

**EXPLORING PCK IN THE PROCESS OF TEACHING RADIOACTIVITY:
STRATEGIES EMPLOYED BY LESOTHO PHYSICS TEACHERS.**

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CANDIDATE'S DECLARATION

I declare that this research report is my own unaided work. It is being submitted for the Degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



Nthoesele Malehlohonolo Hlaela Mohlouoa

7th day of October 2011

NOTE: During the course of my Masters Programme, I changed my names from Maselise Ratlali to Nthoesele Malehlohonolo Hlaela Mohlouoa for reasons of changed marital status, therefore different names on the cover page and the appendices refer to the same person.

ABSTRACT

Some teachers perceive radioactivity as a difficult topic to teach due to its abstract nature. This topic is included at senior secondary level in the combined science syllabus and is taught for the first time to learners who study physics. This study was carried out to make explicit two teachers' PCK (pedagogical content knowledge) on teaching radioactivity and to investigate the role of experience in the PCK of the two physics teachers. Mr Victor had 19 years while Ms Grace had 3 years of teaching experience at the time of this study.

I used pre-observation interviews, video recorded classroom observations, field notes, diagnostic test and post observation discussions as data collection methods. The data was processed using Content Representation (CoRe) and Pedagogical and Professional experience Repertoires (PaP-eRs) as methodological tools to document and portray the teachers' PCK in teaching radioactivity. The CoRe that helped to give insights into how the two teachers framed the topic of radioactivity was constructed from the pre-observation interview data and video recorded classroom observations transcripts. The PaP-eRs were constructed from video recorded classroom observation transcripts and field notes and they were narratives of the classroom practice of the teachers. I also used the model of Rollnick *et al.* (2008) to analyse data.

This study has not come out clear on total absence of PCK in Ms Grace as a beginning teacher. There are some very good aspects that have been demonstrated by Ms Grace that have not been demonstrated by Mr Victor with reference to the topic specific strategies. Both teachers showed that they had a repertoire of teaching strategies to suit their teaching context. As Mr Victor did, Ms Grace as a beginning teacher employed some effective strategies to suit her learning demands and this indicated that the teachers were able to manifest their well developed PCK when the four knowledge domains that generate teachers' PCK were integrated.

Pertaining to knowledge of assessment and curricular saliency, there were no observable PCK differences between the two teachers. The study showed that Mr Victor used a variety of representations to teach radioactivity while Ms Grace's use of representations was more limited. Through the use of the model of Rollnick *et al.* (2008), I indicated that Mr Victor had well developed PCK while Ms Grace's was less developed with regard to representations used. The manifested knowledge of various representations for Mr Victor was produced from the integrated knowledge of the four knowledge domains in the model. The diagnostic test revealed

that Mr Victor had required subject matter knowledge to teach within the syllabus he was teaching. Ms Grace's subject matter knowledge seemed fragile. The existence of PCK in Ms Grace implies that both experienced and beginning teachers can learn from each other to improve their teaching.

DEDICATION

To my beloved mother 'Makhutlang Hlaela (May her soul rest in peace)

My husband John Mohlouoa

And my daughter Kananelo Ratlali

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LIST OF ACRONYMS

PCK: Pedagogical content knowledge

SMK: Subject matter knowledge

CoRe: Content Representation

PaP-eRs: Pedagogical and Professional experience Repertoires

MOET: Ministry of Education and Training

COSC: Cambridge Overseas School Certificate

CHAPTER 1: INTRODUCTION

1.1. Introduction

Some teachers consider radioactivity as one of the more difficult physics topics to teach because of the abstract nature of the topic. As a way of helping their learners understand, physics teachers use multiple strategies to transform their knowledge of the subject matter into a form that can easily be understood by learners. Shulman (1986) defined the knowledge of transforming subject matter into the teachable form that can be understood by learners as pedagogical content knowledge (PCK). I investigate PCK in teaching strategies that are used by two Lesotho physics teachers to teach radioactivity at high school level. In this study, teaching strategies are viewed as the actions that are engaged in by the teacher to help learners understand concepts. While PCK has been studied in experienced teachers teaching other topics such as isotopes (Geddis, Onslow, Beynon & Oesch, 1993), chemical equilibrium (van Driel, Verloop & de Vos, 1998) and the amount of substance and chemical equilibrium (Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008) not as much has been done on PCK of physics teachers teaching radioactivity. This study therefore seeks to add knowledge on PCK in physics teachers through exploring PCK in the teaching of radioactivity.

