying. |
| 5 | | Student | | Listen |
| 6 | | Teacher | | [*having discussed the previous examples at length, the teacher moved to a second example*] … Let's go to the |

| | | |
|---|---|---|
| | | second category – distance multipliers. As the name suggests, there is a movement or some kind of movement … for a movement within a small distance produces movement over a large distance. Do you understand why it is called a distance multiplier? |
| 7 | Students | Yes |
| 8 | Teacher | What do you think can be a good example of a distance multiplier? |
| 9 | Student | Oxcart |
| 10 | Teacher | Not really. But a good example is the bicycle axle. |

MP, School 3, Classroom Observation Transcript

In excerpt number 1, the teacher explained the first (according to the structure of the lesson) type of simple machines. To concretise the discussion, he told the learners that a car jack is an excellent example of a machine in that category. He then asked the learners to describe how a car jack works. He used this example since he was aware that students are more familiar with this than anything else. Eventually, he related students' knowledge about how a car jack works to the new learning. After this, he moved to another type of machine which was the distance multipliers.

He also mentioned a bicycle axle as another example of simple machines that are called distance multipliers (excerpt 10). It was evident that the teacher believed that most students are familiar with this. This observation was further evidenced by the presence of bicycles just outside the classroom. Since this was CDSS (see Table 3-2), most learners commute from their homes to school using bikes which may have prompted the teacher to mention this example. These examples demonstrate how the teachers' goals and purposes, such as *everyday coping*, interact with students' prior knowledge sub-domain. Students' prior knowledge, in this case, is their knowledge about how a car jack or bicycle works. Students might have an idea of how these things work from their everyday life experiences but they might not necessarily link the principles behind the machines to their understanding.

On a different topic, Mr TH's *everyday coping* goal and purpose of science teaching also interacted with students' *prior knowledge*. While teaching about pressure in liquids to the

students, the teacher used learners' prior knowledge to ask a hypothetical question concerning the presence of pressure in liquids:

> *"Alright … there is also another question I would like to learn from you. For example, if you take a dry piece of cassava, right, and then you take that dry cassava into a dish where you have water so you may start dipping somewhere there, and then you leave it. What will happen?" [TH, School 2, Classroom Observation].*

The appropriate answer to this hypothetical question is that a piece of cassava will float on water. The scientific explanation is that a dry piece of cassava's density is less than that of water, so it floats on water. The teacher defended the use of this example by arguing that "*as I was teaching them about density in form two, I used the idea of dry wood floating on water, but now I wanted to use a cassava which is edible and probably most of the students are aware of it*". As a result, he wanted to use a familiar situation for the students to appreciate that there is pressure in liquids. By using everyday examples, he demonstrated to the students the idea that liquid has a pressure that acts on objects immersed in water or any other liquid. Hence teachers' everyday coping goal and purpose of science teaching interacted with students' prior knowledge as it influenced the questions asked by the teacher.

Mr PH's correct explanation goal and purpose of science teaching also interacted with students' prior knowledge. While teaching about electrical energy, which is a sub-topic of electricity and magnetism, he asked students to brainstorm the meaning of electrical energy in pairs. He encouraged the learners to give as many examples as possible that suggested that the teacher wanted to learn more about students' understanding of the concept of electrical energy. He recorded students' discussions on the chalkboard. Later, he used students' prior knowledge to build his lesson. He discussed each contribution of the students by focusing on the strengths and weaknesses of what the students had presented. Using a definition from a book, he then consolidated students' ideas. These examples show how teachers' goals and purposes of science teaching influence teachers' decisions concerning the knowledge of the students. Even though misconceptions are part of students' prior knowledge, no teacher specifically asked questions aimed at eliciting these misconceptions.

### *5.1.1.3.* Goals and purposes of science vs pedagogical knowledge

The teachers' goals and purposes of science teaching also interacted with teachers' pedagogical knowledge sub-domains. In this category, the interaction between goals and purposes of science teaching and *instruction strategies* sub-domain was dominant, as shown in Table 5-1, with no interactions observed with other sub-domains for this category of TPK. For instance, Mr KA held *solid foundation* as well as *structure of science* beliefs about goals and purposes of science during instruction (as shown in Chapter 4). These beliefs interacted with *instructional strategies* sub-domain of pedagogical knowledge. Concerning his *solid foundation* goal, on his CoRe about electricity and electric current, the teacher planned to use a variety of teaching strategies, especially classroom discussions, as well as practical work. During instruction, these were interspaced with teachers' explanations—lecture method to make sure that students had a comprehensive understanding of the concepts. According to the teacher, the use of a variety of teaching strategies enhances or maximises students' retention of concepts which eventually ensures that they have a solid foundation.

Similarly, regarding the *structure of science*, the teacher "implicitly" wanted to demonstrate to the students how science is done. I have used the term implicit since the teacher did not make it explicit, i.e., by deliberately including objectives to do with the structure of science/NoS. However, there is evidence in the literature that the inclusion of practical work where learners interact with the materials implicitly helps learners to understand some aspects concerning the NoS. Nonetheless, during instruction, instead of practical work, the teacher used a "demonstration"—a deviation from the teacher's planned work. When asked about his decision to use a demonstration rather than practical work as initially planned, he explained:

> *"I wanted the students there to be able to see as we are constructing the circuit. I wanted the students to have a picture of how I am connecting this. And also since we do not have enough material, so I thought that one station with one circuit there was possible – as I still more wanted the learners to be able to see how circuits are connected. Even though the group was too large, that's why I was calling them in small groups to come and observe what was happening" [KA, School 1, POI].*

Further evidence about a *solid foundation* goal interacting with *instructional strategies* was observed from Mr MP while he was teaching about power and machines. On his CoRe, he

planned to use a variety of teaching strategies, such questions and answers, demonstrations as well as the lecture method. He justified his choice for each instructional approach that he had planned to use. For instance, he planned to use questions and answers "to check their reasoning", explanations to "clarify concepts in application" and demonstrations and discussions "to set an example for the learners and share ideas". Even though the teacher had planned to use a variety of teaching strategies as indicated on his CoRe, he exclusively used the lecture method of teaching during instruction. When I asked why he had opted to use the lecture method rather than what he initially planned, he argued that:

> *"There was a need for clarity in some issues and that area required a bit more of lecturing so that they should be at least clarification of some concept, for example, the force meter what are these, how do they work? After explaining (teacher explanation), now you may invite the leaners, after giving them one problem or may be one example, they can now participate by giving other examples on their own" [MP, School 3, POI].*

On the other hand, Mr NG's three goals and purposes of science teaching (*solid foundation, structure of science* as well as *scientific skills development*) all interacted with *instructional strategies* similarly as above. He planned to use a variety of teaching strategies to support differentiation. Just like Mr KA, he used practical work to teach the students about the *structure of science* implicitly. Furthermore, practical work was also used to make sure that students learnt about the various scientific investigation skills, such as observation, measurements, etc. He argued that the use of practical work helps the students develop scientific investigation skills. Hence, they have an idea of how science is conducted. This observation was also noted from Mr TH during instruction. While others used hands-on practical work as a way of engaging students, Mr TH used hypothetical questions to engage students' minds-on, as already discussed.

#### *5.1.1.4.* Goals and purposes of science vs assessment knowledge

The teachers' goals and purposes of science teaching also interacted with various sub-domains of assessment knowledge. In the literature review (see Table 2-2), I showed that the assessment knowledge domain has several sub-domains such as *what to assess, reasons for assessment*, etc. In Table 5-1, teachers' goals (though different from teacher to teacher) interacted mainly with *what to assess* as well as the *method of assessment* sub-domains of this assessment

knowledge domain. These goals and purposes informed the teachers' decisions concerning what to assess as well as methods of carrying out the assessment. For instance, data from classroom observations suggest that the teachers who took part in this study tailored students' assessments to what the students had learnt in line with the objectives of the lesson (*what to assess*) as shown in the extracts below. Furthermore, these teachers also articulated how they planned to conduct this assessment. On their CoRes, as well as from the classroom observation data, the question and answer technique (*method of assessment*) seemed to be the dominant method of carrying out students' assessments. A case in point is that of Mr PH whose *solid foundation* goal and purpose of science teaching influenced how and what to assess during instruction. The teacher relied on asking questions (*method of assessment*) to assess students' understanding.

The nature of assessment was aligned to the objectives of the lesson (*what to assess*). At this point, the teacher gave the impression that he was only interested in whether the students' answers were correct. For example, when he was teaching about electric energy, after explaining an example on how to solve mathematical problems related to electric energy, towards the end of the lesson, the teacher asked students if they had any questions. This suggested that the teacher wanted to find out to what extent students understood what he was teaching. Excerpt 1 below demonstrates this. When there was total silence, the teacher took this to mean students had understood. This is probably the reason he said: "*Your understanding will be demonstrated by correctly answering the following question*" (which he had written on the board) as shown in excerpt number 3. In the course of explaining the problem to the learners, the teacher also emphasised three equations he had derived to be used, as shown in excerpt 5. This suggests an interaction between the teacher's goal and purpose of science teaching: *correct explanation* and *curricular knowledge* in *what to assess* sub-domain. The mode of assessment was through questions and answers which the teacher had stated in his CoRe that he prepared for this topic.

| | | | | |
|---|---|---|---|---|
| 1 | - | Teacher | : | Do you have any question? |
| 2 | - | Student[s] | : | No |
| 3 | - | Teacher | : | So if there are no questions, you will show that by answering this question |

4 - Student[s] : *Students listen*

5 - Teacher : So remember, these equations are three; this one, this one and this one [*as he points at the three equations on the board*]. But sometimes you are not given straightforward; they can give you the information and tell you: can you find *I* – the current? So you must make *I* in this equation the subject of the formula. So you must be able to make everything they ask you subject of the formula.

6 - Teacher : *Writes down the problem on the board for the students to do*

7 - Teacher : *Students solve the problem written on the board*

[PH, School 2, Classroom Observation].

NG's scientific skills development goal influenced his assessment decisions. This goal appeared to have interacted with *methods of assessment* sub-domain of assessment knowledge. His lesson on electricity and magnetism, which is a sub-topic under electricity, provided the evidence for this. Having explained the various methods of magnetisation, the teacher asked the students, as homework, to go into the library to read and write an essay/report on the remaining ways of magnetising a substance as shown in the following transcripts:

1 - Teacher : Now let's do this, there are different "methodologies" [*methods*] of charging … well magnetising substances. …

2 - Students : *All students listen attentively*

3 - Teacher : This one [*points at the stroking method which he had explained to the students*] is an example of those methodologies, stroking, there was a mention of the electrical method, and then you talked about the induced ones all those, so I have just explained the

stroking method.

| | | | | |
|---|---|---|---|---|
| 4 | - | Student[s] | : | [*Some students node in agreement* ] |
| 5 | - | Teacher | : | What I want you to do is that you should document the other strategies of magnetising substances, write them … I mean to explain the methodology. You should come up with the method, and then explain how it works … all the methods should be documented and then bring the copies to me so that I mark them. Can you do that by tomorrow? |
| 6 | - | Student[s] | : | *Students take down the major points of the task* |
| 7 | - | Teacher | : | Is it possible to do that? |
| 8 | - | Student[s] | : | Yes |

[NG, School 3, Classroom Observation]

In excerpt 3, the teacher tells the students that he has only explained one way of magnetising substances (stroking method). He acknowledges that, even though the students mentioned electrical methods of magnetising materials, etc., what he has done this far is to explain only one method. In excerpt 5 he, therefore, asks the learners to go and read about other ways in the library and document all those other methods. They are expected to produce a report at the end of this exercise. In this, the teacher has used homework as a mode of assessment at the same time he is also teaching about scientific skills.

#### *5.1.1.5.* Goals and purposes of science vs content knowledge

Data show that goals and purposes of science teaching interacted with content knowledge sub-components. Goals and purposes of science teaching seem to have influenced teachers' decisions concerning content knowledge. From Table 5-1, the sub-domain, *core ideas*, which included things like *facts, concepts, principles, theories, laws,* etc. interacted more with the teachers' various goals and purposes of science teaching. For example, Mr KA had his goals and purposes of science as a *solid foundation* as well as the *structure of science*. Both of these interacted with *core ideas* sub-domain of content knowledge. Specifically, his *structure of science* goal interacted with the practices for scientific knowledge generation sub-domain. Due

to the "*abstractness of the concepts … electrons cannot be seen flowing*", Mr KA decided that the best way of making these concepts more accessible to students was to embed practical work within the lesson. According to the teacher, "*practical work helps the learners to remember things since they interact with the materials*". However, due to a shortage of materials, the teacher deviated from the planned routine as already highlighted above. Instead of having practical work where all learners could get hands-on involvement, he resorted to doing a demonstration. What was important from the teacher's perspective at this point was enhancing the retention of the concepts. This view might have influenced the teachers' pedagogical practice to adopt a demonstration.

The practice of science requires that students are actively involved in the process of scientific knowledge generation through the following: (1) asking questions and defining problems; (2) developing and using models; (3) planning and carrying out investigations; (4) analysing and interpreting data. In this case, his goals and purposes of science teaching, *solid foundation* as well as *structure of science*, interacted with the practices in scientific knowledge generation sub-domain of content knowledge. Practical work, in this case, served to achieve his two goals about science teaching.

Mr NG's goal and purpose of science teaching, *scientific skills development*, interacted with this (practices of scientific knowledge generation) sub-domain. In the lesson where he taught about electrical resistance, the teacher structured the lesson in such a way that students were tasked to carry out practical work to determine the behaviour or resistance in both types of circuits. Normally practical work[s] are supposed to follow the basic approach in scientific knowledge generation as outlined above. However, there may be several modifications to that depending on what the teacher wants to emphasise. The extract below shows what transpired during instruction:

| | | | | |
|---|---|---|---|---|
| 1 | - | Teacher | : | … Now what will happen is that you will be in groups. Depending on the materials, we will have two groups … |
| 2 | - | Students | : | *Students rearrange themselves in groups* |
| 3 | - | Teacher | : | I want you to have the two kinds of circuits … the series … the parallel circuit. So in series circuit, what you are going to have is the cells like this [*points at a circuit drawn on the board*]. |

4 - Students : *Students listen attentively for instruction*

5 - Teacher : What is the behaviour of current in the series circuit?

6 - Student : Current is the same at any point in series circuit [*repeats what the student had said*].

7 - Teacher : Therefore we should check that at any point; current is the same in this circuit.

8 - Student[s] : *Students nod in agreement*

9 - Teacher : Now, let's have representatives from each group – from group 1 and group 2 give us the values. Can I have the values for the first part in series circuit? What do we have? You can come here and write. Can you do it fast?

10 - Student[s] : *Students write down their findings*

11 - Teacher : Ok, can we have results or the other group? Can you do it quickly?

12 - Student[s] : *The other group present their results*

13 - Teacher : What can you say about the total resistance in series now? What can you say in the form of a conclusion about the total resistance? What would you say about the behaviour of resistors in series? If you say they are the same – look at this problem R1 is 1 Ohm and R2 is 11 Ohms, are they the same? But they are in series

[*teacher asks questions based on the practical work the students had just carried out*]

In excerpt 1, after the teacher had retrieved students' prior knowledge, based on the previous lesson, the teacher put the students in groups to conduct practical work where they would determine the behaviour of electrical resistance in series and parallel circuits. Before the students started doing the practical work, he asked the students to recall from theory the behaviour of electrical resistance as in excerpt 5. While the expectation was that students will be tasked to define the problem, for investigation as well as other processes of knowledge generation in science, the teacher used another approach where the emphasis was on students doing the actual practical work with already defined problem and procedures. This is why soon after he has retrieved students' prior knowledge, the teacher asked them to conduct the practical work. After students had finished taking measurements, he asked the group representatives to

report their findings in excerpts 9 and 11. Towards the end, he asked students to use their results to comment on the behaviour of electrical resistance in a series circuit. This extract is a typical example of an interaction between goals and purposes of science teaching and content knowledge sub-domains. From the practical work, students learnt the various scientific skills, such as observation, measurement skills, etc., which are imperative for the teaching and learning of science. Furthermore, an interaction between goals and purposes of science teaching and cross-cutting issues sub-domain of content knowledge was also observed as reported in section 5.1.1.1.

### 5.1.2. Beliefs about teaching and learning of science and TPK domains

Analysis of both CoRes and classroom observation data shows that beliefs about teaching and learning of science interacted with various TPK domains as shown in Table 5-2. In the following sections, I present the findings concerning the interaction between beliefs about teaching and learning of science and TPK. In Chapter 4, I showed that the teachers' beliefs about teaching and learning of science varied from teacher to teacher, however, the nature of interaction seems to be mostly uniform as observed from the various interactions.

#### 5.1.2.1. Teaching and learning of science vs curricular knowledge

Present data suggest that the various beliefs about teaching and learning of science that the participating teachers held interact with curricular knowledge. Even though, as shown in Chapter 4, these teachers have different beliefs about teaching and learning of science, an idiosyncratic pattern of interaction was observed. For instance, all the teachers' beliefs about teaching and learning of science regarding knowing what to and what not to teach interacted with goals and objectives sub-domain of curricular knowledge. Despite teachers having different beliefs about this aspect, what was clear is that their beliefs about this influenced teachers' decisions regarding curricular knowledge. For example, Mr KA's traditional beliefs concerning knowing what to teach during instruction interacted with *goals and objectives* sub-domain of curriculum knowledge. This teacher tended to follow the curriculum document (objectives) step-by-step. While this might show that there is little creativity on the part of the teacher[s] in terms of how the curriculum (especially the sequence of the curriculum as well as objectives) can be restructured to suit the context, the teachers offered an explanation as previously shown in the above sections. Furthermore, the source for such orientations were

traced to how the teachers were oriented on the implementation of the new science curriculum. They claimed that during curriculum orientation, they were told to follow the objectives as they appear in the curriculum for uniformity purposes. Nevertheless, these traditional beliefs were reflected in all the lessons that I observed for this teacher. The teacher's lesson objectives were all taken directly from the curricular document. While this objective could have further been broken down into two i.e. *discussing the sources of energy, classifying the sources of energy into renewable and non-renewable*, there were no modifications (concerning the formulation of the objectives) that the teacher made to suit the context as he argued: "*mostly we are bound by what the curriculum demands of them*". On his CoRe about energy, the teacher planned to achieve the following objectives with his students:

- Identify the different sources of energy

This objective comes directly from the curriculum in use at that particular time. The teacher assumed that, if he teaches his students what the curriculum required, they will have an excellent foundation to do science courses in the future. Even though the teachers explained why such is the case, this pattern of following the curriculum to the letter was observed in all the teachers who took part in the study. The pattern is illustrative of how teachers' orientations influence the kinds of decisions that they make concerning curriculum knowledge.

Similarly, an interaction between beliefs about what to teach and linkages to other topics was also observed. This was detected when Mr MP, a teacher at school 3, taught about specific heat capacity. He made links to the topic "*change of subject of the formula topic in mathematics*" which he reviewed to give the learners an understanding of how changing the subject of the formula is done.

No interaction was observed between beliefs about teaching and learning of science and scope and sequence as well as curriculum coherence.

**Table 5-2: Interaction between beliefs about teaching and learning of science and TPK**

| | | Beliefs about teaching and learning of science | | | | |
|---|---|---|---|---|---|---|
| **TPK Domain** | TPK sub-domain | **KA** | **PH** | **TH** | **NG** | **MP** |
| **Assessment Knowledge** | What to assess | + | + | | | + |
| | Reasons for assessment | | | | | |
| | Methods of assessment | | | | + | + |
| **Pedagogical knowledge** | Classroom management | | | | | |
| | students engagement | | | | | |
| | Instruction strategies supporting differentiation | + | + | + | + | + |
| **Knowledge of students** | Students' differences | | + | + | | + |
| | Pre-requisite knowledge | + | | + | + | + |
| | Misconceptions | | | | | |
| **Curriculum Knowledge** | goals & objective | + | + | + | + | + |
| | Scope and sequence | | | | | |
| | curriculum coherence | | | | | |
| | Linkage to other topics | | | | | + |
| **Content Knowledge** | Practices for scientific knowledge generation | + | | | | |
| | Core ideas (facts, concepts, principles, theories) | | + | + | + | + |
| | Cross-cutting issue | | | | | |

### 5.1.2.2. Teaching and learning of science vs knowledge of the students

Knowledge of students has several sub-domains such as *students' differences, pre-requisite knowledge* and *students'* misconceptions as highlighted in Chapter 2. Present data show that there was a lot of interaction between beliefs about teaching and learning of science and students' *pre-requisite knowledge* as well as *students' differences* sub-domains as shown in

Table 5-2. There were no interactions observed between beliefs about teaching and learning of science and students' misconceptions. For instance, Mr MP's beliefs about teaching and learning of science interacted with *students' prior knowledge*. As a way of maximising students' learning during instruction, on his CoRe about specific heat capacity, he planned to ask the following questions to establish students' existing knowledge about the topic:

1. *Asking learners to recall the basic units involved*
2. *Asking learners some obvious phenomena such as why a frying pan is made of an insulator*

From the two questions above, it appears that the teacher believes that learning proceeds from experience and therefore he based his lesson on *learners' prior knowledge*. Unlike the other teachers who showed a limited understanding of what prior knowledge (***especially during instruction***) is, this teacher demonstrated on his CoRe that his understanding of prior knowledge goes beyond what the students learnt in the previous lessons. This is illustrated by the fact that he included question number 2 as shown above.

In task 1, the teacher was aware that the nature of the topic is mathematical hence he wanted to have an understanding of how much students already know about the basic units of measurements, such as temperature, mass, etc. He linked this to the new learning where students will be performing different calculations about the specific heat capacity of substances, and they need to present the information in the correct units of measurements. In task 2, the teacher wanted to establish if students were aware that it takes more heat energy to raise the temperature of wood than metal since insulators, such as wood, has a higher specific heat capacity than metal. This relates to students' *prior knowledge* which the teacher felt was relevant for this lesson. These are illustrative of how teachers' beliefs about teaching and learning of science and ways of maximising students' learning influence teachers' knowledge of students' prior knowledge. Even though the teacher seemed to have a comprehensive understanding of what prior knowledge is, as indicated on his CoRe, however, like the rest of the teachers who took part in this study, prior knowledge seemed to be limited to what students had learnt in the previous lessons as shown in the extract below:

1 - Teacher : Last time we were looking at heat capacity … specific heat capacity in terms of definition, so let's just remind

ourselves on the definition of these

2 - Student[s] : *Students answer the question and listen attentively*

3 - Teacher : Ok – what are the basic units of the following: *Mass, temperature, heat energy*?

4 - Student[s] : Mass = Kilograms, Temperature = Kelvins, Heat energy = Joules

5 - Teacher : What is heat capacity?

6 - Student[s] : It is the amount of energy required to raise the temperature by 1kg [*his fellow students laughs the moment he said by* 1kg]

7 - Teacher : [*after asking further probing questions they agree*] …What about specific heat capacity? What is it? Specific heat capacity?

8 - Student[s] : This is the amount of energy that is required to raise the temperature of a substance of 1Kg by 1K

9 - Teacher : … So that's what we did last time, but today … we are going to do some calculations on how these things are calculated. We are talking of the amount of energy required – so how do we calculate these things?

[MP, School 3, Classroom Observation]

The extract above is from the specific heat capacity lesson that the teacher delivered. As a way of retrieving prior knowledge from the students, the teacher relied on the question and answer technique. The nature of questions, as can be seen from the above extract (from excerpts 1 through 7), focused on what students had covered in the previous lessons. However, there was one question in excerpt 3 from Mathematics which seem to gauge students' mathematical knowledge or abilities.

On the other hand, the teacher did not ask one of the questions, "*why is a frying pan made of an insulator*?" that he had prepared on his CoRe. This represents a deviation from his original plans. When I asked him why he had omitted the question, he argued that "… *you know, the topic of specific heat capacity is long, you cannot cover it in a single 30 minutes' period. Hence,*

*that prior knowledge question [the second question on his CoRe], I am going to ask in the next lessons' introduction*".

An interaction between teachers' beliefs about teaching and learning of science and *students' differences* sub-domain of knowledge of students was observed. Data seem to suggest that teachers who took part in the study were aware that their classes consisted of learners of different abilities, as they articulated during interviews. This, they argued, is a challenge as learners have different needs which must be addressed in the course of instruction. Hence, their beliefs about students' learning influenced their decisions concerning the knowledge of students. Specifically, their beliefs about students' best ways of learning science interacted with *students' differences* sub-domain of knowledge of students. For instance, Mr KA acknowledged that "*sometimes it's challenging to teach the fast, slow learners in the same class session within the limited class period*." By talking about slow and fast learners, the teacher is acknowledging the existence of a different range of students in a class that need special attention. To mitigate this, he planned to use a variety of teaching strategies as a way of helping these learners of different abilities. For example, in the lesson where he was teaching about electric current, he planned to use practical work, the lecture method, questions and answers, etc. He argued that practical work would be used so that "*students should easily establish a link between theory and practical aspect of the lesson*". While questions and answers will "*help students to participate in the lesson actively*". On the other hand, he also stated on his CoRe that teacher explanation (lecture method) helps "*to simplify some concepts so that students grasp the ideas easily*". This is evidence on how teachers' beliefs about teaching and learning of science interacted with their knowledge of the students to influence their decisions.

#### 5.1.2.3. Teaching and learning of science vs pedagogical knowledge

Under Pedagogical Knowledge, the following are some of the sub-domains: *classroom management, students' engagement* and *instruction strategies* as shown in Chapter 2. Instructional strategies are of two kinds: those that support differentiation where a teacher acknowledges that students are different and deliberately modifies the instructional strategies to support the needs of the learners, and those that do not support differentiation which are teacher-centred. Present data strongly suggest that the beliefs that the five teachers have about

teaching and learning of science influence teachers' decisions regarding their pedagogical knowledge. Specifically, teachers' beliefs about maximising students' learning interacted mostly with *instructional strategies* sub-domain of pedagogical knowledge as shown in Table 5-2. There was no interaction between teachers' beliefs and *students' engagement* as well as *classroom management* sub-domains. Interview data suggest that, in their professional duties, these teachers, as already shown above, are aware of the students' differences in their respective classrooms. For instance, when asked to describe how they would maximise students' learning of science in their class, one of the teachers argued that there is a need to vary instruction since:

> *"... you are dealing with a variety of learners; they learn differently, and they also have different paces of getting things, understanding things. So if you vary your methods, then you are able, at least, to incorporate all the students or most of the learners" [MP, School 3, Interview Transcript].*

The above quote suggests that using different instructional strategies cater for the needs of all the learners during instruction. This belief is widely supported in the literature and contemporary methods of teaching science emphasise this. Differentiated classrooms bring forth different challenges concerning the structuring of instruction. Mr TH, who held transitional beliefs concerning maximising students' learning, acknowledged the problems of teaching students of different backgrounds. Therefore, on his CoRe, he planned to use the POE teaching strategy. POE, developed by Gunstone & White (1992), is an acronym for Predict, Observe, Explain to reveal a students' prediction and a reason for their forecast concerning a phenomenon. He planned to ask the students to predict what would happen to the *mass* (both reactants and products) when atoms combine and that they should also offer an explanation. Through the use of this strategy, the teacher was able to engage the learners in the thinking process as shown in the extract below:

| | | | | |
|---|---|---|---|---|
| 1 | - | Teacher | : | If the reactants form a new product like this one [*points at a chemical equation on the board*] … do we expect the mass of the reactants to be different from those of the products? |
| 2 | - | Students | : | Yes [*Students responded*] |
| 3 | - | Teacher | : | A chemical reaction is the rearrangement of atoms to form a new substance. Here we have reactants and, of |

course, products. Now, if a new substance is formed, is the mass of reactants different from the mass of products? [*teacher tries to rephrase the question so that students understands it*]

4 - Student : Yes, it is different? [*one students responds*]

5 - Teacher : Who else? Are they different? Why do you think the mass of reactants will be different from the mass of the products?

6 - Student : Yes. Because they have rearranged themselves to form a new substance

7 - Teacher : In fact, during a chemical reaction, no atoms are formed, and also no single atom is destroyed

[TH, School 2, Interview Transcript].

In excerpt 1, the teacher wants the students to predict whether the mass of the reactants and products will be the same or different after the reaction to which most students said, "*yes they will be different since there is a formation of new substances*". At this stage, the teacher expected that students would say the masses of both products and reactants will be the same according to the law of conservation of matter. He was going to teach the students but which he briefly stated in excerpt 7, that matter is never created or destroyed. This is the "predict" stage. At the same time, the teacher pointed at the "chemical reaction equation" on the board so that students should make an **observation**, especially regarding the atoms in both the reactant and product. Noting a misconception, "*masses of reactants and products will be different"*, the teacher rephrased the question as demonstrated in excerpt 3 to which the students still maintained that their masses (reactants and products) would be a different response. Even though students seemed to have a misconception, in excerpt 5, the teacher still wanted the students to explain why they think the masses will be different. This is done to understand their source of misconceptions and think of the best way of addressing them. This is the **explanation** phase of the instruction strategy he planned to use.

Apart from that, the teacher also planned to use cooperative learning [group work] where students could solve a problem together. Traces of the lecture method of teaching were also

observed during instruction particularly when he was introducing a concept or when he was clarifying the concept. This integration of instructional strategies (lecture, cooperative learning, POE) is a typical example of an interaction between teachers' beliefs about teaching and learning of science with *instructional strategies* that support the differentiation sub-domain of pedagogical knowledge.

Interactions between teachers' beliefs about teaching and learning of science with instructional strategies that do not support differentiation were also observed. One teacher, for instance, held instructive teacher-centred beliefs about maximising students' learning that influenced his decisions regarding the nature of instruction. His traditional beliefs regarding students' learning were evident from the nature of instruction he presented. In all the lessons that I observed for this teacher, he dominated the teaching and learning process. Simple question and answer techniques and lecture methods were characteristic of his lessons. There were no activities planned for the students to facilitate the teaching and learning process. As a result, students' involvement in the learning process was limited to the simple questions the teacher asked. The extract below, on the topic of *electric current and electric energy,* is a typical example of how the lessons that I observed for this teacher progressed:

| | | | | |
|---|---|---|---|---|
| 1 | - | Teacher | : | What is energy? ... Because we are talking about electrical energy [*teacher seem to be reminding the students that even though he has asked this question, their focus is on electrical energy*] |
| 2 | - | Student | : | Energy is the ability to do work |
| 3 | - | Teacher | : | And what is work in science? Is it farming 20 ridges per minute? |
| 4 | - | Student | : | No [*one student answers*] |
| 5 | - | Teacher | : | Work in science means what? |
| 6 | - | Student | : | Force and what distance? [*student not sure*] |
| 7 | - | Teacher | : | Where there is force … product of force and distance, that's when or sometimes known as work done |
| 8 | - | Students | : | *Students listen* |
| 9 | - | Teacher | : | So, in short, where there is work done, where you can do something, that's the ability to do something is what is called energy. |

10 - Students : *Students listen*

11 - Teacher : And energy comes in various forms – including which forms of energy do you know? These forms of energy – heat energy … electrical energy that we want to define. And what? Even magnetic energy, electromagnetic energy

12 - Students : *Students listen*

13 - Teacher : All right, so as we can see, energy, electrical energy, it can be defined in several ways. There are several ways how we can define electrical energy. Electrical energy can be observed in several phenomena, or some are seen where there is the flow of current. If there is a flow of current in a circuit, then we can say there is electrical energy.

14 - Students : *Students listen*

15 - Teacher : Even in static electricity that we are starting there was energy because something was happening in lightning

[PH, School 2, Interview Transcript].

In excerpt 1, the teacher tried to define the concept of electrical energy for the students. He wanted to use students' prior knowledge hence his decision to ask the student to define energy. From excerpt 1 through 5, the teacher interacted with the students by asking simple questions. However, the teacher's dominance of the learning process is visible from excerpts 7 through 15. This is where the teacher is seen lecturing, telling students what they are supposed to learn. During this time, the task of the students was reduced to listening to the teacher's talk. Teacher dominance, as well as minimal or no students' engagement in the learning process, are typical characteristics of the lecture method of teaching. All these characteristics are reflective of the instructive, teacher-centred beliefs the teacher held regarding maximising students' learning of science in class. This shows an interaction between the teacher's beliefs about teaching and learning of science and pedagogical knowledge.

#### 5.1.2.4. Teaching and learning of science vs assessment knowledge

An analysis of classroom observations and teachers' CoRes indicates that teachers' beliefs

about teaching and learning of science interact with various sub-domains of teachers' assessment knowledge. In Chapter 4, I showed that teachers rely on various ways of establishing whether students understand the content of the lesson. The process of doing this, which was evident during instruction, takes place both during the lesson or after the lesson (summative assessment) which mostly happens towards the end of the term. For this aspect, teachers' beliefs about teaching and learning of science seem to influence the nature of decisions teachers make concerning students' assessments. For instance, Mr PH who held traditional, teacher-centred beliefs, knows when learning is occurring in the classroom from the way he structured his assessment. The teacher's interest in assessment seems to be focused on "order" and "how attentive" the students were during instruction. In the lessons that I observed for this teacher, he tended to ask learners questions that were closely aligned to the objectives of the lesson. In the first lesson on electromagnetism, the teacher asked: "Any questions at this point? So, when we meet, we are going to look at the laws for electromagnetism". After noting that there were no questions, he said, "This marks the end of our lesson". Similarly, the following also took place in the classroom when he was teaching about electrical energy and power:

1 - Teacher : Do you have questions?

2 - Student[s] : *Silence from the students*

3 - Teacher : So if there are no questions, you will show that by answering this question

4 - Student[s] : *Students copy down the notes*

5 - Teacher : So remember these equations are three, this one, this one and this one. But sometimes you are not given straightforward; they can give you the information and tell you can 'you find I – the current?' So you must make I in this equation the subject of the formula. So you must be able to make everything they ask you subject of the formula

6 - Student[s] : *Students listen attentively*

*[PH, School 2, classroom observation]*

Towards the end, the teacher wanted to establish whether students understood. In excerpt 1,

the teacher appeared to be asking the students if they had any questions on what they had just learnt. Having noticed that there was no response from the students, he interpreted that as an understanding of the lesson. Excerpt 2 presents this evidence where the teacher says: "You will show this understanding by answering the following question" which he had written on the board. To make sure that students got it right, he proceeded by giving them a hint as shown in excerpt 5 on how to solve problems on such a topic.

Similarly, Mr MP's traditional beliefs about establishing students' understanding of the content interacted with the *methods of assessment* sub-domain. He used both questions and exercises as a way of assessing the students' understanding. On his CoRe, for instance, he planned, as a way of ascertaining students' understanding, to ask students to "distinguish" heat, temperature, heat capacity as well as specific heat capacity from one another. Apart from that, he also planned to ask the learners to explain "*why mercury is used in thermometers rather than water*". This, according to him, ensures that students have understood the concept of specific heat capacity and its applications. However, his assessment decisions were influenced by his traditional beliefs concerning how he establishes students' knowledge of the material. For instance, the nature of the assessment that he gave the students only focused on determining whether students were attentive to his lectures. As a result, the exercise, which he gave the students towards the end of the lesson, was very similar to the example he had just given the students. He also spent a lot of time emphasising the need for the learners to change the subject of the formula so that they get everything right as shown in the excerpts below.

1 - Teacher : Right so that's the answer – that's the specific heat capacity – that's how we obtained that. So you can now look at this. Let me give you another sum so that now you can tackle it on your own [*writes down an exercise on the board*].

2 - Student[s] : *Students do the problem…*

3 - Teacher : Ok I have observed that some of you are about to finish, I have forgotten my red pen, someone with a red pen, please? So that I should start marking

4 - Student[s] : *Students go to get their solutions checked*

5 - Teacher : Yeah, those that have finished marking, they can bring here so that … we can mark their exercise

6 - Student[s] :

7 - Teacher : Yeah, I have noted that some of you are having problems … look here, we are saying c equals Q over the change in temperature multiplied by mass. So, in this question, we are given this one c. We are also given mass, and we are also given change in temperature so what was required to find is Q. Ok so how are we going to find Q? in this case, we are going to take this one and multiply it with *c*, you get that point? Yeah that's how you will find Q. take the denominator and multiply it this side

These examples show how teachers beliefs about the teaching and learning of science interact with the various sub-domains of TPK.

### 5.2. Teachers' beliefs about nature of science do not interact with TPK domains.

Present data suggest that teachers' beliefs about the nature of science do not interact with TPK domains. This is because even though the teachers appeared to have sophisticated beliefs about the nature of science, as shown in chapter 4, they did not explicitly include any nature of science objective in their lessons. Even though other studies still contend that the fact students may learn about nature of science implicitly, most studies on nature of science call for explicit inclusion of nature of science beliefs in the teaching and learning process. Present data further suggests that teachers' beliefs about the nature of science will only interact with TPK domains only if the teachers are teaching the actual nature of science topic. While I have briefly explored some reasons for this observation in chapter 4, I discuss this observation in chapter 7.

### 5.3. Summary

In this chapter, I presented the findings concerning the second research question regarding the interaction between teachers' teaching orientations and teacher professional knowledge domains. Data analysis showed that STOs interact with TPK domains by actively engaging with various sub-domains of TPK, i.e., by influencing these sub-domains during teacher planning or instruction. These interactions were illustrated through the following three assertions: first, goals and purposes of science teaching interact with TPK, secondly, teachers'

beliefs about teaching and learning of science interact with TPK domains and, last, teachers' beliefs about the NoS do not interact with TPK domains unless teachers are teaching the actual topic of NoS.

Concerning teachers' goals and purposes of science teaching, data show that the teachers' multiple beliefs interact with various sub-domains both during lesson preparation and instruction. These interactions were manifested in various ways as illustrated in the chapter. Concerning teachers' beliefs about teaching and learning of science, it was observed that the various beliefs on the TBI influenced or interacted with the various sub-domains of TPK. Concerning teachers' beliefs about the NoS, it was observed that, even though the teachers had sophisticated beliefs about the NoS, their beliefs did not interact with any of the sub-domains of TPK. This was rather unexpected since the teachers were much more experienced and demonstrated to have sophisticated beliefs about the NoS. I discuss these findings in Chapter 7.

# CHAPTER 6. INSIGHTS LEARNT FROM THE INTERACTION BETWEEN STOs AND TPK DOMAINS

## 6.1. Introduction

In Chapters 4 and 5, I presented the findings of this study about the teachers' STOs and the interaction between STOs and TPK domains, respectively. The findings in these two chapters addressed the first two research questions: "What beliefs or teaching orientations about the nature of science; teaching and learning of science; goals and purposes of science teaching do experienced Malawian Physical science teachers have?" And, "To what extent do their STOs influence the enactment of TPK domains?" respectively.