1.2. Context

I carried out this study in two schools in Maseru, Lesotho. Lesotho is a developing country that is landlocked within South Africa. Lesotho has a shortage of qualified science teachers and a large number of poorly resourced schools (Qhobela, 2008). The country is characterized by the poor teaching and learning conditions in schools (Qhobela, 2008). Qhobela outlines these conditions as: absence of laboratories, lack of laboratory equipment and chemicals, empty libraries, overcrowded classrooms and laboratories, lack of some teaching and learning facilities such as computers and teaching aids. The government of Lesotho has introduced free compulsory primary education and this has increased enrolment at the primary and secondary level (Nyabanyaba, 2008) contributing to overcrowded classrooms. Some of the problems contributing to poor education quality in this country are stated by the Ministry of Education and Training (MOET) (2005) as, “high pupil-teacher ratios and inadequately trained teachers” (p.17).

The education system in Lesotho consists of 12 years of schooling; 7 years at the primary level, 3 years at the junior secondary level and 2 years at the senior secondary level. At the primary level and junior secondary level, science is a compulsory subject that integrates biology,

chemistry and physics (Mokuku, 2001). However at the senior secondary level science is not compulsory and those choosing science, study different combinations of science subjects such as biology, combined science (physics and chemistry) (Nyabanyaba, 2008). Teachers who teach junior secondary science generally also teach senior secondary science. Specialisation in science subjects begins at the senior secondary level (Qhobela, 2008). The combination of subjects to be studied at this level depends on the school administration. Some schools choose learners who performed well at the junior secondary level to study science subjects while at other schools learners choose to study science subjects even if they performed poorly at the junior secondary level. In both schools in this study, combined science students had a pass in both junior secondary mathematics and science so the classes in both schools comprised mixed ability students as students were not streamed according to the grades they got.

The qualifications of teachers vary. Some schools have qualified science teachers while others do not. Qualified teachers' qualifications vary from MSc, BSc, diploma and certificate in science education. Learners' enrolment also differs in schools; some schools are overcrowded with about 60 learners per class while others have a manageable number of about 20 learners per class. English is the official medium of instruction in Lesotho high and upper primary schools but most learners and teachers speak English as an additional language, they are mostly Sesotho first language speakers. Some schools are more resourced than others in terms of laboratory equipment, qualified teachers and libraries that may enhance the study of science. Science teachers teach science differently depending on their working environment, their teaching experience, the type of students they are teaching and their subject matter knowledge. In Lesotho, the concept of radioactivity is introduced at senior secondary level in Form E¹. This is the final year that prepares learners for the Cambridge Overseas School Certificate (COSC) Examinations at the O-level (Mahao, 2003) in addition to developing learners into scientifically literate citizens. The content covered in this topic is; detection of radioactivity, characteristics of the three types of emission, nuclear reactions, half-life and safety precautions (MOET, 2010): See (appendix 21) for details.

1.3. Problem statement

As mentioned above, many teachers find radioactivity an abstract topic that is difficult to teach (Lungu, 2009). Learners encounter radioactivity for the first time at Form E level often towards the end of the year. It has been a concern that students do not perform well in science subjects

¹ Form E level is equivalent to grade 12.

and combined science 5124 is not an exception. Qhobela (2008) showed that there has been a consistent poor performance in science subjects for students who sat for different science subjects' examination from 1997 to 2004. Questions on radioactivity are asked almost every year in the COSC combined science 5124 (physics and chemistry) examination, in both paper 1 and paper 2 contributing to the total marks that students get to pass. This poor performance needs to be improved.