In this chapter, therefore, I offer a synthesis of lessons that I learnt from understanding the interactions between STOs and TPK domains. These insights address the third research question for this study – "what insights do we learn from the understanding of the interaction between STOs and TPK domains?" In Chapters 1 and 2, I explained that STOs, according to Friedrichsen et al. (2011) are defined in terms of the three dimensions: *goals and purposes of science teaching, beliefs about nature of science and teachers' beliefs about teaching and learning of science.* Hence the presentation of these insights in this chapter follows a similar pattern as the two previous chapters. This chapter presents the insights concerning: (i) teachers' beliefs about the goals and purposes of science learning; (ii) teachers' beliefs about teaching and learning of science; and (iii) teachers' beliefs about the NoS dimensions. I have divided this chapter into four sections that correspond to the three dimensions above as well as a section concerning insights on the interaction between STOs and TPK domains. I give supporting evidence to substantiate my claims and I close the chapter with a summary of the contents.

## 6.2. Insights about teachers' goals and purposes of science teaching

Concerning the goals and purposes of science teaching, insights include (i) the teachers' multiple goals and purposes of science teaching; (ii) dominant and non-dominant goals; and (iii) goals being aligned to the grade level a teacher is teaching.

### 6.2.1. Multiple goals and purposes of science teaching

Data for this study show that the teachers who took part in this study had multiple goals and purposes of science teaching while teaching a particular topic. This trend was observed in all the teachers who took part in this study, as shown in Table 4-1 in Chapter 4. These goals and purposes of science teaching interacted with various TPK domains both during instruction as well as during lesson planning, as shown and described in Chapter 5 of this research report.

### 6.2.2. Dominant and auxiliary goals and purposes of science teaching

Another insight that I observed concerns the issue of dominant vs auxiliary goals and purposes of science teaching. An analysis of the data, especially from classroom observations, post-observation interviews and CoRes, revealed that, among these multiple goals and purposes of science teaching, some appeared to be more dominant. Dominance, in this case, means that some goals and purposes had more control over the decisions the teacher made during instruction. For instance, goals such as *everyday coping*, *solid foundation*, as well as *correct explanation*, appeared to drive the instructional process for the teachers. An example is Mr TH who, during instruction, had *everyday coping* as one of his many goals for science teaching. When he taught about pressure in liquids, he structured the lesson so that most of the lesson was dominated by examples of everyday coping. As seen in the extract in Chapter 5, the teacher tended to ask questions that appeared to test students' familiarity with everyday life phenomena. This kind of teaching was not only observed during instruction, but it was also reflected on his CoRes. Hence, everyday coping not only dominated the decisions the teacher made, but it also controlled the whole structure of the lesson in terms of the questions to ask, the representations to use, the teaching methods to use as well as the methods of assessment to use during instruction. All these illustrate how everyday coping controlled the lesson.

Another example illustrates the dominant nature of some goals and purposes of science teaching. During instruction, Mr NG had two goals and purposes of science teaching (*correct explanation and scientific skills development*). However, the *correct explanation* appeared to dominate the instruction process. During interviews, he explained that he maximises students' learning by using a variety of teaching methods to make sure he attends to the needs of every student. The goal of correct explanation is to ensure that students master the basic concepts, laws, theories of science. There was a deliberate effort by the teacher to use several teaching

methods to ensure that students understood what he had prepared for them. For instance, on his CoRe for the topic of electricity and magnetism, he planned to use the *lecture method, practical work,* and *cooperative learning strategies* (*group work*). All of these methods were blended to make the content more accessible to the learners so that learners understood these science core principles, theories and facts. These examples illustrate the dominant nature of these goals. Hence, dominant goals drive the instruction process by informing the decisions the teachers made that included all those already highlighted in Chapter 5, such as what teaching strategy to use, what activities to include and what kind of questions to ask, to help the learners understand the various concepts the teachers wanted them to learn.

The teachers also had goals and purposes of science teaching which were auxiliary. I have used the term "auxiliary" to mean those goals and purposes of science teaching that provide supplementary or additional support to the dominant goals. These goals included *scientific skill development* and the *structure of science*. While dominant goals drove the instruction process, these auxiliary goals were apparent but not always visible during instruction. For instance, it was imperative for teachers to inculcate critical scientific skills in learners. Hence, some teachers deliberatively included a form of practical work in their instruction. Concerning the level of influence goals and purposes of science teaching have on instructional practice, they can be presented on a continuum as shown in Figure 6-1. Non-dominant goals are essential but do not drive the instruction process/practice so they appear at the end of the tail while dominant goals drive instruction practice and are close to instructional practice as shown in Figure 6-1.


**Figure 6-1: Continuum for goals and purposes of science teaching**

The terms "dominant" and "auxiliary" are just umbrella terms because, under each category, there are a different set of goals and purposes of science teaching for different contexts that have different philosophies, resources and aims of education. Furthermore, these sets of goals and purposes of science teaching may change depending on what is happening in a particular context. While I offer plausible contextual reasons to explain the dominance and auxiliary nature of goals and purposes of science teaching captured in this study in Chapter 7, there is a need for further studies to investigate the factors that explain the dominant nature of goals and purposes of science teaching and possibly consider the implications of the same in both practice and theory.

### 6.2.3. Alignment of goals and purposes to grade level

While holding other factors constant (such as *context* and *time*), another insight concerns the alignment of goals and purposes of science teaching to grade-levels which are either junior or senior classes. In Malawi, a secondary school education cycle takes four years: two years for junior education and an additional two years for senior education. Towards the end of year four, all students sit for national examinations. Therefore, teachers at the senior level have a duty to prepare the students for the national examinations. Concerning the grade-level alignment, those teachers who taught junior classes had the following goals and purposes of science teaching: *everyday coping*, and *solid foundation*. While everyday coping will ensure that learners link science to everyday phenomena, *solid foundation* prepares the learners for

more advanced science lessons at a senior level. Hence, there is this alignment of goals and purposes to the level of education.

The teachers who were teaching senior classes had the following goal and purpose of science teaching: *correct explanation,* as can be seen in Table 3-1, since, at senior level, teachers mainly focus on preparing students for the national examinations. Hence, teachers structure their lessons to ensure learners achieve *correct explanation*. This was demonstrated during instruction, as most of their lesson focused on achieving the *correct explanation*. One of the teachers who taught senior classes argued that

> *"Our teaching is determined by several factors such as time and also like for example the form fours they have got a target whereby they are going to write national examinations, so by national examinations we have the syllabus because the national examinations will cover the whole syllabus. Hence we have the duty to help these learners to have a good understanding of the content prescribed in the syllabus. As a result, we have to utilize whatever means we can to help them especially the use of different methods of teaching which ensures that everyone is taken on board" (NG, School 3 POI).*

### 6.3. Insights concerning teachers' beliefs about teaching and learning of science

Another significant insight concerning teachers' beliefs about teaching and learning of science is the issue of "compartmentalisation of teachers' beliefs". This means that teachers' beliefs about particular aspects are discrete, that is, a particular aspect of this dimension does not affect other aspects of the same dimension. In other words, the beliefs appeared to be unrelated. As I highlighted in Chapter 3 that I used a TBI schedule developed by Luft & Roehrig (2007), the belief items on this schedule, according to the authors, are interrelated based on the evidence they have from different studies they conducted using the TBI. In this study, while the expectation was that the aspects about this would be interrelated and hence affect one another, present data seem to suggest the contrary (see

Table 6-1). For instance, on the question concerning the role of the teacher, Mr KA had transitional beliefs as illustrated by the quote below:

> *"My role is to make sure that students are having a positive attitude towards science, and that the students like the subject. Another role is to show the students at least that science as a subject, is a subject which can be learned, can be understood there, it is practical actually."*

The teacher illuminated these transitional beliefs when he explained that he ensured that students achieve a positive attitude by deliberately designing instruction that includes simplifying the language, which can be a barrier. He also explained that, apart from the issue of language, he uses a variety of teaching strategies, such as experimentation or demonstration, to ensure that students understand the concepts. This explanation illustrates that the teacher's beliefs are more student-centred as the teacher believes that students should dominate the instruction process.

However, the same teacher, during the same interview, appeared to have *instructive* beliefs concerning the best ways for students to learn science. "Best ways students learn science" is an item on the TBI schedule that explores teachers' views on what they think are the best ways through which the students learn science. These two aspects of TBI are closely related and therefore one would expect that a transitional or reform-based teacher would illuminate his beliefs about the role of the teacher in the best ways students learn science. On the contrary, he claimed that his students learn science better "*when I am explaining the things to them*". This simply means the teacher dominates the instruction process. If "the role of the teacher during instruction" and "best ways students learn science" were aligned, the teacher talk could have manifested what the teacher thinks his role is during the teaching and learning of science on this aspect (best ways students learn science). However, the lack of alignment between these beliefs items on the TBI schedule illustrates the compartmentalisation of teachers' beliefs.

**Table 6-1: Summary of teachers' beliefs on teaching and learning of science**

| | Teacher | | | | | |
|---|---|---|---|---|---|---|
| **Interview Items** | **KA** | **MP** | **TH** | **PH** | **NG** | **Belief type** |
| **Maximising students' learning** | Transitional | Transitional | Transitional | Transitional | Transitional | **Ideal belief** |
| **Role of the teacher** | Transitional | Reform-Based | Traditional | Transitional | Responsive | **Ideal belief** |
| **Knowing students' understanding** | Traditional | Instructive | Responsive | Reform-Based | Reform-Based | **Ideal belief** |
| **Knowing what and what not to teach** | Transitional | Traditional | Traditional | Traditional | Traditional | **Ideal belief** |
| **When to move to the next topic** | Instructive | Instructive | Instructive | Traditional | Instructive | **Ideal belief** |
| **Students' best ways of learning science** | Instructive | Transitional | Transitional | Transitional | Transitional | **Ideal belief** |
| **Occurrence of learning in the classroom** | Transitional | Instructive | Instructive | Instructive | Instructive | **Ideal belief** |

Mr NG, who had *reform-based beliefs* concerning "knowing when students understand" – one of the items on the TBI, had *instructive beliefs* concerning how the teacher detects the occurrence of learning during the teaching and learning process (see

Table 6-1). The aspect, "knowing when students understand", concerns assessment – how teachers gauge students' understanding of the lessons' concepts. Regarding this aspect, the teacher had reform-based beliefs – these are student-centred beliefs that "exemplary" teachers hold. The quote below shows how he responded when I asked him how he knows when students understand during instruction:

> *"They should be able to answer questions based on my objectives, but also they should be able to give me practical situations of the ideas later, or they can be giving me examples of the situations where we can apply this idea in the day-to-day life. And then what rings in me is that they have understood the idea of trying to marry it to the situation."*

As pointed out in chapter 4, such sentiments in the above quote illustrate the teacher's reform-based beliefs concerning this aspect. Teachers with reform-based beliefs are not only interested in how students recall the basic facts, concepts, theories, etc., they further provide students with a chance to extend their understanding by showing instances on how a particular concept, principle or theory may be applied. However, when I asked him to explain how he ensures students' understanding during instruction (*gauging occurrence of learning in class*), his response suggested that he held instructive beliefs – which are student-centred. The teacher explained this in the following way:

> *"I usually take note of that when they are following up the steps. When learners are doing the steps logically, for example, I can go to a class maybe it is a practical session, then they have done step one, step two but they are failing to do step three, then I know, ok, if you are at step three then you have done step one and step two, which means for step one and two, its ok for them."*

The quote above suggests that the teacher, as a way of gauging students' understanding, wanted students to do exactly what he had presented to them. It also shows that this teacher gauges this by a measure which the teacher determines, such as when students follow the steps logically. This is in contrast to the fact that the teacher held reform-based beliefs in a closely related aspect on this TBI.

These examples illustrate the idea that teachers' beliefs about the different items concerning teaching and learning of science are discrete and do not necessarily interrelate. This tendency was observed in most of the teachers, as shown in

Table 6-1. If this was observed during instruction, a mere misalignment would have been reported. However, this happened during the same interview. Similarly, the compartmentalist nature of teachers' beliefs about teaching and learning of science was also observed during instruction as shown in Table 6-2. In Chapter 7, I offer possible reasons that may explain this observation; furthermore, I should point that studies need to be constituted to explore this observation.

**Table 6-2: Summary of teachers' beliefs on teaching and learning of science from classroom observation data**

| **Interview Items** | **Teacher** | | | | | **Belief type** |
|---|---|---|---|---|---|---|
| | **KA** | **MP** | **TH** | **PH** | **NG** | |
| **Maximising students' learning** | Transitional | Transitional | Transitional | Instructive | Transitional | **Practical belief** |
| **Role of the teacher** | Transitional | Traditional | Transitional | Traditional | Transitional | **Practical belief** |
| **Knowing students' understanding** | Instructive | Instructive | Instructive | Instructive | Transitional | **Practical belief** |
| **Knowing what to and what not to teach** | Traditional | Traditional | Traditional | Traditional | Traditional | **Practical belief** |
| **When to move to the next topic** | Traditional | Instructive | Instructive | Traditional | Instructive | **Practical belief** |
| **Students best ways of learning science** | Traditional | Traditional | Transitional | Transitional | Transitional | **Practical belief** |
| **Occurrence of learning in the classroom** | Instructive | Traditional | Instructive | Traditional | Instructive | **Practical belief** |

## 6.4. Insights about teachers' views concerning NoS

An analysis of teachers' questionnaires shows that the teachers had sophisticated beliefs about the NoS. However, they could not translate their sophisticated beliefs into practices. Specifically, the insight is that most teachers treat the nature of science as a standalone topic. Standalone, in this case, means that a teacher teaches a particular topic and once the topic is over, the teacher does not mention aspects about that topic in subsequent topics. One thing that

was notably more visible was the fact that the teachers did not either explicitly or implicitly include *any* objective concerning NoS in their CoRes or subsequent instruction.

When I asked them in follow-up, post-observation interviews why they did not explicitly or implicitly include the nature of science objectives in their lesson during instruction, all the teachers' responded that the NoS topic is a standalone topic. Most teachers said that they had already taught this topic when they were teaching Physics/Chemistry in form one. Hence, according to them, there was no need to re-teach aspects concerning NoS during subsequent topics.

## 6.5. Insights about the interaction between STOs and TPK domains

### 6.5.1. Apparent uniform interaction between goals and purposes of science and TPK domains

Goals and purposes of science appear to interact in a uniform fashion. Even though teachers had different goals and purposes of teaching, their interaction was almost identical in the sense that there were unique TPK sub-domains with which these goals interacted with more often. For instance, Mr KA had the following goals and purposes of science teaching during instruction: *everyday coping, the structure of science and solid foundation*. These goals mainly interacted with the following sub-domains of TPK: *instructional strategies* of Pedagogical Knowledge, *pre-requisite knowledge* of "knowledge of students", *goals and objectives* of curriculum knowledge, and *the core idea* of content knowledge. This observation was despite the fact that TPK domains have several sub-domains with which the goals could interact. Similarly, Mr PH, whose goals were the *correct explanation, solid foundation* and *everyday coping*, interacted more with the mentioned sub-domains. This observation is despite the fact that these teachers are different and also that their TPK domains have several different sub-domains to interact with. The above pattern suggests a common teacher training pattern that the teachers experienced.

### 6.5.2. The complex interaction between STOs and TPK domains

Another insight learned from this is that the interaction between STOs and TPK is complex as there are several factors that affect interaction. For instance, as shown above, in the current

study, data shows that there is no interaction between the NoS dimensions of STOs and TPK domains. There are a number of factors that influence this kind of relationship. For instance, I asked the teachers why they did not implement some of their beliefs concerning the teaching and learning of science. Some argued that the high number of students makes it increasingly difficult for them to implement student-centred teaching methods and that student-centred teaching methods are time demanding, and hence, they would not be able to cover the curriculum requirements.

### 6.6. Summary of research questions

In this study, the main research question focused on understanding the nature of the interaction between STOs and TPK domains. Given the diversity in terms of the definition of STOs as well as a lack of research studies that specifically target this area, this study provides insights concerning the interaction between STOs and TPK domains with experienced in-service teachers to address the research question.

The idea was to get an in-depth understanding from experienced teachers who have a developed PCK and TPK as I have argued above. It was also the reasoning used to adopt the most recent Friedrichsen et al. (2011) as well as Gess-Newsome (2015) theoretical positions concerning STOs and TPK notions, respectively. These two studies guided the conceptualisation as well as the analysis of the data generated.

The main research question for this study was about understanding the nature of the interaction between STOs and TPK domains. Specifically, it was to understand the interaction between STOs, i.e., beliefs about teaching and learning of science, beliefs about goals and purposes of science teaching and beliefs about the NoS and TPK domains. To achieve this, I had three sub-question: “what beliefs about the NoS, teaching and learning of science as well as goals and purposes of science to Malawian teachers have?”, “to what extent do STOs influence the enactment of TPK domains (*assessment knowledge, curricular knowledge, content knowledge, pedagogical knowledge and knowledge about students*)?” and “what insights do we learn from the understanding of the interaction between STOs and TPK domains?” I used a variety of data collection methods, which included classroom observation, semi-structured interviews, questionnaires, CoRes as well as post-observation interviews. These three sub-questions, I believe, were enough to adequately address the main research question for this study. Hence in

the sections below, I present the answers to these three research questions.

### 6.6.1. Research Question 1: What beliefs or teaching orientations about the nature of science, teaching and learning of science, and goals and purposes of science teaching do Malawian physical science teachers have?

This question was about understanding the teachers' STOs while they are talking about the three dimensions of STOs (according to Friedrichsen et al.2011).

To briefly answer this research question, deductive data analysis shows that teachers have various beliefs about the three dimensions. These beliefs, as shown in Chapter 5, influence the various TPK domains when it comes to teaching and learning of science as well as when teachers are planning for science lessons. For instance, concerning the goals and purpose of science teaching, data show that the teachers who took part in this study had multiple goals and purposes of teaching science. These goals included *everyday coping, scientific skills development* and *the structure of science*, among others. While these goals informed the teachers' actions regarding the handling of classes, there were some dominant goals and purposes of science teaching that appeared to drive the instruction. There were others which were less dominant during instruction. The nature of being dominant or not seems to be dependent on the context of teaching, as highlighted above.

Concerning beliefs about teaching and learning of science, it was observed that, as teachers were expressing themselves on the various items of the TBI schedule, their beliefs on the items were discrete. This means that these beliefs did not affect other items on the same TBI schedule. While the lack of interaction among the TBI items was observed, these beliefs, just like goals and purposes of science teaching, were also instrumental in influencing the various TPK domains, as shown in Chapter 5.

Regarding the third dimension of STOs, teacher's views about the NoS, results revealed that most of the teachers had sophisticated beliefs about science. However, what was apparent was the lack of interaction between the NoS and TPK domains. This means that the teachers had a good understanding about the nature of scientific knowledge, about the difference between a scientific theory and law, and about how science relates to society. However, translating these beliefs into practice was visibly lacking for all the teachers. During post-observation

interviews, the teachers cited several reasons that contributed to this including the lack of PKC for nature of science as I discuss in Chapter 7. Hence, to answer this question, teachers have a set of STOs in terms of goals and purposes of science teaching, beliefs about teaching and learning of science as well as views about the NoS of science. These STOs are instrumental in informing the various TPK domains during instruction and when it comes to planning about teaching.

### 6.6.2. Research Question 2:to what extent do STOs influence the enactment of TPK domains?

The main focus of this study was to examine the interaction between STOs and TPK domains by specifically looking at the extent of the influence of STOs on the enactment of TPK domains. I have shown in the literature review that TPK domains have sub-domains, for instance, a teacher's knowledge domains; knowledge of students has the following sub-domains: *students' differences, pre-requisite knowledge and students' misconceptions.* These sub-domains interact with STOs. For instance, to detect the interaction between goals and purposes of science teaching and knowledge about students' domain, I show that a specific goal has either influenced students' differences or pre-requisite knowledge as shown in Chapter 3. Data concerning this question were mainly generated through CoRes, classroom observations and post-observation interviews. I used inductive analysis to analyse CoRes as well as classroom observation.

Therefore to answer this question, inductive analysis revealed three claims which I highlighted in Chapter 5: *goals and purposes of science teaching interact with various TPK domains, teachers' beliefs about teaching and learning of science interact with various TPK domains and teachers' beliefs about the NoS do not interact with TPK domains* for various reasons stated by the teachers. The interaction between goals and purposes of science as well as beliefs about teaching and learning of science were uniform among the teachers. This means that, despite the teachers having different goals and purposes of science, their goals or beliefs about teaching and learning of science interacted with specific sub-domains. For example, everyday coping was one of the goals and purposes of science teaching for Mr PH. This goal interacted mainly with goals and objectives sub-domain of curriculum knowledge. Similarly, Mr NG, whose one goal and purpose of science teaching was scientific skills development interacted

with goals and objectives sub-domain of the curriculum domain. This illustrates the uniform nature of the interaction. Hence to briefly answer this research question, STOs interact with TPK domains by influencing the individual TKP sub-domains as illustrated in Chapter 5.

### 6.6.3. Research Question 3: What insights can we draw from the understanding of these interactions?

While I used raw data to address the first two research questions, in this question, I relied on an inductive analysis approach to generate the lessons learnt from understanding the interaction between STOs and TPK. Furthermore, even though this question was about highlighting the lessons learned from the interaction between STOs and TPK domains, I also highlighted the lessons learnt concerning goals and purposes of science teaching, beliefs about teaching and learning of science as well as teachers' beliefs about the NoS**.**

For this question, a reflection on the findings reported in Chapters 4 and 5 yielded the insights reported above. Concerning teachers' goals and purposes of science teaching, there were three main insights that were revealed: the multiple goals and purposes of science teaching that teachers hold, the dominant vs auxiliary dominant goals and purposes of science teaching and the alignment of goals and purposes to grade level. Concerning teachers' beliefs about science teaching and learning, the significant insight was the apparent discrete nature of teachers' beliefs about the teaching and learning of science.

These three questions have provided insights to adequately address the main research question which was: "to what extent to STOs influence the enactment of TPK domains, i.e., content knowledge, curricular knowledge, pedagogical knowledge, assessment knowledge and students' knowledge?" The answer to this question was reflected in the behaviour of the teachers while they were delivering a lesson or while they were planning about teaching a particular lesson. There was a lack of observable interaction between beliefs about the NoS and TPK domains despite the teachers having sophisticated beliefs. Probable reasons for this are in Chapter 7 of this research report.

## 6.7. Summary

In the previous chapters, I presented data pertaining to the first two research questions. In this chapter, the main aim was to highlight the lessons learnt from understanding the nature of the interaction. Even though the main aim was to present lessons concerning the interaction between STOs and TPK domains, I have also presented lessons concerning the individual dimensions of STOs. Concerning the goals and purposes of science teaching, I highlighted the following lessons: teachers having multiple goals of science teaching and dominant and less dominant goals, among others. Concerning teachers' beliefs about the teaching and learning of science, I also highlighted the following critical insights: teachers' beliefs about the individual items on the TBI schedule are compartmentalised. As shown above, this means that they are discrete belief systems and do not affect one another. Lastly, concerning the interaction between STOs and TPK domains, I highlighted two main lessons: the apparent uniform interaction between STO dimensions and TPK domains across the teachers and the complex nature of the interaction between STOs and TPK domains. In Chapter 7, I discuss these findings against what has already been established in the literature.

# CHAPTER 7. DISCUSSION, IMPLICATIONS CONCLUSION

## 7.0. Introduction

The teaching and learning of science is hampered by a plethora of problems. This study was conceived to examine the interaction between Science Teaching Orientations (STOs) and Teacher Professional Knowledge (TPK) domains to shed light on the influence of STOs on TPK domains enactment during instruction process. This is because research has shown that STOs filter or amplify the teachers' various knowledge domains. Specifically, this study was conceptualised to answer the following research questions:

1. What beliefs or teaching orientations about the nature of science; teaching and learning of science; goals and purposes of science teaching do Malawian Physical science teachers have?
2. To what extent do STOs influence the enactment of content knowledge, curricular knowledge, pedagogical knowledge, assessment knowledge, and knowledge of the students during instruction?
3. What insights can we draw from the understanding of these interactions?

In Chapters 4, 5 and 6, I presented findings that emanated from this study. In Chapter 4, I presented findings concerning the five teachers' STOs. These teachers' beliefs about goals and purposes of science teaching, their beliefs about teaching and learning of science, and their responses on the nature of science questionnaire answered the first research question shown above. While classroom observations and CoRe data answered the second research question, a synthesis of these findings helped me to answer the third research question. In Chapter 6, I showed how these data sets helped me to answer the research questions I had set out to investigate. It is important to note that in this chapter (chapter 6), these insights are lessons which are drawn directly from the findings of the study as I highlight in section 7.4.

In this chapter, I present a discussion of the findings, implications as well as the conclusion of the study. In the discussion, I link my research study findings to the theoretical position as well as previous research studies that have been carried out. To start, there is a discussion concerning the existence of STOs and their nature. Secondly, I discuss the findings in terms of interactions of STOs and TPK. Reflections are made on the insights learnt from the study. The empirical

findings are examined, and the implications for teacher development, specifically within the context of Malawi, are drawn and discussed. I also list recommendations for future research.

### 7.1. Results summary

In this section, I will highlight the findings of the study in a summary form. The main focus of the study was to examine the interaction between STOs and TPK domains. To achieve this, I divided the main research question into three sub-research questions as shown above. I used various methods to collect data to answer these three research questions. These methods included semi-structured interviews, questionnaires on the NoS, classroom observations, as well as post-classroom observation interviews.

To provide a summary of the findings, the following was uncovered: concerning goals and purposes of science teaching, data show that the teachers held multiple goals and purposes of science teaching. These goals were instrumental in informing the teachers' decisions which they made while planning for instruction or during the actual instruction. Data also show that, while the teachers held multiple goals and purposes of science teaching, there were some goals which appeared to drive the instruction process rather than others. Those goals and purposes that controlled the instructional process are called "dominant goals", and the other less dominant goals are called "auxiliary goals".

Concerning teachers' beliefs about teaching and learning of science, teachers demonstrated sophisticated beliefs. For instance, most of the teachers commented that the role of the teacher during instruction is to facilitate the learning process. However, most of these beliefs about teaching and learning of science were not translated into practice. In other words, there was a misalignment between teachers' beliefs about teaching and learning of science and their practices.

Regarding teachers' views about the NoS of science, while teachers had sophisticated beliefs concerning the various aspects of the NoS, teachers did not translate their beliefs into practice. Contextual as well as policy factors were cited as being among the reasons for not including the aspects of the NoS in their teaching and learning of science.

Concerning the question about the interaction between STOs and TPK domains, I highlighted

three significant claims that are: *goals and purposes of science teaching interact with TPK domains, teachers' beliefs about teaching and learning of science interact with TPK domains, and teachers' beliefs about the NoS do not interact with TPK domains*. In the sections below, I discuss these findings and provide reasons for the observations that I made. I have aligned the discussion in a similar fashion to other chapters.

## 7.2. Science Teaching Orientations

The first question was about science teachers' teaching orientations which include the ideal and practical teaching orientations held by the teachers. Although this was not the main aim of the study, the question had to be asked to establish the teaching orientations of the participants. The literature shows that it is an established fact that science teaching orientations exist but there is little research regarding the nature of science teaching orientations as defined by Friedrichsen et al. (2011). Most of the research conducted on science teaching orientations was based on the Magnusson et al. (1999) framework where, as discussed in Chapter 2, teachers were mainly grouped into one of the nine types/categories which, according to Friedrichsen et al. (2011), diluted the complexity of the notion of teaching orientations. Furthermore, Friedrichsen et al. (2011) also report that there is little or no evidence of teaching orientations as defined in this way. Hence, the emphasis on the notion of science teachers' teaching orientations, using the Friedrichsen et al. (2011) framework, to strengthen the evidence for teaching orientations.

### 7.2.1. Teachers' goals and purposes of science teaching

#### *7.2.1.1.* The issue of multiple goals

Chapter 6 shows that the findings suggest that the teachers who took part in this study had multiple goals and purposes of science teaching. This finding is consistent with findings from previous studies (e.g. Demirdöğen, 2016; Friedrichsen & Dana, 2005; Friedrichsen, Van Driel, & Abell, 2011; Kiran, 2016). For instance, in a study where the interaction between teaching orientations and PCK domains was examined with pre-service teachers, Demirdöğen (2016) reported that the teachers held multiple goals and purposes of science teaching which interacted with PCK domains. In Chapters 4 and 6, for instance, Mr KA, during instruction, had the goals

of *everyday coping, the structure of science,* as well as a *solid foundation*. The fact that teachers have multiple goals and purposes of science teaching shows that goals and purposes are closely linked to the concepts, topic and context the teachers are in (i.e., concept-specific goals and purposes of science teaching). There are several reasons that could explain these multiple goals and purposes of science teaching observation. One reason for this observation is the interrelated nature of these goals and purposes of science which means that the goals and purposes of science teaching might be dependent on one another. For example, a teacher might decide to give students a practical task: *design and describe a simple gadget that will detect the presence of rainfall outside a house*. In this example, while the aim is the detection of rains (*everyday coping*), the teacher has used practical work (*scientific skill development*) as a strategy. This, therefore, shows the interrelated nature of goals and purposes of science teaching hence teachers having multiple goals. Even though this example explains this observation, there is a need for further empirical studies to examine the interrelated nature of the goals and purposes of science teaching.

#### *7.2.1.2.* The issue of different multiple goals

Even though the teachers had multiple goals and purposes of science teaching, findings also show that these goals and purposes of science teaching were *different* from teacher to teacher as shown in Table 4-1 in Chapter 4. For instance, Mr KA had the following goals and purposes of science; *everyday coping, the structure of science,* and *solid foundation*, on the other hand, Mr TH had the following goals and purposes of science teaching; *everyday coping and correct explanation*. This finding confirms Magnusson et al. (1999) claims that STOs (*in this case goals and purposes of science teaching*) are influenced by the nature of the topic one is teaching at a particular time.

On the other hand, this (*different goals and purposes*) finding is in sharp contrast to a more recent study (see Kiran, 2016) that examined the interaction between STOs and PCK domains. While my study has shown that the teachers who took part in this study, had different goals and purposes of science teaching from one another (as shown in Table 4-1 in Chapter 4), Kiran (2016) on the other hand showed that the teachers that took part in her study had the same goals and purposes of science teaching which were: *everyday coping, solid foundation*, and *correct explanation.* There are several explanations for this observation. However, one probable

explanation is the issue of "context in which the study was carried out". Kiran's study and my study were contextually different. While Kiran's study examined the teachers' goals and purposes of science teaching with experienced teachers on the same topic (*mixtures*), my study, on the other hand, examined the teachers' goals and purposes of science teaching with experienced science teachers who were teaching different topics of science (*as argued in chapter 2 of the conceptual framework*).

Furthermore, the above explanation is also in agreement with Roberts (2015) who claims that goals and purposes of science teaching are influenced by the context a teacher finds himself in. The context, in this case, may include *level, topic* as well as a *school ethos*. Friedrichsen & Dana (2005) showed that one of the sources of STOs (*including goals and purposes of science teaching*) is the curriculum that is in use in a particular country. Even though curriculum interpretation is dependent on the teachers' abilities and understanding (Kelly, 2004), there are other things which the curriculum makes them available to all teachers. These things include: *suggested teaching and learning materials, suggested teaching and learning strategies, suggested assessment methods* etc. Hence, in the case of Kiran's study, the fact that the teachers were teaching on the same topic (*mixtures*) at the same level means that the teachers were exposed to the same curriculum, same suggested teaching and learning strategies as well as same assessment methods which the curriculum might have suggested. These things would make the teachers have similar views concerning the teaching of science hence similar teaching patterns while teaching the same topic at the same level. This scenario, therefore, significantly enhances the probability of the teachers holding the same goals and purposes of science teaching, unlike when they are teaching different topics. This finding further confirms Magnusson et al. (1999) claims that STOs (*in this case goals and purposes of science teaching*) are influenced by the nature of the topic one is teaching at a particular time.

Moreover, several researchers have argued and shown that PCK is topic-specific (e.g. Hill, Ball, & Schilling, 2008; Mavhunga, 2012; Rollnick & Davidowitz, 2015). Perhaps this also explains why teachers teaching the same topic held similar teaching orientations. Since the nature of the topic, the arrangement of concepts would basically have a role in determining teachers' teaching orientations. However, for this study, the fact the teachers were teaching different topics, is a reason enough for teachers to have different goals and purposes of science teaching. As different topics present different contexts and hence demands different ways of

handling them.

Despite the fact that these findings shed some insights concerning the nature of goals and purposes of science teaching hence STOs, it will be interesting to have more studies that delve into the possible alignment of goals and purposes of science teaching to the topic in order to provide empirical evidence for this claim.

#### *7.2.1.3.* Explaining the issue of dominant vs auxiliary

Apart from teachers having multiple goals and purposes of science teaching, findings also show that there are other goals and purposes which were more "dominant" while others were "auxiliary" as shown in Chapter 6. These goals and purposes of science teaching were dominant as they appeared to be instrumental in shaping the nature of instruction. For instance, in Chapter 6, I showed that goals and purposes, such as *everyday coping, correct explanation* and *solid foundation*, were dominant while goals and purposes, such as *scientific skills development* and *structure of science*, were auxiliary. This finding is similar to the conclusions drawn by Friedrichsen & Dana (2005) who used the terms "central" and "peripheral" to denote dominant and auxiliary goals and purposes of science teaching, respectively. Central goals and purposes are those that "dominate the teacher's thinking and appear to drive the instructional decision-making process" (p. 225). These goals and purposes are highly visible, and hence, they are the most repeated themes in teachers' talk (Friedrichsen & Dana, 2005). Peripheral goals and purposes are those goals which teachers hold but are less influential in driving an instruction decision-making process. While these authors did not explain the reasons for central and peripheral goals, in the sections below, I offer reasons aligned to this study.

First, the overemphasis of some goals and purposes of science teaching in certain essential documents, as well as the media, offers insights. These documents include newspapers, curricular documents, textbooks, official government documents, such as the Malawi Growth and Development (MGDS, 1,2,3), National Commission of Science and Technology policy document, among others. In all these documents, science is regarded as a subject which is linked with the development of the nation as well as *everyday coping* of the people in their environment. The quote below is taken from the new Physics curriculum:

> *"Physics helps students to become more scientifically literate, i.e. it enables them to think*

> *critically and creatively based on explanations developed and evaluated from experiments and models. The subject will, therefore, help students to develop a scientific mind/view necessary for identifying and solving current and emerging/new scientific issues. Moreover, physics is the backbone of natural and applied sciences, which are important for the social and economic development of the nation" (Ministry of Education, Science and Technology, 2013).*

Hence, the new physics curriculum has been structured on the premise that the teaching and learning of science should be linked to local as well as everyday contexts to enable learners not only to relate scientific knowledge to the things they are familiar with but also to explain or use scientific knowledge to solve problems affecting local contexts. This is evident in the way the objectives, suggestions, etc. have been formulated in the science curriculum. For example, each topic in the curriculum has an aspect of "*application of the concept[s] to everyday life*". This encourages the teacher and students to link the concepts to everyday life. This explains why *everyday coping* was more dominant in the teachers' teaching and learning processes.

Chapter 6 showed that some goals and purposes of science teaching are auxiliary. This means that, even though they do not drive the instruction process, they are essential in complementing the dominant goals and purposes of science teaching. Surprisingly, in this study, goals and purposes, such as *scientific skills* and *development and structure of science*, were found to be auxiliary even though the curriculum, as well as PD programmes, emphasise the need for students to develop critical scientific skills through the use of practical work. For example, the quote below shows what the chemistry curriculum emphasises regarding the development of scientific skills:

> *"Through the investigative approach, chemistry equips students with essential skills for effective communication of scientific information, problem-solving and pursuit of further education" (Government of Malawi, 2013, p. xi)*

Similarly, scientific skill development as a goal and purpose of science teaching is also emphasised during PD programs (such as SMASSE). For example, all the teachers who participated in this study, qualify and annually take part in the organised SMASSE training workshops. From this training, apart from emphasising teachers' use of more effective science teaching strategies and students' scientific skills development, such as problem-solving skills, scientific investigations are also promoted. Through the use of Activity, Student-centred,

Experimenting and Improvisation (ASEI), teachers are asked to modify instruction so that students develop problem-solving, inquiry and practical skills. Specifically, the focus is on where students "do" rather than "listen". This situation will probably remain like this until studies are conducted to further explore this observation

Similarly, the *structure of science* as a goal and purpose of science teaching, despite its prominence in the national curriculum, was also found to be auxiliary in this study. This finding is similar to the findings of previous studies (cf Demirdöğen, 2016; Kiran, 2016). As already reported in chapters 5 and 6, there was no explicit inclusion of objectives or aspects of the NoS by any of the teachers. Reasons such as *time* and *availability of materials* were cited by the teachers to explain the conspicuous absence of the NoS aspect during instruction. While these reasons might explain the lack of explicit inclusion of the NoS, an undeveloped PCK for NoS was found to be the most plausible reason for this observation. I discuss more of this in section 7.2. 3.

### 7.2.2. Teachers' beliefs about science teaching

Findings suggest that all the teachers who took part in this study (except Mr KA) believe that a curriculum is the only document that teachers rely on when it comes to what to teach and what not to teach while thinking about or planning their teaching. When the teachers were asked how they determined what to teach and what not to teach during interviews, their replies suggested that they trusted the curriculum to inform them about what they are supposed to teach.

During instruction, all teachers' CoRes had objectives which were taken from the curriculum. There were no bridging objectives[4] which the teachers had formulated on their own and there

[4] This need to be exemplified further:

For instance, in the curriculum, on the topic of digital electronics, there is an objective which states: "By the end of this lesson, students must be able to **discuss semiconductor devices**." For a 40-minute lesson, this objective is too broad and hence a teacher may decide to break it into smaller ones such as:

- Define a semiconductor
- State the examples of semiconductors
- Describe the process of developing a semiconductor
- Explain the characteristics of semiconductor devices

was a lack of coherence with other topics or subject disciplines. Anecdotal evidence offers useful insights for this observation. I am a teacher educator at one of the intuitions where some of these teachers graduated from. The curriculum courses which these teachers were offered relays the message which strongly suggests that the curriculum is the ultimate source of what the teachers can teach and what they cannot teach. Furthermore, in one of the curriculum orientation workshops which the curriculum, especially objectives, developers organised, described the curriculum as a "Bible". This means that the curriculum must not be altered in any way. Even though this is true (*curriculum is the source of what teachers are supposed to teach*) and while this might be intended to achieve uniformity, at the same time, it denies teachers the chance to exercise autonomy in deciding what and how to teach science content to the students (see footnote 4). This implies that the teachers lack "curriculum mapping" (Ervin et al., 2013) skills where the teacher could map out topics to see cross-cutting issues and other things that need to be taken into consideration when teachers are thinking about the teaching and learning of science.