Some physics teachers in Lesotho are professional teachers who have studied physics content at tertiary level up to a diploma level, equivalent to year 1 physics, some have learned other science subjects other than physics and they teach physics because graduate mathematics and science teachers leave Lesotho for better job opportunities in other countries (Miric, 2009). Mokuku (2001) asserts that the predominant method for science teaching in Lesotho secondary science teachers is the lecture method. Hence, a need to use multiple teaching strategies in order to enhance learners' performance therefore exists. Traditionally, teacher-centred methods are the norm, even more so where teachers lack subject matter knowledge (Gess-Newsome, 1999). For teachers with a lack of pedagogical content knowledge, it may be difficult to teach this topic for understanding and this may lead to bad performance of learners in this topic. Tekkaya, Rochford, Moru, Inal and Demirtas, (2003) state that teachers believe that better teaching methods might improve students' attitude towards science, increase students' interest in science and with the better methods to teach science, teachers might be able to teach effectively even if there is lack of resources.

1.4. Aim of the study

The aim of this study is to make explicit two teachers' PCK on teaching radioactivity through a systematic investigation into their teaching of radioactivity and to understand their PCK better. The study was also done to investigate the role of experience in the PCK of the two physics teachers.

The focus of this study is on capturing and documenting the PCK of two teachers teaching radioactivity. The study is also aimed at looking at how PCK is manifested in certain teaching strategies that these teachers use specifically for the teaching of radioactivity.

1.5. Research questions

1. How can the PCK of the two teachers be captured and portrayed?
2. How is the PCK of the two teachers manifested in their teaching of radioactivity?
3. What is the role of experience in the PCK of two physics teachers?
4. What is the SMK of two physics teachers of different experience?

1.6. Rationale

In a study carried out in Malawi, Lungu (2009) found that many teachers considered radioactivity as a difficult topic to teach. This might also be the case with physics teachers in Lesotho. For this reason, it would be a good deed to carry out a close study of two teachers teaching the topic. Teachers' knowledge of teaching certain topics in science is rarely written down therefore through doing a close study in the teaching of radioactivity; I would be able to document this teachers' knowledge for other teachers to access it. As Miric (2009) states that science is mostly taught by novice teachers in Lesotho, this study might therefore help the novice teachers to learn more on how radioactivity is taught by other teachers, for them to adjust their teaching strategies to forms that can help learners understand better and to reflect on their teaching. Of the two teachers investigated in this study, one had 19 years and the other had 3 years teaching experience. Both teachers were qualified and both confident to teach radioactivity and willing to be observed teaching. The difference in experience would help to reveal the role of experience in teaching certain topics. Through this study science teachers in Lesotho may access ways of developing effective science teaching strategies to make radioactivity easier to teach. As a concerned physics teacher about poor combined science performance in Lesotho, I wanted to conduct the study to look at how physics teachers teach this topic as this would give insight into how teachers deal with the teaching difficulties in this topic that might lead to either bad or good performance, which might even reflect on the teaching approaches in other combined science topics or other science disciplines.

Radioactivity is an important topic which is included in the syllabus and also relates to learners' daily life, so it is important that learners are taught concepts on radioactivity. Millar, Klaassen and Eijkelhof (1990) argue that radioactivity often appears in media for public debate and there is a need to teach learners about radioactivity so that they may contribute their knowledge in public debate, knowing the basic concepts and the terminology in radioactivity. In addition, learners may need to know that while radioactivity has applications which make their life better,

such as in medicine, it can also be dangerous if people do not know the safety precautions they need to take against radioactive radiation. Anjos, Facure, Lima, Gomes, Santos, Brage, Okuno, Yoshimura and Umisedo (2001) indicate that many people are not aware that the same ionizing radiation used in medical purposes is the one causing nuclear accidents and argue that if learners are taught about radioactivity at school, radiological accidents could be avoided in cases where there are nuclear accidents such as the one that has recently occurred in Japan. There are learning difficulties in radioactivity which learners face. These include misconceptions about half-life and stability of a nucleus (Nakiboglu & Tekin, 2006) of which through this study, I wanted to show how these teachers dealt with them in class. Doing a study on this topic would also benefit me as a physics teacher, studying the challenges that other teachers meet while teaching the topic and to see how they resolve their challenges, by so doing developing my PCK as I study other teachers' PCK in this topic.

1.7. Sequence of the research report

Chapter 1 is the introduction of the study. In chapter 2, the theoretical framework with regard to PCK is discussed and the literature germane to this study is reviewed. The teaching and learning difficulties related to the teaching of radioactivity are considered together with the teaching strategies that are engaged by physics teachers to teach physics.

In chapter 3, I elaborate on how the research has been carried out; looking at the research design, its rationale, the methods and instruments that I used to collect data and the discussion on gaining access to schools and teachers. I also discuss how trustworthiness was ensured in this study.

Chapter 4 presents the portrayal of PCK of two physics teachers teaching radioactivity. This is part of results analysis where CoRes (Content Representations) and PaP-eRs (Pedagogical and Professional-experience Repertoires) as analysis instruments have been used to capture, document and portray the PCK of the two teachers. These instruments have been used to answer question 1 and 3 of my research questions:

- How can the PCK of these teachers be captured and portrayed?

And

- What is the role of experience in the PCK of two physics teachers?

Chapter 5 is divided into two sections: ascertaining teachers' subject matter knowledge and the teaching strategies employed by Lesotho physics teachers. One section deals with the analyses of the diagnostic test the other section discusses the PCK in teaching strategies employed by Lesotho physics teachers. The chapter attempts to answer the following research questions:

- How is the PCK of the two teachers manifested in their teaching of radioactivity?

And

- What is the SMK of two physics teachers of different experience?

Conclusions and recommendations made from the study are discussed in chapter 6.

CHAPTER 2: THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1. Introduction

In this chapter, pedagogical content knowledge (PCK) as an academic construct is discussed with respect to how different authors conceptualise it, how it informs the observable teachers' classroom practice and its topic specific nature. A model of capturing, portraying and documenting PCK to make the teachers' teaching knowledge accessible to both beginning and experienced teachers is also reviewed. Empirical studies guided by PCK are looked at to show how this construct has been used. Central to this study is the teaching of radioactivity as a topic in physics at high school level; therefore the teaching and learning difficulties in this topic are discussed together with the strategies that physics teachers engage for different reasons to teach this topic.

2.2. Pedagogical content knowledge

The idea of pedagogical content knowledge (PCK) was coined by Shulman (1986) who observed that teacher education and research into science teaching concentrated more on generic pedagogical knowledge neglecting the subject matter knowledge which informs teachers' instruction, Shulman refers to this disregard of subject matter knowledge as the "missing paradigm" (p. 6). He further proposed that teacher knowledge that grows in the mind of a teacher can be understood through distinguishing three categories namely; subject matter knowledge, pedagogical content knowledge and curricular knowledge. In a later paper, Shulman (1987) broadened these categories and added four more categories that constitute the knowledge base of teachers; general pedagogical knowledge, knowledge of learners, knowledge of educational context and knowledge of educational ends, purposes and values.

Shulman (1987) considered pedagogical content knowledge to be the most important of the above categories because it integrates both content and pedagogy. This integration results in comprehension of how the concepts of certain topics can be presented in forms of representations, how the concepts can be organized and adapted in relation to the type of students taught, their interests and different abilities. He claimed that this category differentiates a teacher from a content specialist. According to Shulman, it is important for a teacher to be able to identify the most important ideas to be learned in certain topics and to identify the peripheral ideas for students to develop a good understanding of subject matter knowledge.

After Shulman (1986, 1987), other scholars conceptualized PCK in different ways, incorporating knowledge components that are included to form PCK as shown in the table created by Kind (2009a).