This result leads to a suggestion that content for teacher education programs in Malawi should be tailored in such a way that "teachers' autonomy" and "curriculum mapping" should be emphasised when formulating objectives. While curriculum mapping would allow teachers to identify gaps and see cross-cutting issues, teacher autonomy would allow them to fill those gaps. This would also allow teachers to sequence the topics in such a way that related or context-specific topics are tackled at an appropriate time in order to capitalise on the existing resources.

Inconsistencies in teachers' beliefs were also observed across the items on the Luft & Roehrig (2007) TBI schedule. For example, while a teacher may have responsive (student-centred) beliefs regarding the role of a teacher in a science classroom, the same teacher would be found to harbour traditional (teacher-centred) beliefs concerning the best ways to learn science.

Against other studies (such as Brownlee, Boulton-Lewis, & Purdie, 2001; Kang & Wallace, 2005; Luft & Roehrig, 2007) that reported that beliefs are connected in a particular manner, the findings for this study suggest that teachers' beliefs about teaching and learning of science

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This is not a depature from the above objective, but brings more clarity on how the objective may be achieved.

are “compartmentalised”. This means that each aspect on the TBI that I investigated had no influence on other items. This was based on how teachers responded to the items during interviews as well as during instruction. Hence, their beliefs were discrete and not intertwined, as reported in other studies. For instance, when these teachers were discussing the role of the teacher in a science classroom, they all believed that the role of the teacher is to “facilitate” instruction as shown in Table 4-2. They explained that this entails them structuring a lesson in such a way that it empowers the learners to own the teaching and learning process. As a result, the teaching and learning process is dominated by the learners rather than the teacher. However, there seemed to be a disjoint between the role of the teacher and the item that sought to understand teachers’ views on when to move to another topic.

Another illuminating example comes from *beliefs about students’ best ways of learning science* and *assessment of students’ understanding of the same*. During instruction, most of the teachers seemed to hold traditional beliefs regarding the best ways of teaching science. Structure of PD, teacher training programs, as well as curriculum emphases, explain this observation. For instance, in the national science curriculum, student-centred methods of teaching are emphasised as effective methods of teaching science rendering teachers with a facilitatory role. Likewise, PD activities centre on the role of the teacher in a student-centred classroom, while neglecting other equally important aspects about teaching and learning of science, such as knowing when students understand or knowing what to teach from the curriculum. Against this background, I suggest that teacher training programs should ensure that content for teacher education makes the aspects of these beliefs items more visible. This will address some of the inconsistencies that have been observed in this study.

### 7.2.3. Nature of science

Findings for this study demonstrated that most of the teachers have sophisticated beliefs regarding *what science is* as well as concerning *the nature of scientific knowledge* as opposed to other aspects such as *the difference between theories and laws* or *the social embeddedness of science* of the NoS. As shown in Chapter 4, teachers believe that scientific knowledge is tentative and subject to change with time depending on the availability of convincing, contrary evidence. On the contrary, most teachers seemed not to have a clear understanding regarding the difference between theories and law.

This finding is consistent with other previous studies (e.g. Mudavanhu & Zezekwa, 2017). Mudavanhu & Zezekwa (2017), while subjecting science teachers to a questionnaire based on the seven aspects of the NoS, reported that, even though the participants had informed views about the tentativeness of scientific knowledge, their views were in contradiction with other aspects about the NoS. This is despite the fact that other studies (see Khine, 2012; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) argue that "exposure" as well as "experience in teaching" enhances teachers' views about NoS in that those teachers with more experience will have more informed views about the NoS. Several reasons, in this context, explains why teachers are more familiar with other aspects of science NoS, unlike the others.

In this study, "the science curriculum" as well as "instructional materials", such as textbooks, are found to be plausible reasons to explain this observation. As shown in Chapter 4, about teachers' *beliefs about teaching and learning of science*, it is evident that the teachers' source of knowledge regarding what to teach at a particular time comes from the curriculum in use. This implies that the teachers feel obliged to implement whatever is emphasised in the curriculum. For instance, while the NoS is dynamic and the issue concerning the fundamental aspects is still contentious (Aslan & Tasar, 2013; Khine, 2012), the NoS in this new science curriculum is synonymous with *scientific investigation*. Thus, the science curriculum advances the idea that science is empirical and that it is mostly "based on and/or derived from observations of the natural world" (Khishfe, 2015, p. 1642). Students are tasked with scientific investigations with the aim of "engaging" them in the learning process. Hence, a large part of the curriculum is devoted to portraying science as a discipline that relies heavily on the Baconian image of science (Aslan & Tasar, 2013). This is where science is mostly taken as objective, developed by induction and not connected to human creativity or imagination. Similarly, in the senior science curriculum, much emphasis is still placed on students conducting scientific investigations under controlled circumstances. This makes teachers more familiar with these aspects while neglecting other equally important aspects.

The new curriculum includes the NoS as one of the critical issues students should be aware of when learning science. While the recommended textbooks for the new curriculum include NoS topic, there is a haphazard discussion concerning the NoS. For instance, in one of the textbooks for the junior secondary school section, there is a comprehensive discussion concerning "what science is", and the "nature of scientific knowledge", neglecting other aspects, such as the

difference between theories and laws, science as a human endeavour, etc. In another textbook, there is a discussion on what science is (which is an aspect of the NoS) but the discussion ends with a brief talk on the branches of science while ignoring critical aspects of the NoS, such as tentativeness of scientific knowledge, the difference between scientific theories and laws, etc. The book continues by discussing "scientific investigations" which is a more extended topic than the one on the NoS messages. This makes teachers more familiar with certain aspects of the nature of science than with others. It should also be noted that the discussion on the NoS is limited to the junior level of the curriculum and that there is no NoS at the senior level, not even as suggested teaching and learning activity.

### 7.3. Interaction between STOs and TPK

In this section, I present a discussion concerning the interaction between the STOs and TPK domains. As in the previous chapters, I have structured the sections according to the three dimensions of STOs, i.e., beliefs about teaching and learning of science, goals and purposes of science teaching and views about the NoS. Inductive analysis of the data, as shown in Chapter 5, revealed three central claims: *goals and purposes of science teaching interact with TPK domains, teachers' beliefs about teaching and learning of science interact with TPK domains* and *teachers' views about the NoS do not interact with TPK domains*. See the discussion below concerning these claims.

#### 7.3.1. Goals and purposes of science teaching vs TPK Domains

Inductive analysis of the data revealed that goals and purposes of science teaching interacted with TPK domains. Even though the findings show that teachers had multiple goals and purposes of science teaching, as shown above, not all goals and purposes of science teaching interact with all TPK domains. This is similar to other studies (cf Demirdöğen, 2016; Kiran, 2016) reported in the literature that concurs that goals and purposes of science interact with TPK domains in different ways. Demirdöğen (2016) found that content related goals and purposes of science teaching (such as *correct explanation* and *solid foundation*) interacted with all TPK domains. Even though *solid foundation* was not frequently mentioned by the teachers during interviews – probably because teachers lacked the language to articulate their PCK (Baxter & Lederman, 1999), it was one of the most observed goals and purposes of

science teaching during instruction.

A critical insight comes from Roberts (1988) and Roberts (2015), who discussed the issue of "default" goals and purposes of science teaching. Roberts (1988) explained that some of these goals and purposes of science teaching are "*default science messages*". While some goals may be "dominant" (stemming from context) in influencing teachers' practice, as explained in Chapter 6, according to Roberts (1988), other goals and purposes (*solid foundation* and *correct explanation*) are *default science messages* irrespective of the context. By "default", he means that this is where "no explicit communication is provided to the student about the purpose of learning science" (p. 37). In this case, the curriculum framers do not necessarily have to communicate to the students why they are learning science at a particular level, it is an implicit, default message that they are learning science at this level so that it prepares them for science content at another level. Similarly, recent studies also found that *solid foundation* is also one of the default implicit curriculum emphases found in curricular documents (de Vos et al., 2002; van Driel et al., 2008).

Even though *solid foundation* and *correct explanation* had more interactions with teachers' TPK domains, *everyday coping*, on the other hand, appeared to be "dominant" and interacted mainly with knowledge of students and curriculum knowledge as shown in Table 5-1 in Chapter 5. However, the number of teachers with those interactions was low. There could be several reasons to explain this.

Firstly, the topic-specific nature of PCK may explain why *everyday coping* had few interactions with teachers' TPK domains and why only a few teachers were explicit about it. While Davis et al. (2008) argue that PCK is discipline-specific; it enables teachers to have an idea of how a specific discipline works, related to other disciplines, Mavhunga & Rollnick (2013) and Gess-Newsome (2015) on the other hand, contend that PCK is located in a specific topic and is different from topic to topic. Those teachers who had *everyday coping* as one of their goals and purposes of science teaching taught on topics which were closely related to everyday life. For instance, Mr MP taught about power and simple machines, while Mr TH taught about pressure in liquids. Traditionally, these topics offer a platform to make explicit links to everyday life, unlike other topics. For instance, the topic of power and machines introduces students to simple machines, like a bicycle axle and inclined planes, which students are familiar with.

Secondly, much as PCK is topic-specific (Mavhunga & Rollnick, 2013), the structure of topic objectives in the curriculum also offers insights regarding this observation. For instance, despite *everyday coping* being "dominant" (as discussed above), in the curriculum (almost for each and every topic), it is structurally positioned towards the end of each topic, rather than being entrenched in each concept. This implies that, when observing a teacher at the beginning of the topic or midway through the topic, there is a high chance that the teacher will not make explicit links to everyday life about the teaching and learning of science. For example, in the topic of energy, in the junior curriculum, out of the six[5] objectives on this topic, it is only objective number 5 (which is towards the end of the topic in the footnote 5 below) that explicitly requires students to describe changes of energy in "practical situations". Practical situations, in this case, mean everyday life (which is *everyday coping*). The rest do not make explicit links to everyday life. If teachers make these links to everyday life midway through the topic, it is their own effort to link a concept to everyday life. This might explain the observation that some teachers did not have an *everyday coping* goal and *purpose of science teaching* during instruction. To further substantiate this, the two teachers reported above whose purpose of science teaching was *everyday coping*, were handling the last lessons on their respective topics, which means that *everyday coping* objectives were aligned to the way they are structured in the curriculum.

Similarly, the *structure of science*, as well as scientific skill development goals and purposes of science teaching had few interactions with the teachers' TPK domains. Time, especially for *structure of science*, as well as resources, especially for scientific skills development, have been argued to be the main reasons for this observation. Concerning time, teachers seem to be aware of student-centred instructional strategies as, during interviews, they gave examples of these strategies but argued that time limits do not allow them to use these instructional strategies frequently. They claimed that these strategies are time-consuming and, with the

5

1. define energy
2. identify different sources of energy
3. describe different forms of energy
4. describe the law of conservation of energy
5. **describe energy changes in practical situations**
6. calculate energy gained/lost by an object

pressure of trying to cover the whole syllabus, they use less time demanding instructional strategies which happen to be teacher-centred. Practical work is one of the platforms that enhance students' development of critical scientific skills such as problem-solving, measurement, observation, as well as inquiry skills. However, the teachers said that a lack of resources was a major hindrance to conducting practical work with the students. Hence the conspicuous absence of this goal and purpose in their practice.

### 7.3.2. Beliefs about teaching and learning of science vs TPK

Findings in this category suggest that, even though there were traceable interactions between teachers' beliefs about teaching and learning of science and TPK domains, in some cases, it was found that there were inconsistencies between their beliefs and practices. This means that teachers' beliefs about teaching and learning of science did not translate into classroom practice. These findings are consistent with results from previous studies (see Fletcher & Luft, 2011; Mansour, 2013; Ogan-Bekiroglu & Akkoç, 2009). Ogan-Bekiroglu & Akkoç (2009), for instance, concluded that the beliefs that teachers have about teaching and learning of science interact with practice in a much more sophisticated way. What teachers profess as their beliefs about something may not be consistent with what happens in the classroom. Even though teachers' beliefs reflect their personal values and philosophies on teaching (Verloop et al., 2001), this is not always reproduced in their practice. There are always inconsistencies, which are not unexpected (Fang, 1996).

Studies (e.g. Fang, 1996; Mansour, 2013; Margot & Kettler, 2019) on teachers' beliefs about teaching and learning show that there are several contextual factors that explain this observation, i.e., inconsistencies between teachers' beliefs and practices. While reviewing research on teachers' beliefs and practices, Fang (1996) concluded that contextual factors, such as school/classroom and policy contexts, play a critical role in explaining this observation. School or classroom contexts include things such as *availability of resources, class size, students' socio-economic background, classroom conditions,* and *time available for teaching and learning materials* as well as *support from the administration* (Fang, 1996; Rollnick et al., 2008). Policy contexts include *curriculum, high-stakes standardised testing on the narrowing of academic content* and *teacher classroom practices* (Fang, 1996; Mansour, 2013). Similarly, while reviewing research on teachers' beliefs about the integration of STEM in education,

Margot & Kettler (2019) reported several barriers that hinder teachers' beliefs concerning the integration of STEM in education. These barriers include *pedagogical, curriculum, structural, students* and *assessment challenges*. All these challenges fall within Fang (1996)'s contextual factors.

Although this listing of contextual factors is comprehensive, there are a few *school* as well as *contextual policy* factors that are more applicable to the findings of this study. School factors include, in this case, class size. Studies (e.g. Brühwiler & Blatchford, 2011; Shi, 2019; Wright et al., 2019) show that class size has considerable implications concerning the alignment of teachers' beliefs and practices. For instance, in a study where the relationship between class size and teacher practice was examined, Blatchford, Moriarty, Edmonds, & Martin (2002) conclude that class size affects the practice of teachers. They argued that smaller classes offer teachers more chance to implement individualised lessons than larger classes. Similarly, while small class sizes give teachers a chance to tailor instruction to students' needs (Gracemary Eloheneke Moluayonge & Innwoo Park, 2017), large class sizes present challenges regarding classroom management, planning students' instruction and students' interaction that puts a strain on the teachers. What this means is that for instance, if a teacher has reform-based beliefs about the best way to teach science, with large classes, the teacher may be unable to implement his/her beliefs as he/she cannot give individual teaching that caters for the needs of different students. Large classes require more time, need more resources and cause more stress for teachers who have to manage the class particularly with student-centred instructional strategies. The implications for large class sizes go beyond the effects on the teachers but also affect the students. For example, Wright et al. (2019), report that students claimed that they felt anonymous and disconnected in large classes.

Mr PH, who was teaching form 4 (final year of secondary school education), had reform-based beliefs concerning the role of the teacher and how to assess students (*during interviews*) but conducted his class in a traditional way (see Chapter 5). In all the lessons that I observed, he relied on the lecture method of teaching where students' involvement was limited to answering teachers' questions. Furthermore, he relied on a vague way of gauging students' understanding of the concepts. He only asked, "Are we together?" to find out if students understood. When asked why he structured his instruction in that manner, apart from a lack of materials to support students' activities, he said that the large size of the class hindered him from aligning his beliefs

about teaching and learning of science with his practice. He had about 120 students in his class against the recommended ratio of one teacher to 40 students. He contended that "a large class size makes it impossible to implement cooperative[6] learning strategies and design individualised instruction to properly structure instructional activities that align with what they believe as the best ways of learning science". Even though the teacher wanted to do practical work with the students, the limited resources and large class size make this unattainable and therefore he resorted to traditional ways of teaching. Even if a school is well resourced, the problem of large class-size impacted on how the teachers could use the available resources for the students.

Regarding the policy factor, high-stakes national examinations determine to what extent teachers can implement their beliefs and practices about teaching and learning of science. Studies (e.g. Aydin, 2012; Aydin, Friedrichsen, Boz, & Hanuscin, 2014) report the effects of examination-based systems on teachers' teaching orientations. Even though teachers might prefer to teach in a particular way, they might be forced to use a different method of teaching in order to adapt to the demands of the examination-based system. In this study, the teachers, especially those teachers teaching in the senior classes, recognised the importance of conducting practical work; however, most of them do not carry out practical work with their students due to a lack of time and therefore focus on teaching science content so that they cover the whole curriculum. In Malawi, in order to go to college, learners have to get good grades and be within the allocated quota for that particular district. To make sure that students get good grades, teachers rather spend time drilling[7] (*examination driven instruction*) students rather than conducting practical work or teaching science using time-intensive cooperative learning strategies. During drilling, teachers usually focus on helping students to answer examination questions rather than focusing on students' engagement with content and their

[6] These are strategies where students work in small groups to achieve a particular task. The tasks range from simple ones, such as solving a multi-step problem, to complex ones, such as developing and designing solutions to problems as well as testing their solutions.

[7] "Drilling is a method of instruction characterised by systematic repetition of concepts, examples, and practice problems. Drilling is used as a means of teaching and perfecting a skill or procedure" The common example of drilling practice is the question and answer where a teacher poses a question and provides a model answer for students to master.

understanding. While Kwon, Lee, & Shin (2017) showed the social as well as economic effects of high-stakes examinations, other studies, such as Zhang et al. (2005), showed the effects of these exams on the teachers' instructional strategies during teaching and learning.

Lastly, there is the issue of time constraints that prevent teachers from implementing their beliefs about teaching and learning of science. Time constraints, coupled with other factors, such as the examination-oriented nature of the curriculum, make it increasingly difficult for the teachers to implement their beliefs during instruction. Teachers regularly have to make decisions about the time required to complete an activity, which Lantz & Kass (1987) call "pedagogical efficiency". Hence, the use of time-consuming student-centred instructional strategies is deemed pedagogically inefficient. For instance, Mr MP, who had reform-based beliefs concerning the role of the teacher in a science classroom, relied on traditional methods of teaching during instruction. During a post-classroom observation interview, he spoke about how limited time made it increasingly difficult for him to put his beliefs about the teaching and learning of science into practice. On many occasions, he has to make a decision regarding how much time to devote to a particular activity. For instance, he argued that cooperative teaching techniques (see footnote 6), which research studies (e.g. Brackenbury, 2012; Froyd & Simpson, 2008; Sanaie et al., 2019; Weltman, 2007) show are effective means of engaging students in the teaching and learning process, are time-consuming. Even though "a cooperative learning approach provides the platform for active participation of learners in cognitive, metacognitive and motivational learning areas and helps them set learning goals" (Sanaie et al., 2019, p. 36), Farrell & Lim (2005) report on the resistance of experienced teachers to the use of cooperative instructional strategies as they are time-consuming. While doing the delicate balance of using cooperative learning to engage students in the learning process, the examination-orientated nature of the curriculum causes teachers to use traditional instructional strategies, such as drilling, to prepare students for the national examinations.

In the sections above, I discussed three factors that explain the observed misalignment of teachers' beliefs and practices. These factors work together with other factors to influence teachers' decisions.