Table 2.1: Different models of pedagogical content knowledge. Adapted from Kind (2009b)

Authors	Representations and instructional strategies	Students' subject specific learning difficulties	Purposes/ orientations/ nature of science	Curricular knowledge	Subject matter knowledge	Context for learning	General pedagogy/ classroom management	Assessment	Socio-cultural issues	School knowledge
Shulman (1987)	P	P	K	K	K	K	K	O	O	O
Grossman (1990)	P	P	P	P	K	K	K	O	O	O
Magnusson, Krajcik and Borko (1999)	P	P	P	P	K	K	K	P	O	O
Marks (1990)	P	P	O	P	P	O	O	O	O	O
Fernández-Balboa and Stiehl (1995)	P	P	P	O	P	P	O	O	O	O
Koballa, Gräber, Coleman and Kemp (1999)	O	P	O	P	P	P	P	P	P	O
Cochran, deRuiter and King (1993)	O	P	O	P	P	P	P	O	O	O
Veal and MaKinster (1999)	P	P	P	P	P	P	P	P	P	O
Banks, Leach and Moon (2005)	O	O	O	O	P	O	P	O	O	P
Bishop and Denley (2007)	O	O	O	P	P	P	P	O	O	O
Rollnick, Burnett, Rhemtula, Dharsey and Ndlovu	K	P	O	K	P	P	P	K	O	O
Geddis, Onslow, Beynon and Oesch (1993)	P	P	O	P	K	O	O	O	O	O

Notes: 'P' shows components believed to comprise PCK; 'K' denotes a component in a teacher's knowledge base; 'O' shows components not discussed explicitly.

There are different explanations of what PCK is. Pedagogical content knowledge is the knowledge which relates content to its teachability (Shulman, 1986). Shulman indicated that teachers' pedagogical content knowledge includes:

the most useful forms of representations of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others (Shulman, 1986, p. 9).

It follows that a teacher with well developed PCK would be viewed as a teacher who has multiple ways of presenting the content learned, having informed choices of the teaching approaches involved in a certain topic for particular learners with certain learning difficulties on the topic. Cochran, DeRuiter and King (1993) refer to PCK as pedagogical content knowing (PCKg) because they consider it as a process of knowing how to teach in which this knowledge is constructed by integrating the knowledge components rather than a product of the combined knowledge components. Magnusson, Krajcik and Borko (1999) describe PCK as a unique domain of teacher knowledge that results from the transformation of different types of knowledge for teaching. They also regard PCK as the knowledge of instructional strategies suitable for specific topic and the knowledge of reasons associated with the choice of the teaching strategies to address learning difficulties coupled with the topic being taught. According to Shulman (1986), pedagogical content knowledge incorporates prior knowledge of students of a particular age and the knowledge of teaching strategies which can be helpful to learners' understanding of the subject being taught.

Bishop and Denley (2007) view PCK as an amalgam of the six knowledge base categories for teaching which were proposed by Shulman (1987). In this model, the separate categories of the knowledge base are believed to be discrete but the professional knowledge results from the combination of all the separate knowledge base categories which produce PCK. This means that as discrete these categories are, their combination produces a different understanding which is different from individual categories. As individuals, these knowledge bases do not result in rich PCK but their combination which is different from each category results in the deep PCK of a teacher. This implies that the observable knowledge of teaching results from integrated categories of the knowledge base for teachers. There is a similarity between this model and that of Cochran *et al.* (1993) in that PCK is seen as a result of integrating knowledge bases and is considered a dynamic construct that develops with experience and with addition of knowledge

from research. The difference in these models is that Cochran *et al.* (1993) take into account the integration of four knowledge base categories to the formation of pedagogical content knowing, leaving out the knowledge of educational values and purposes and knowledge of curriculum while Bishop and Denley (2007) include these two knowledge base categories in the blending of knowledge bases that results in the understanding of teaching that the teacher has.

Teaching comprises acting and reasoning, that is for every action a teacher takes during instruction there should be a reason for doing that and the choices are guided by the knowledge base of the teacher (Shulman, 1987). Magnusson, Krajcik and Borko (1999) agree with Shulman that teachers draw from several types of knowledge that they transform in order to teach learners for understanding. Rollnick, Bennett, Rhemtula, Dharsey and Ndlovu (2008) provide a model that includes Shulman's (1987) model of categories of the knowledge base for teachers but alter this model by classifying the categories of the knowledge base into knowledge domains for teaching and manifestations. This model is also similar to that of Cochran *et al.* (1993) that integrates the knowledge base components to form teachers' PCK. Combined together, the knowledge domains integrate to form the teachers' PCK which results in classroom manifestations which can be seen. These knowledge domains are: "knowledge of subject matter, knowledge of students, general pedagogical knowledge and knowledge of context" (Rollnick *et al.*, 2008, p. 1380). Manifestations refer to observable teaching practices in the classroom. Although the model does not cover all manifestations in classroom, a few chosen manifestations are representative of those not included in the model and these include; "subject matter representations, topic-specific instructional strategies, curricular saliency and assessment" (Rollnick *et al.*, 2008, p.1380). The model is shown below and each category in the model will be discussed in detail.

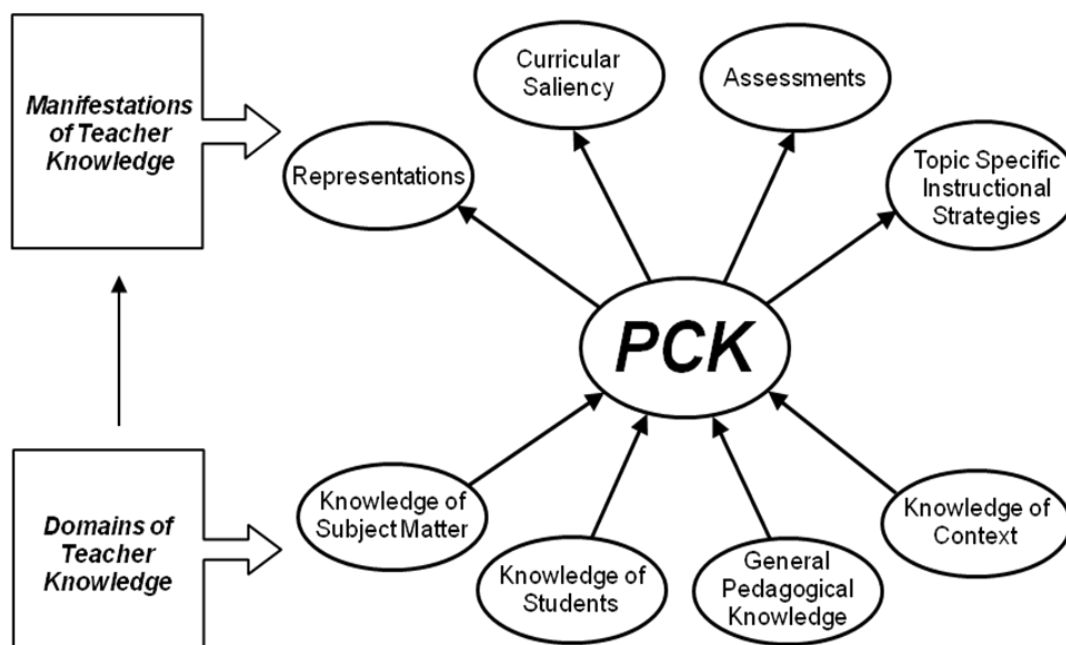


Fig. 2.1: Model of Rollnick *et al.* (2008)

The categories of the knowledge domains that produce teachers' PCK are described below. The description of the teachers' knowledge domains is taken from (Rollnick *et al.*, 2008, p. 1381).

Table 2.2: Teachers' knowledge domains

Domain	Nature of knowledge
Knowledge of subject matter	The teacher's raw untransformed SMK.
General pedagogical knowledge	Understanding what counts as good teaching, the best teaching approaches in a given context, informed by knowledge of applicable learning theories.
Knowledge of students	Appreciation of students' prior knowledge, how they learn, their linguistic abilities, and interests and aspirations.
Knowledge of context	All contextual variables influencing the teaching situation, e.g., availability of resources, class size, students' socio-economic background, curriculum, the situation in the country, classroom conditions, and time available for teaching and learning.