### 7.3.3. Nature of science vs TPK

Findings for this study show that the teachers who took part in the study have a good

understanding of the nature of science. However, the teachers did not translate their understanding of the nature of science into practice. This finding is similar to findings of other studies (such as Demirdöğen, 2016; Kiran, 2016). In a study that investigated the interaction between STOs and PCK domains, Kiran (2016) reported that the two participating teachers' beliefs about the NoS did not interact with the PCK domains. Hence, this finding further substantiates the argument that having a comprehensive understanding of the nature of science does not necessarily translate to the incorporation of NoS aspects in the teaching and learning process (Lederman, Lederman, Kim, & Ko, 2012; Lederman & Lederman, 2019). Lederman & Lederman (2019) highlight several reasons that explain this observation such as *pressure to cover content, classroom management and organisation principles, concerns for students' abilities and motivation, lack of instructional intention to teach the NoS, institutional constraints, lack of subject matter knowledge and teaching experience*. While these are presented as some of the general factors that explain this observation and are equally applicable in this study, *lack of instructional intention to teach the NoS, institutional constraints,* and *pressure to cover content* have been found to be more plausible in explaining the observations made in this study. In addition to that, studies show that teachers' exposure to explicit lessons about the NoS alone is not enough (Demirdöğen et al., 2016), teachers need to be helped to develop a PCK for NoS.

Firstly, the teachers' inability to include aspects of the NoS during instruction demonstrate an apparent lack of a PCK for the NoS. While most teachers complained about time constraints, their reasoning, as shown in Chapter 4, clearly demonstrates a lack of PCK for NoS. Researchers (e.g. Demirdöğen et al., 2016; Faikhamta, 2013; Hanuscin et al., 2011) argue that PCK for NoS is imperative if teachers are to incorporate the targeted aspects of the NoS during instruction. For instance, in a critical review concerning teachers' understanding of the NoS, Abd-El-Khalick & Lederman (2000) argued for the importance of the PCK for the NoS. He posited that PCK for NoS would include:

> *"an adequate understanding of various aspects of NoS, knowledge of a wide range of related examples, activities, illustrations, explanations, demonstrations, and historical episodes. These components would enable the teacher to organise, represent, and present the topic for instruction in a manner that makes target aspects of NoS accessible to pre-college students. Moreover, knowledge of alternative ways of representing aspects of NoS would enable the teacher to adapt those aspects to the diverse interests and abilities of*

*learners (p. 692).*

It is apparent from the above quote that PCK for NoS would allow the teachers to integrate NoS aspects in the teaching and learning process. Even though there have been efforts (e.g. Abd-El-Khalick, 2013; Khine, 2012; Kruse, 2008) to improve teachers' understanding of the NoS, studies still show that a comprehensive understanding of the NoS does not translate to classroom practice (Faikhamta, 2013). Since it is the PCK for the NoS that would equip science teachers with the necessary knowledge domain (NoS PCK), teachers would be able to transform NoS content into more accessible units for the students (Supprakob et al., 2016).

While a lack of PCK for NoS explains this observation, policy constraints also contribute to teachers failing to incorporate aspects of NoS into their lessons. Two of these policy constraints are *time*, as well as the *structure of the curriculum*. These two factors have significantly contributed to the observations made in this study. Firstly, when I followed up (post-observation interviews) with the teachers on why they did not incorporate or integrate the NoS in their teaching, most of them cited reasons to do with time. They argued that "limited time" did not allow them to integrate aspects about the nature of science successfully. For instance, one teacher who was teaching at a double-shift[8] CDSS argued that they do not have time for this because, unlike other schools whose lessons last 40 minutes, in his school, each lesson lasts 30 minutes. This impacts on the teachers' ability to include aspects of the NoS. The issue of time is further compounded by the examination-orientated nature of the curriculum. Teachers always have to consider the national examinations their learners will be sitting for. As a result, teachers do not have time to include such aspects when teaching science. Hence, their teaching is limited to only the objectives in the curriculum. Their target is to finish the whole curriculum as fast as possible and devote the rest of the time to drilling the learners for national examinations. One teacher commented that, in two weeks' time, "*I will be finishing*[9] *the whole curriculum, this then would allow me to focus on helping the students prepare for*

[8] Schools which have different sets of learners in the mornings and afternoons, but the same number of lesson hours as pupils in single-session schools, and different teachers for each session. Double-shift schools in Malawi normally have 30-minute lessons rather than the normal 40 minutes for most non double shift schools.

[9] As a precursor to this statement, I collected data in the second term of the academic year. Students sit for national examinations towards the end of their third term. Yet this teacher claimed he was about to finish the curriculum in two weeks' time of the second term (at this time, they had just opened for the second term).

*examinations*." There is a complex interplay between time and examination orientation of the curriculum which places pressure on the teachers to cover science content. This eventually, means less time to cover aspects of the NoS.

Secondly, the lack of interaction between teachers' beliefs about NoS and TPK domains can also be attributed to the "structure of the curriculum". This means the way the Malawian science curriculum has been designed in terms of what the teachers are supposed to teach and the philosophy behind it. In Chapter 4, I showed that the teachers who took part in this study rely on the curriculum for what they are supposed to teach. This was evident when the teachers spoke about their beliefs about teaching and learning of science. The Malawian science curriculum specifies that, despite the realisation that the NoS is essential, it is presented as a "suggested teaching and learning activity" under the core element of "scientific investigations" (see Appendix Q. Extract from the National Science curriculum). This implies that it can be included during instruction or left out altogether. Also, there are no corresponding objectives that specifically address the NoS aspects in the curriculum as a topic or in subsequent topics.

Furthermore, in the recommended textbooks, NoS is treated as a standalone topic. This means that aspects of the NoS are not incorporated into other topics. The implication of this is that, once the teacher teaches that topic, he/she will probably not relate NoS to other topics. Being a suggested teaching and learning activity, compounded by the teachers' lack of a PCK for NoS, makes it increasingly difficult for them to see the importance of incorporating NoS aspects in their teaching of science. Even though other studies (e.g. Khishfe & Abd-El-Khalick, 2002) argue that students are also able to learn about the nature of science implicitly (where there is no explicit mention of NoS), explicit teaching about the NoS has been found to be the most effective approach of teaching it (for example see, Demirdöğen et al., 2016; Hanuscin et al., 2011; Lederman et al., 2012). The explicit approach is where teachers deliberately modify instructions to make the teaching and learning of aspects of the NoS more visible in the learning process. To achieve this, they suggest that teaching and learning should be accompanied by a corresponding "measurable" NoS objective or learning outcome (Demirdöğen et al., 2016). For instance, if a teacher is teaching about atomic structure and the periodic table, he/she might include a nature of science objective, such as, *describe the tentativeness nature of scientific*

*knowledge*[10], so that students are able to demonstrate that scientific knowledge is tentative.

In the above sections, I have raised several issues concerning the interaction between the STOs and TPK domains. There is a complex interaction between STOs and other related factors, such as school ethos, contextual factors, etc. STOs appear to be filtered first by these factors before they influence the teachers' knowledge domains.

### 7.3.4. Apparent uniform interaction between STOs and TPK domain

In chapter 6 I highlighted on the apparent uniform interaction between goals and purposes of science teaching and TPK domains. I substantiated this by showing that goals and purposes of science teaching of both Mr KA and PH, despite being different, interact with specific pedagogical knowledge sub-domain (*instructional strategies*), knowledge of the students' sub-domain (*pre-requisite knowledge*) as well as curriculum knowledge sub-domain (*goals & objectives*). This pattern was also observed with beliefs about teaching and learning of science dimensions of STOs that interacted with specific sub-domains of TPK. Hence, STOs interact with TPK domains to the extent that the interaction is uniform as they appear to interact with specific sub-domains of TPK. One plausible explanation points to a situation whereby the initial teacher training programmes are similar. This makes more sense especially when you consider that TPK domains are canonical and freely available to everyone (Gess-Newsome, 2015). Hence, teacher training institutions tap and use this knowledge pool to develop the knowledge base for the teachers. It also further shows how these institutions might be closely working together for a common good. However, these claims need to be substantiated by

[10] In this objective, the teacher, while teaching the atomic structure, would take students through the various structures of an atom in history. For instance, the teacher may present the following models:

1. Dalton atomic model--1800's
2. Plum pudding model--First proposed by J.J Thomson in in 1904
3. Nuclear model –proposed by Rutherford in 1911
4. Bohr model –proposed by Bohr in 1913
5. Cloud model –proposed by quantum mechanics scientists

A historical discussion of all these models of atomic structure will help the teacher to illustrate to the learners how our knowledge about the structure of the atom has changed over time. Eventually illustrating the tentativeness of scientific knowledge.

empirical evidence.

## 7.4. Implications

In this study, the aim was to examine the interaction between the STOs and TPK domains. The findings suggest that STOs and TPK domains interact in a complicated way. The findings of this study have several implications concerning teacher education as well as theoretical implications which I discuss below according to the sections. However, before I delve into the implications of the study, I would like to point out the differences between the discussion ensued in chapter 6 (*insights or lessons learnt*) and this section. While discussing the lessons learnt from the findings of this study, I particularly focused on the issues that were coming out such as *dominant vs non-dominant* goals, *teachers' multiple goals and purposes of science teaching* and the *apparent alignment of goals to the grade level*. These, as already pointed out, are lessons drawn directly from the findings of the study. On the other hand, in this section, I highlight some 'implications' of the findings of the study. By implication I mean the repercussions of the findings on curriculum development, teacher education as well theory.

### 7.4.1. Implications towards teacher education in Malawi

The finding that suggests that teachers lack PCK for NoS has implications for teacher education in Malawi. Firstly, it suggests the need for reforms in teacher education programs. During teacher training programs, teacher educators should emphasise the importance of NoS in the teaching and learning process. Furthermore, teacher educators should ensure that they do activities (such as the development of lesson plans that explicitly include NoS activities) with pre-service teachers that develop their PCK for NoS. Once this is achieved, teachers will know the importance of explicit teaching of NoS aspects in all topics. For in-service teachers, this could be achieved through the use of already developed PD programs, such as the SMASSE, where they could train teachers on the importance of NoS and the effective ways of making NoS aspects more visible to the students during instruction.

Secondly, the nature of the interaction between STOs dimensions and TPK has revealed an "interaction map" that suggests a teacher training pattern. For instance, most interactions

between teachers' goals and purposes of science teaching as well as beliefs about teaching and learning of science were observed on particular sub-domains of teacher knowledge. For instance, the various goals and purposes of science teaching that teachers held interacted with *goals and objectives sub-domain* of curriculum knowledge. Similarly, these goals and purposes exclusively interacted with *instructional strategies* of pedagogical knowledge. This map reveals a deeper pattern in terms of the knowledge domains which teacher educators emphasise during pre-service programs, which is a gap in teacher training that needs to be properly rectified so that teachers have robust teacher knowledge

### 7.4.2. Curriculum implication

The findings of the present study also have implications linked to the curriculum as follows. The inclusion of the NoS in the new curriculum is a welcome development as the NoS is critical in as far as understanding science is concerned. However, there is a need for curriculum developers to explicitly embed objectives concerning the NoS on every topic. This will ensure that teachers teach about aspect[s] about the NoS every time they are teaching a particular topic. potentially this will help learners to understand and appreciate the nature of science better while it is being taught in context. Furthermore, this will also help to enhance the teachers' PCK about the NoS.

### 7.4.3. Theoretical implications

On the theoretical level, the findings of the study affect the theoretical underpinnings of the STOs. There is a need to further re-examine the notion of STOs to address the following:

- Firstly, Friedrichsen et al (2011) argue for the three dimensions of STOs, i.e., *goals and purposes of science teaching, beliefs about teaching and learning of science,* and *views about the nature of science*. What still remains unclear, however, is the question of the goals and purposes of science teaching. Is it in terms of the curriculum emphases proposed by Roberts (2015) or others?

- Secondly, there is also a need to develop analytical frameworks for the three dimensions. For instance, in their review, Friedrichsen et al. (2011) suggest a number of theoretical and analytical frameworks when looking at STOs, such as the concepts

of curriculum emphasis, the TBI analytical framework, etc. Furthermore, presently, it is frustrating trying to construct research instruments since there are a number of suggestions which potentially would lead to a different understanding of the notion altogether. This has the potential to divert the issues further, similar to the notion of PCK as I showed in the literature review chapter. Hence, like the consensus model of PCK, there should be a consensus model regarding how issues on STOs should be transacted.

- There should be research that specifically targets the understanding of the level of dominance among the STO dimensions. For instance, which are the most dominant and how does their relationship affect the translation of the other dimensions?

### 7.4.4. Limitations

This research study was limited by the fact that I only conducted the study for one month. Hence, it was impossible to observe the teachers on several occasions. The fact that I also observed the teachers only on two lessons implies that other interactions would not have been observed. Hence there is a need for a prolonged study in the field to investigate the interaction of STOs and assessment knowledge as most teachers plan their assessments towards the end of the term.

## 7.5. Summary

In this chapter, I presented a discussion of the findings for each research question. The main purpose was to interpret the findings and provide plausible explanations concerning the findings I reported in the three findings chapters by drawing insights from the literature. Relating to goals and purposes of science teaching, I highlighted in both Chapters 4 and 6 that the teachers who took part in this study held multiple goals and purposes of science teaching and that they appear to be linked to concepts. Since there are several concepts on a topic, each concept might have specific goals hence the multiple goals and purposes of science teaching.

In the same chapter, I discussed the reasons for the misalignment of their beliefs and practices. Both the teachers who took part in the study and the literature agree that context is a determinant factor that can either be an enabler or inhibitor concerning the implementation of teachers' beliefs about teaching and learning in their practices. I also highlighted the issue of

the compartmentalisation of teachers' beliefs about teaching and learning of science. These issues, as I suggest, need further research for an in-depth understanding.

Concerning the interaction between STOs and TPK domains, one of the major issues was the seeming lack of interaction between STOs and teachers' beliefs about the nature of science and TPK domains. For this, I raised the issue of a lack of a PCK for the nature of science, structure of the curriculum as well as the issue of education policy that affect the learning and teaching of science. PCK for the NoS is important when it comes to the translation of beliefs about the NoS into practice.

I discussed the possible implications of the study on both teacher educators as well as research-practice. Specifically, I highlighted the need for teacher educators to make the teaching and learning of the nature of science explicit in terms of how teachers can translate their beliefs into practices. I also highlighted that there is a need to re-examine the concept of STOs and develop a consensus model to improve the teaching and learning of science in our schools.

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# APPENDICES

## Appendix A: Ethical approval letter

**Wits School of Education**

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

24 October 2017

Student Number: 709526

Protocol Number: 2017ECE032D

Dear Bob Maseko

**Application for Ethics Clearance: Doctor of Philosophy**

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:

**Examining the interaction between in-service Physical Science teachers' science orientations with their Professional Knowledge and Skills**

The committee recently met and I am pleased to inform you that **clearance was granted**. However, there were a few small issues which the committee would appreciate you attending to before embarking on your research.

**The following comments were made:**

- Consent forms: remove whichever data collections methods are not applicable – i.e. writing a test; photography
- Check for minor errors in letters to participants

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,

MMaseko

Wits School of Education

011 717-3416

Cc Supervisor: Dr Emmanuel Mushayikwa

**Appendix B. Letter from the District Education Manager**

**REF. NO. SEED/ADM/VOL. II/473** **6th January, 2018**

**FROM** : THE EDUCATION DIVISION MANGER, SOUTH EAST EDUCATION DIVISION, PRIVATE BAG 48, ZOMBA.

**TO** : THE HEADTEACHERS, ZOMBA URBAN SECONDARY SCHOOLS.

## AUTHORITY TO CONDUCT RESEARCH

I write to kindly request your office to allow MR BOB MASEKO, a PHD Student at WITS UNIVERSITY, JOHANESBURG, RSA to undertake research related activities at your institutions focusing on interaction between in-service Physical Science teachers' teaching orientations and Teacher Professional Knowledge (TPK) domain.

I would be most grateful if Mr Maseko, who is also Lecturer at Chancellor College but on study leave, is given all the necessary support and guidance so that his activities are carried out successfully.

I look forward to your usual support and hoping at the same time that you will accord this request all the attention and urgency that it deserves.

M.S.D. ALUFANDIKA

**EDUCATION DIVISION MANAGER**

## Appendix C. Information Sheet for the Head Teacher

From : Bob Maseko
University of the Witwatersrand
Wits School of Education
Private Bag 3
Wits 2050
Johannesburg

**To :** The Head Teacher

Dear Sir,

My name is Bob Maseko I am a PhD student in the School of Education at the University of the Witwatersrand. I am doing research that examines the interaction between science teachers' teaching orientations and Teacher Professional Knowledge (TPK) domains. The aim of this research is to understand how their beliefs about science teaching and learning, their beliefs about nature of science and their beliefs about the goals and purpose of science teaching inform teachers' knowledge.

My research involves interacting with Physical Science teachers that will be selected from your school. The form of interaction will be through interviews with the teachers on how they prepare their lessons, I will also ask the teachers to respond to a questionnaire and prepare Content Representations (CoRes) where they will articulate their reasoning on a particular topic. The Questionnaire-Views on Nature of Science (VNOS) seeks to understand teachers' views about the nature of science. Apart from that, I will also do classroom observations that would complement some of the methods used to collect data for this study. The interview schedules will be between 40-50 minutes.

The main reason I have chosen your school and hence Physical Science teacher(s) is that the teachers themselves have experience in teaching this subject.

I am therefore inviting your school to participate in this research. It is envisaged that the findings of this research will help me understand teacher knowledge and eventually help to inform teacher trainers on the design training as well as Professional Development (PD) programs that ensure the production of quality science teacher teachers who eventually will help in the attainment of vibrant science education.

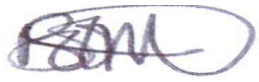
The research participants will not be advantaged or disadvantaged in any way. I will assure them that they can withdraw their permission at any time during this project without any penalty. There are no foreseeable risks in participating in this study. The participants will not be paid for this study.

The names of the research participants and the identity of the school will be kept confidential at all times and in all academic writing about the study. Your individual privacy will be maintained in all published and written data resulting from the study.

All research data will be destroyed between 3-5 years after completion of the project.

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

Yours sincerely,



Bob Maseko

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Email: 709526@students.wits.ac.za

: bobmaseko@gmail.com

## Appendix D. Information sheet for the Teacher

Date: 16 January 2018

Dear Teacher,

My name is Bob Maseko; I am a full-time PhD student in the School of Education at the University of the Witwatersrand.

I am doing research that examines the interaction between science teachers' teaching orientations and Teacher Professional Knowledge (TPK) domains. The aim of this research is to understand how your beliefs about science teaching and learning, your beliefs about nature of science and your beliefs about the goals and purpose of science teaching inform teachers' knowledge.

I, therefore, would like to invite you to take part in an interview, answering questionnaires and classroom observations. All the interviews are planned to last between 40-50 minutes and for classroom observations. I am targeting one-period lessons which typically last between 30-40 minutes. With your permission, I would also like to audio record the interviews as well as videotape classroom observations using digital devices.

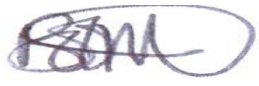
Your experience in teaching Physical Science is the main reason I have selected you to take part in the study. Your participation will help me understand teacher knowledge and in the end, help to design teacher training programs as well as Professional Development programs that ensure the production of quality science teacher teachers who eventually will help in the attainment of vibrant science education.

You will not be advantaged or disadvantaged in any way. Your participation in this study is voluntary, so you can withdraw your permission at any time during this project without any penalty. There are no foreseeable risks in participating and you will not be paid for taking part in this study.

Please let me know if you require any further information.

Thank you very much.