There is a debate on how subject matter knowledge (SMK) relates to PCK. For example, (Rollnick *et al.*, 2008; Bishop & Denley 2007; Cochran *et al.*, 1993) consider SMK to be integrated with other knowledge components to produce PCK while Kind (2009b) in agreement with Shulman (1986) contend that SMK is separated from PCK but teachers transform SMK using PCK to teach effectively. Despite this debate, all of these authors regard SMK as an important aspect in teaching. For example, Shulman (1986) contends that for a teacher to teach any subject; the teacher must have the knowledge of content in that subject. This means that

content knowledge is the basic requirement for teachers to teach in different domains as Shulman further argues that a teacher should have knowledge of concepts of the domain taught. Cochran, DeRuiter and King (1993) also consider subject matter knowledge as one of the essential ingredients that form teachers' PCK. According to Shulman (1987), a teacher should have a broad knowledge of subject matter. This will enable the teacher to help students understand by engaging many different ways of explaining concepts and principles to students of different abilities and characteristics in different contexts. Park, Jang, Chen and Jung (2011) contend that teachers' content knowledge is necessary but not sufficient for the teachers' highly developed PCK. They point out that the teacher's content knowledge should be integrated with the teachers' knowledge of students' reasoning process around a particular concept for the teacher to have advanced PCK. While it would be expected that content knowledge would develop with experience, Hoz, Tomer and Tamir (1990) found that the level of experience has no effect on subject matter knowledge.

Manifestations of teacher knowledge

a. Representations

According to Shulman (1986), a teacher should be able to construct or provide alternative representations in the form of examples, illustrations, analogies or explanations that would enable students to understand the topic being taught. Shulman (1986) indicates that these forms of representations may develop from research or through the experience that one has in teaching. Geddis and Wood (1997) add models, simulations and metaphors as other forms of representations that can be used by the teachers. Treagust, Chittleborough and Mamiala (2003) indicate that macroscopic, symbolic and sub-microscopic levels of representations are used by chemistry teachers to explain chemical phenomena. This study was done on chemistry teachers' use of these different types of representations but the representations are relevant to the teaching of radioactivity because this topic also involves chemical formulae, chemical equations and sub-microscopic particles such as neutrons, electrons and atoms. According to Treagust *et al.* (2003), macroscopic level of representations involves the observable phenomena that draw in students' daily life experiences. The symbolic level involves pictorial, physical and computational forms that include equations, graphs, analogies and models. Rollnick *et al.* (2008) define representations in a similar manner to Shulman (1986) and argue that effective representations that can be used in teaching result from the blending of the four knowledge domains in the model above.

b. Curricular saliency

Geddis, Onslow, Beynon and Oesch (1993) refer to curricular saliency as the importance of the topic to the overall curriculum that teachers are dealing with. According to Geddis *et al.* (1993), experienced teachers manage to cover the curriculum they teach because of their ability to select the important content to be taught looking at what is central and peripheral in the taught topics. This ability lacks in novice teachers. This ability is the one that makes a teacher include or omit some content and determines the depth of how the teacher should go about teaching a particular content. The teacher decides what to teach based on the knowledge of context and the motivation for teaching what the teacher deems important to include or exclude (Geddis *et al.*, 1993).

c. Assessment

Assessment involves the teachers' choice for both formative and summative tasks and this is shaped by the teachers' knowledge of the subject matter (Rollnick *et al.*, 2008). Magnusson, Krajcik and Borko (1999) argue that knowledge of assessment includes the knowledge of what dimensions of scientific literacy are important to assess in a certain topic and the methods of assessment that can be used to assess that specific content. The knowledge of assessment includes the teachers' understanding of the procedures or approaches that would be suitable to test students' understanding of important sections of scientific learning and the advantages and disadvantages of using certain ways to evaluate students' understanding (Magnusson *et al.*, 1999).