Yours sincerely,



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## Appendix E. Information Sheet to the teachers

From : Bob Maseko
University of the Witwatersrand
Wits School of Education
Private Bag 3
Wits 2050
Johannesburg

**To :** Science Teachers

Date: 16 January 2018

Dear Teacher,

My name is Bob Maseko; I am a full-time PhD student in the School of Education at the University of the Witwatersrand.

I am doing research that examines the interaction between science teachers' teaching orientations and Teacher Professional Knowledge (TPK) domains. The aim of this research is to understand how your beliefs about science teaching and learning, your beliefs about nature of science and your beliefs about the goals and purpose of science teaching inform teachers' knowledge.

I, therefore, would like to invite you to take part in an interview, answering questionnaires and classroom observations. All the interviews are planned to last between 40-50 minutes and for classroom observations. I am targeting one-period lessons which typically last between 30-40 minutes. With your permission, I would also like to audio record the interviews as well as videotape classroom observations using digital devices.

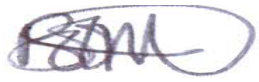
Your experience in teaching Physical Science is the main reason I have selected you to take part in the study. Your participation will help me understand teacher knowledge and in the end, help to design teacher training programs as well as Professional Development programs that ensure the production of quality science teacher teachers who eventually will help in the attainment of vibrant science education.

You will not be advantaged or disadvantaged in any way. Your participation in this study is voluntary, so you can withdraw your permission at any time during this project without any penalty. There are no foreseeable risks in participating and you will not be paid for taking part in this study.

Please let me know if you require any further information.

Thank you very much.

Yours sincerely,



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## Appendix F. Information sheet to the learners

From : Bob Maseko
University of the Witwatersrand
Wits School of Education
Private Bag 3
Wits 2050
Johannesburg

Date: 18 January 2018

Dear Student,

My name is Bob Maseko and I am a student in the School of Education at the University of the Witwatersrand.

I am doing a research that examines the interaction between science teachers' teaching orientations and Teacher Professional Knowledge (TPK) domains. The aim of this research is to understand how their beliefs about science teaching and learning, their beliefs about nature of science and their beliefs about the goals and purpose of science teaching inform teachers' knowledge

My investigation involves interviewing your teachers on their beliefs about teaching and learning, their views about the purpose and goals of science. I will also be asking your teachers to fill a questionnaire that captures their views about the nature of science. I will also do classroom observation where I would like to see how your teacher teaches Physical Science. With your permission, I would like to record these classroom observations. The recordings will be made in such a way that the camera will only be focused on the teacher and not you. I would also like to make it clear that any features that would eventually identify you will be edited out of the video and also that the videos will not be shared by any other person.

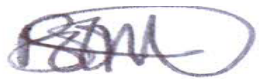
Your names will not be used in the analysis. All information about you will be kept confidential in all my writing about the study. Also, all collected information will be stored safely on a password-protected computer and shall be destroyed between 3-5 years after I have completed my project.

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

I look forward to working with you!

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

Yours sincerely,



Bob Maseko

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Email: 709526@students.wits.ac.za

: bobmaseko@gmail.com

## Appendix G. Information sheet to the parents

**From :** Bob Maseko
University of the Witwatersrand
Wits School of Education
Private Bag 3
Wits 2050
Johannesburg

Date: 8 January 2018

Dear Parent,

My name is Bob Maseko I am a full-time PhD student in the School of Education at the University of the Witwatersrand.

I am doing research that **examines the interaction between in-service Physical Science teachers' teaching orientations and Teacher Professional Knowledge (TPK) domains**. The aim of this research is to understand how teachers' knowledge bases are informed by their beliefs about science teaching and learning, their beliefs about nature of science and their beliefs about the goals and purpose of science teaching.

My research involves interacting with Physical Science teachers that will be selected from your child's school. The form of interaction will be through interviews with the teachers on how they prepare their lessons, I will also ask the teachers to respond to two questionnaires that have been prepared. The two questionnaires are Content Representations (CoRes) where they will articulate their reasoning on a particular topic and Views on Nature of Science (VNOS) questionnaire. This questionnaire seeks to understand teachers' views about the nature of science. Apart from that, I will also do classroom observations that would complement some of the methods used to collect data for this study. The interview schedules will be between 40-50 minutes.

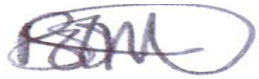
The reason why I have chosen your child's class is that her class is taught by one of the experienced teachers that I am interested in in this study. I would like to observe this teacher teach the class where your child belongs. I would like to ask your permission if I can observe this teacher in teaching your child's class and with your permission, I also would like to record the observations. I would like to make it clear that your child's face will not be recorded, as I will be interested in what the teacher does, the kind of activities he gives to the learners. Hence, no camera will be pointing at learners. Any feature that might help in identifying your child will be edited out of the video.
Your child will not be advantaged or disadvantaged in any way. S/he will be reassured that s/he can withdraw

her/his permission at any time during this project without any penalty. There are no foreseeable risks in participating and your child will not be paid for this study.

Your child's name and identity will be kept confidential at all times and in all academic writing about the study. His/her individual privacy will be maintained in all published and written data resulting from the study.
All research data will be destroyed between 3-5 years after completion of the project.
Please let me know if you require any further information.

Thank you very much for your help.

Yours sincerely,



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**Appendix H. Consent form for Parents**

Please fill in and return the reply slip below indicating your willingness to allow your child to participate in the research project called: **Examining the interaction between in-service Physical Science teachers' teaching orientations and Teacher Professional Knowledge (TPK) domains**

I, _____ the parent of _____

| **Permission to observe my child in class** | **Circle one** |
|---|---|
| I agree that my child may be observed in class. | YES/NO |

**Permission to be videotaped**

| | |
|---|---|
| I agree my child may be videotaped in class. | YES/NO |
| I know that the videotapes will be used for this project only. | YES/NO |

**Informed Consent**

I understand that:

- my child's name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- he/she does not have to answer every question and can withdraw from the study at any time.
- he/she can ask not to be audiotaped, photographed and/or videotape

all the data collected during this study will be destroyed within 3-5 years after the completion of my project.

Sign_____ Date_____

**Appendix I. Consent form for the learners**

Please fill in the reply slip below if you agree to participate in my study called: **Examining the interaction between in-service Physical Science teachers' teaching orientations and Teacher Professional Knowledge (TPK) domains**

My name is _____

**Permission to observe you in class**

I agree to be observed in class. YES/NO

**Permission to be videotaped**

I agree to be videotaped in class. YES/NO

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

**Informed Consent**

I understand that:

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

Sign_____ Date_____

**Appendix J. Consent form for the parents**

Please fill in and return the reply slip below indicating your willingness to allow your child to participate in the research project called: **Examining the interaction between in-service Physical Science teachers' teaching orientations and Teacher Professional Knowledge (TPK) domains**

I, _____ the parent of _____

**Circle one**

**Permission to observe my child in class**

I agree that my child may be observed in class. YES/NO

**Permission to be videotaped**

I agree my child may be videotaped in class. YES/NO

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

**Informed Consent**

I understand that:

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

Sign_____ Date_____

**Appendix K. Consent form the teachers**

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called: **Examining the interaction between in-service Physical Science teachers' teaching orientations and Teacher Professional Knowledge (TPK) domains**

I, _____ give my consent for the following:

| **Permission to review/collect documents/artefacts** | **Circle one** |
|---|---|
| I agree that (SPECIFY DOCUMENT) can be used for this study only. | YES/NO |
| **Permission to observe you in class** | |
| I agree to be observed in class. | YES/NO |
| **Permission to be audiotaped** | |
| I agree to be audiotaped during the interview or observation lesson | YES/NO |
| I know that the audiotapes will be used for this project only | YES/NO |
| **Permission to be interviewed** | |
| I would like to be interviewed for this study. | YES/NO |
| I know that I can stop the interview at any time and don't have to answer all the questions asked. | YES/NO |
| **Permission for questionnaire** | |
| I agree to fill in a question and answer sheet or write a test for this study. | YES/NO |
| **Permission to be videotaped** | |
| I agree to be videotaped in class. | YES/NO |
| I know that the videotapes will be used for this project only. | YES/NO |

**Informed Consent**

I understand that:

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

Sign_____ Date_____

## Appendix L. Goals and purposes of science teaching interview schedule

1. What is the purpose of science education?
2. Why do you teach science?
3. What do students know and be able to do when they learn science?
4. What is your purpose when you teach science?
5. What kind of knowledge and capabilities do your students achieve when you teach science to them?
6. What kind of instruction do you design to achieve your purposes and goals of science teaching?
7. What part of the curriculum do you focus most on in your classroom and why?

**Appendix M. CoRe sample used**

**Teacher NAME……**

**Topic……**

**Class……**

| | **Big Idea 1** | **Big Idea 2** | **Big Idea 3** |
|---|---|---|---|
| What do you intend the students to learn about this idea? | | | |
| Why it is important for students to know this. | | | |
| What else you might know about this idea (that you do not intend students to know yet). | | | |
| What Difficulties & limitations are connected with teaching this idea? | | | |
| What Strategies do you use for determining students' existing ideas about this idea | | | |
| Are there any other factors that influence your teaching of this idea? | | | |
| What teaching procedures would you use to engage students, and why, for this idea? | | | |
| How would you ascertain student understanding of, or confusion about, this idea? | | | |

**Appendix N. Views on Nature of science Questionnaire (VNOS)**

Please insert the following data

**Name :** _____

**Class :** _____

**Experience :** _____

**Date :** _____

My name is **Bob Maseko**; I am a full-time PhD student in the School of Education at the University of the Witwatersrand.

I am doing research that examines the interaction between science teaching orientations and Teacher Professional Knowledge domains. The aim of this research is to understand how their beliefs about science teaching and learning, their beliefs about nature of science and their beliefs about the goals and purpose of science teaching inform teachers' knowledge.

I, therefore, would like to invite you to take part in, answering questionnaires this questionnaire. The questionnaire seeks to capture your views about the nature of science. There are no right or wrong answers to any of the questions. Please carefully read each question and place your answer in the space provided. If you need extra space, feel free to write on the back of each page. **Be sure to use examples to explain/defend each of your answers**.

If you have any questions please send them to 709526@students.wits.ac.za or call +265 996787515.

Thank you very much.

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?

2. Scientists produce scientific knowledge. Some of this knowledge is found in your science textbooks.
   a) Do you think this knowledge may change in the future?

   b) If your answer is ‘‘yes,’’ explain why. If your answer is ‘‘no,’’ explain why. Give an example.

3. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support:

i. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction.

ii. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction.

How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

4. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus as shown below.

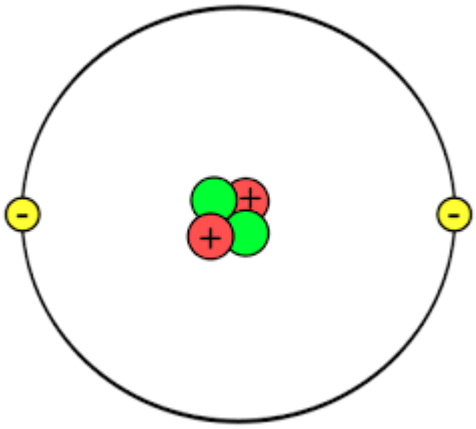


**Figure 2: Diagram of an Atom**

a) How certain are scientists about the structure of the atom?

b) What specific evidence, or types of evidence, do you think scientists used to determine what an atom looks like?

5. Is there a difference between scientific theories and laws? Illustrate your answer with an example.

6. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practised. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values and intellectual norms of the culture in which it is practised.

   a) If you believe that science reflects social and cultural values, explain why and how. Defend your answer with examples.

   b) If you believe that science is universal, explain why and how. Defend your answer with examples.

# END OF QUESTIONAIRE

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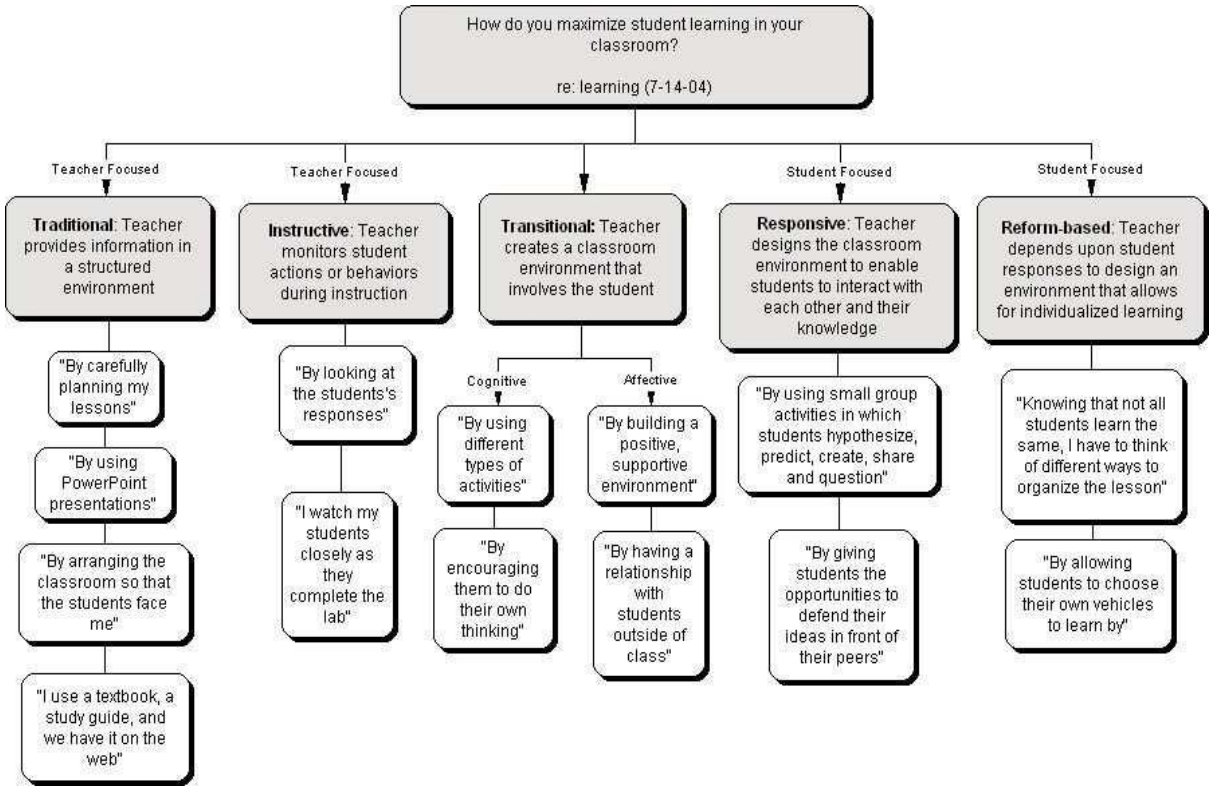
**Appendix O. Beliefs about teaching and learning interview Schedule**

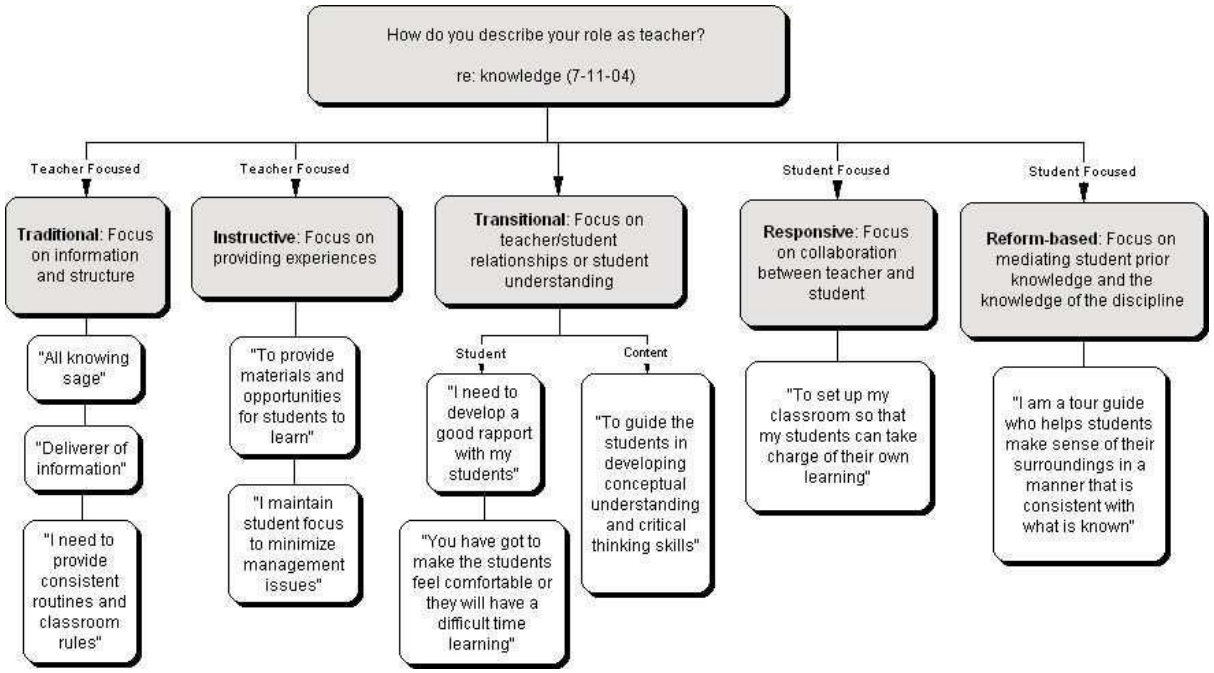
1. How do you maximize student learning in your classroom? (learning)
2. How do you describe your role as a teacher? (knowledge)
3. How do you know when your students understand? (learning)
4. In the school setting, how do you decide what to teach and what not to teach? (knowledge)
5. How do you decide when to move on to a new topic in your classroom? (knowledge)
6. How do your students learn science best? (learning)
7. How do you know when learning is occurring in your classroom? (learning

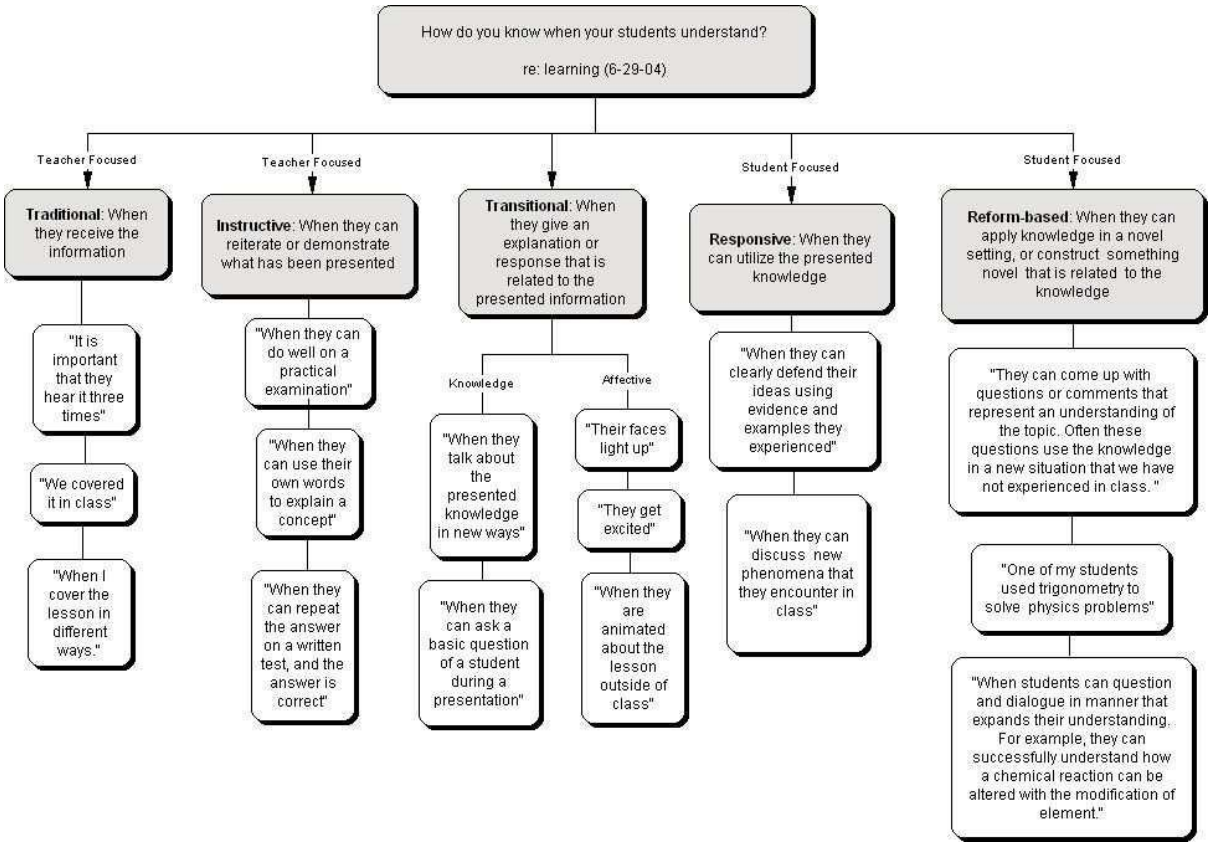
## Appendix Q. Extract from the National Science curriculum

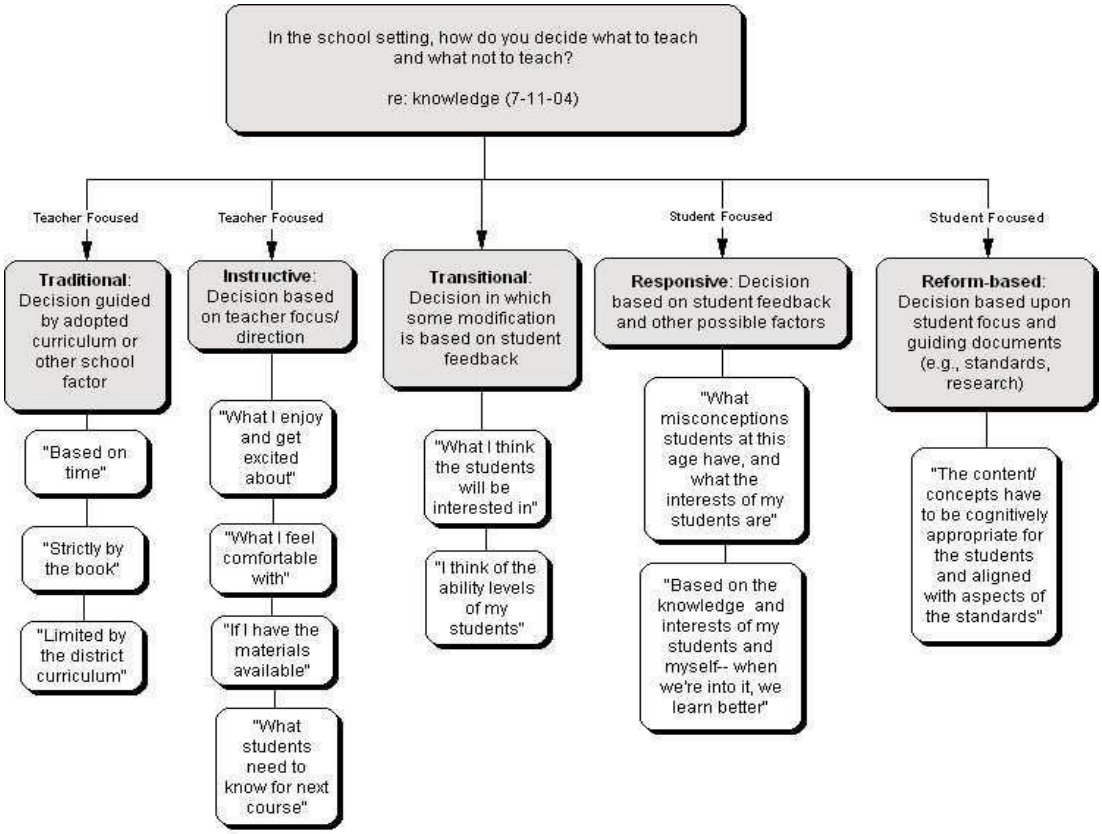
| Assessment standard | Success criteria | Theme/topic | Suggested teaching and learning activities | Suggested teaching, learning and assessment methods | Suggested teaching and learning resources |
|---|---|---|---|---|---|
| We will know this when the students are able to:<br>• demonstrate an understanding of physics as a science | The student must be able to:<br>1 explain why physics is a science | Physics as science | • discussing what science is<br>• describing the nature of science<br>• discussing how physics fits into science disciplines<br>• listing branches of physics<br>- mechanics<br>- nuclear physics<br>- electricity and magnetism<br>- properties of matter<br>- oscillation and waves | • brainstorming<br>• group discussion<br>• oral/written questions<br>• reading out summary<br>• researching<br>• literature review | • handouts<br>• books<br>• charts<br>• internet |
| | 2 describe the history of physics | | • studying literature on the history of physics<br>• narrating the historical advancement of physics | • brainstorming<br>• group discussion<br>• oral/written questions<br>• reading out summary<br>• literature review | • handouts<br>• books<br>• charts<br>• internet<br>• resource persons |

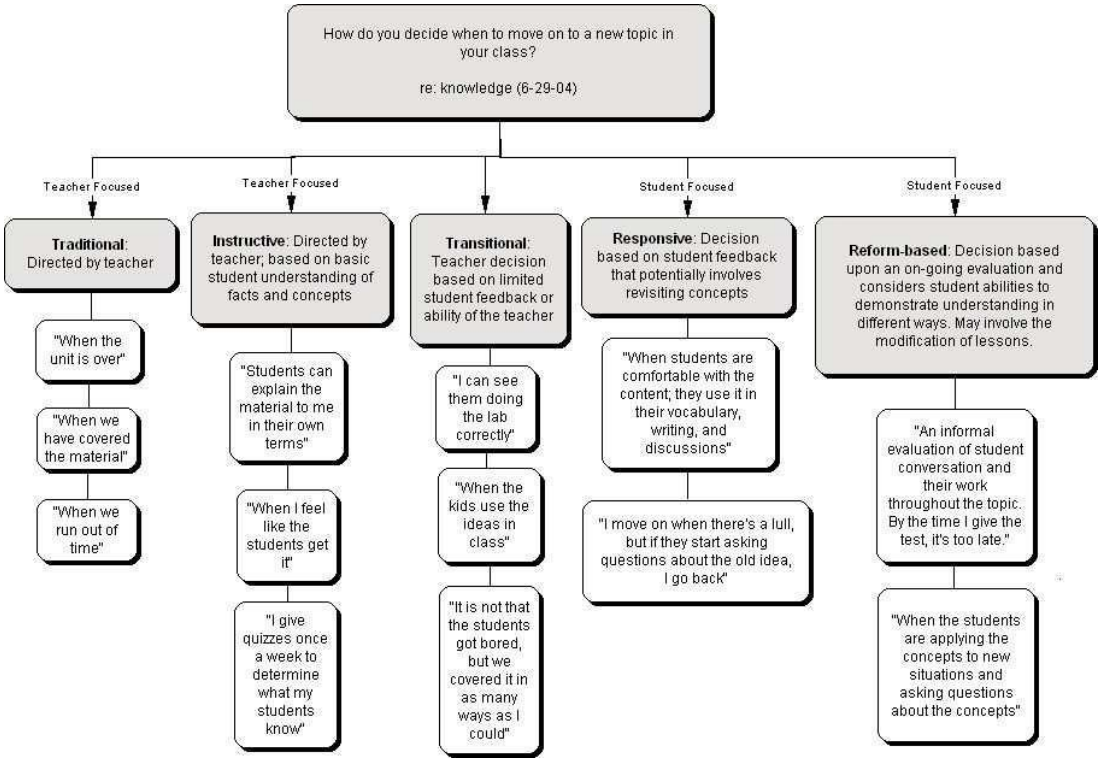
## Appendix R. Beliefs about teaching and learning of science Coding Scheme

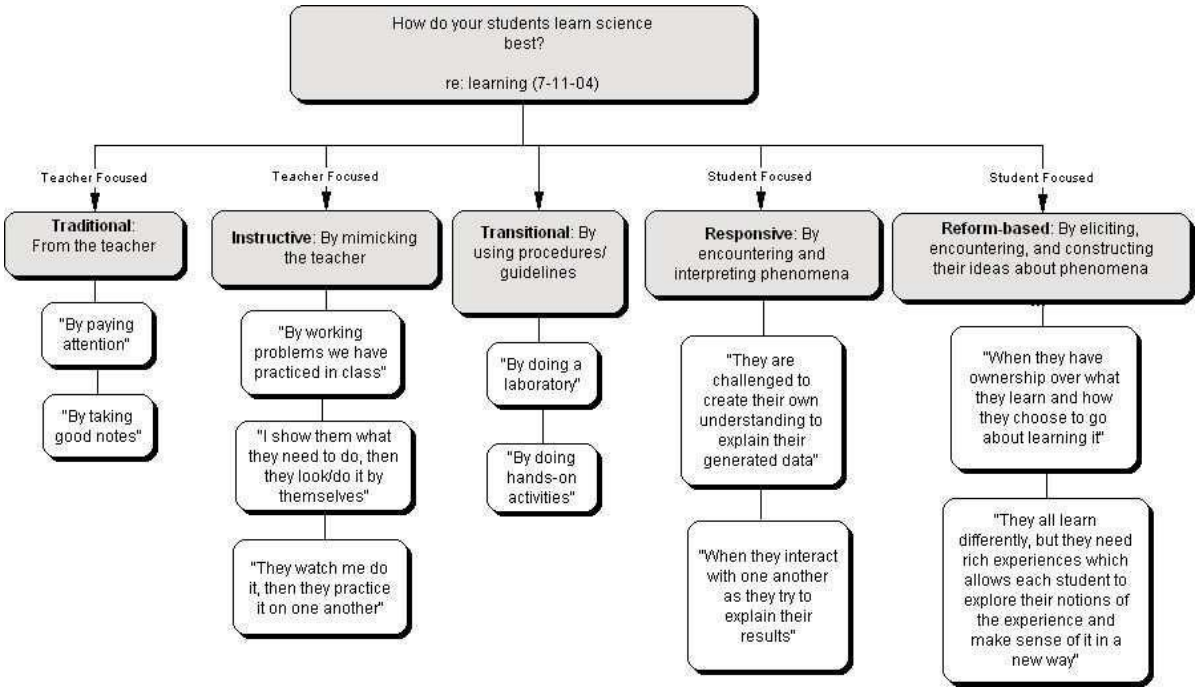


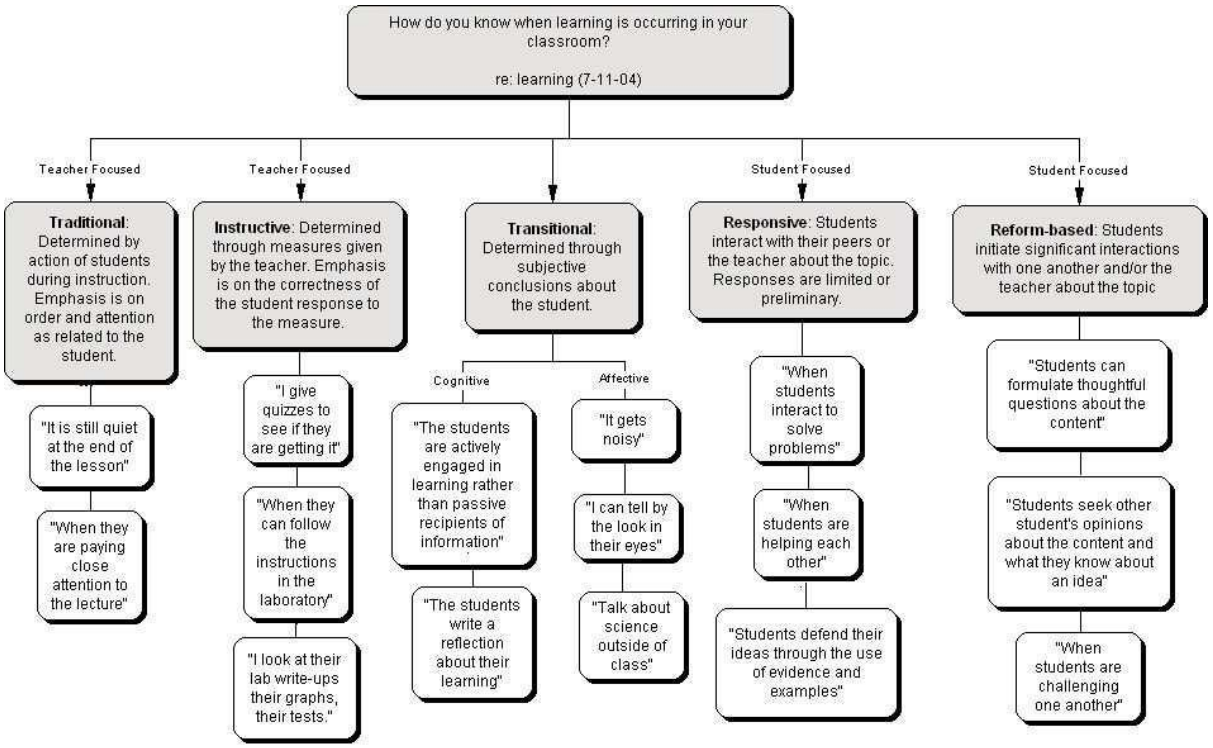




How do you know when your students understand?
re: learning (6-29-04)
Teacher Focused
Traditional: When they receive the information
"It is important that they hear it three times"
"We covered it in class"
"When I cover the lesson in different ways."
Teacher Focused
Instructive: When they can reiterate or demonstrate what has been presented
"When they can do well on a practical examination"
"When they can use their own words to explain a concept"
"When they can repeat the answer on a written test, and the answer is correct"
Transitional: When they give an explanation or response that is related to the presented information
Knowledge
"When they talk about the presented knowledge in new ways"
"When they can ask a basic question of a student during a presentation"
Affective
"Their faces light up"
"They get excited"
"When they are animated about the lesson outside of class"
Student Focused
Responsive: When they can utilize the presented knowledge
"When they can clearly defend their ideas using evidence and examples they experienced"
"When they can discuss new phenomena that they encounter in class"
Student Focused
Reform-based: When they can apply knowledge in a novel setting, or construct something novel that is related to the knowledge
"They can come up with questions or comments that represent an understanding of the topic. Often these questions use the knowledge in a new situation that we have not experienced in class."
"One of my students used trigonometry to solve physics problems"
"When students can question and dialogue in manner that expands their understanding. For example, they can successfully understand how a chemical reaction can be altered with the modification of element."


In the school setting, how do you decide what to teach and what not to teach?
re: knowledge (7-11-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: Decision guided by adopted curriculum or other school factor
"Based on time"
"Strictly by the book"
"Limited by the district curriculum"
Instructive: Decision based on teacher focus/ direction
"What I enjoy and get excited about"
"What I feel comfortable with"
"If I have the materials available"
"What students need to know for next course"
Transitional: Decision in which some modification is based on student feedback
"What I think the students will be interested in"
"I think of the ability levels of my students"
Responsive: Decision based on student feedback and other possible factors
"What misconceptions students at this age have, and what the interests of my students are"
"Based on the knowledge and interests of my students and myself-- when we're into it, we learn better"
Reform-based: Decision based upon student focus and guiding documents (e.g., standards, research)
"The content/ concepts have to be cognitively appropriate for the students and aligned with aspects of the standards"


How do you decide when to move on to a new topic in your class?
re: knowledge (6-29-04)
Teacher Focused
Traditional: Directed by teacher
"When the unit is over"
"When we have covered the material"
"When we run out of time"
Teacher Focused
Instructive: Directed by teacher; based on basic student understanding of facts and concepts
"Students can explain the material to me in their own terms"
"When I feel like the students get it"
"I give quizzes once a week to determine what my students know"
Transitional: Teacher decision based on limited student feedback or ability of the teacher
"I can see them doing the lab correctly"
"When the kids use the ideas in class"
"It is not that the students got bored, but we covered it in as many ways as I could"
Student Focused
Responsive: Decision based on student feedback that potentially involves revisiting concepts
"When students are comfortable with the content; they use it in their vocabulary, writing, and discussions"
"I move on when there's a lull, but if they start asking questions about the old idea, I go back"
Student Focused
Reform-based: Decision based upon an on-going evaluation and considers student abilities to demonstrate understanding in different ways. May involve the modification of lessons.
"An informal evaluation of student conversation and their work throughout the topic. By the time I give the test, it's too late."
"When the students are applying the concepts to new situations and asking questions about the concepts"


How do your students learn science best?
re: learning (7-11-04)
Teacher Focused
Traditional: From the teacher
"By paying attention"
"By taking good notes"
Teacher Focused
Instructive: By mimicking the teacher
"By working problems we have practiced in class"
"I show them what they need to do, then they look/do it by themselves"
"They watch me do it, then they practice it on one another"
Transitional: By using procedures/ guidelines
"By doing a laboratory"
"By doing hands-on activities"
Student Focused
Responsive: By encountering and interpreting phenomena
"They are challenged to create their own understanding to explain their generated data"
"When they interact with one another as they try to explain their results"
Student Focused
Reform-based: By eliciting, encountering, and constructing their ideas about phenomena
"When they have ownership over what they learn and how they choose to go about learning it"
"They all learn differently, but they need rich experiences which allows each student to explore their notions of the experience and make sense of it in a new way"


How do you know when learning is occurring in your classroom?
re: learning (7-11-04)
Teacher Focused
Traditional: Determined by action of students during instruction. Emphasis is on order and attention as related to the student.
"It is still quiet at the end of the lesson"
"When they are paying close attention to the lecture"
Teacher Focused
Instructive: Determined through measures given by the teacher. Emphasis is on the correctness of the student response to the measure.
"I give quizzes to see if they are getting it"
"When they can follow the instructions in the laboratory"
"I look at their lab write-ups their graphs, their tests."
Transitional: Determined through subjective conclusions about the student.
Cognitive
"The students are actively engaged in learning rather than passive recipients of information"
"The students write a reflection about their learning"
Affective
"It gets noisy"
"I can tell by the look in their eyes"
"Talk about science outside of class"
Student Focused
Responsive: Students interact with their peers or the teacher about the topic. Responses are limited or preliminary.
"When students interact to solve problems"
"When students are helping each other"
"Students defend their ideas through the use of evidence and examples"
Student Focused
Reform-based: Students initiate significant interactions with one another and/or the teacher about the topic
"Students can formulate thoughtful questions about the content"
"Students seek other student's opinions about the content and what they know about an idea"
"When students are challenging one another"