d. Topic specific instructional strategies

The teachers' knowledge of topic specific strategies means the knowledge of specific strategies that are useful for helping students understand concepts in the topic being taught (Magnusson *et al.*, 1999). These include the knowledge of topic specific representations from which when they lack, the teacher lacks flexibility in their teaching when they are confronted with students' questions or misconceptions. The knowledge of topic specific activities is also considered as the aspect of the teachers' PCK (Magnusson *et al.*, 1999). The activities include experiments, simulations and problems that the teacher can use to improve understanding of concepts and their relationship in the topic. Magnusson *et al.* (1999) argue that the teacher should not only know topic specific instructional strategies but should also know the limitations and strengths

associated with the strategies used in order to choose the strategies that would be more useful in teaching the topic.

The model of Rollnick *et al.* (2008) is the model that I used in this study to explore the teaching of radioactivity. This model proved useful in my study in that it enabled me to infer the teaching practice drawing from the knowledge domains and then helped me to categorise data into the categories of manifestations which were observable in classroom practices. This model demonstrates the teachers' knowledge domains that integrate to form the teachers' knowledge that can be observable in the classroom practice of the teacher; it therefore has been helpful to make the teaching knowledge of the teachers to be explicit. According to Rollnick *et al.* (2008), teachers obtain their knowledge of teaching from the integrated domains of teacher knowledge which are shown on the model above. This model has been beneficial in this study in that it helped me to come up with description of the PCK in the strategies that the teachers used from the categories of manifestations and to infer teachers' pedagogical reasoning for the strategies they used to teach the topic of radioactivity from the categories of knowledge domains. The manifestations that emerged out of data give insight into the teachers' PCK with regard to the way they taught radioactivity.

2.3. Topic specific nature of PCK

PCK can be differentiated at different levels being the general PCK, domain specific PCK that is more distinct than general PCK and topic specific PCK that is more explicit than domain Specific PCK (De Jong, Veal & van Driel, 2002). General PCK does not separate the knowledge of teaching certain content into disciplines but domain specific PCK is the knowledge of teaching content in specific domains such as physics, chemistry or biology. Topic specific PCK is the most distinct level of PCK that applies only to the knowledge of teaching specific content areas such as radioactivity in the domain of physics. According to De Jong *et al.* (2002), the knowledge of representations which can be used to teach different topics in one domain may differ even though there can be representations that can apply across the domain. A teacher develops and accumulates knowledge of teaching a particular topic in a certain way that is unique to the concept being taught (Hashweh, 2005). According to Veal and MaKinster (1999) common topics such as the atomic theory common in both chemistry and physics are taught differently within these different subjects; the teaching strategies, representations and demonstrations used differ from subject to subject. It follows that physics teachers have their way of teaching certain topics which differs from other science teachers teaching the same topic.

2.4. Capturing, portraying and documenting PCK

Hiebert, Gallimore and Stigler (2002) argue that professional knowledge base for teaching is personal and difficult to share and contend that this knowledge

Must be public, it must be represented in a form that enables it to be accumulated and shared with other members of the profession and must be continually verified and improved (Hiebert, Gallimore & Stigler, 2002, p. 4).

To show how teachers learn in various forms to improve their professional knowledge, Hiebert *et al.* (2002) analysed cases in which two teachers were teaching in different disciplines. In one case, a beginning teacher was teaching reading comprehension and the lessons were video recorded for later discussions of the lessons by the beginning teacher and the experienced teacher. Through discussions of the lessons, the experienced teacher was able to help the beginning teacher about what could have been done to make students understand more. Through reflection and sharing the knowledge of teaching with the experienced teacher the beginning teacher's knowledge of teaching was improved. In another case, an experienced teacher who thought she was very good at teaching addition and subtraction in Mathematics to first-grade students found that she knew very little about the methods that her students engaged in solving addition and subtraction problems through the workshop she attended. Through the workshop the teacher was able to learn methods that students use to solve problems which improved her knowledge on how students solve problems to get answers.

These cases used by Hiebert *et al.* (2002) indicate that other teachers can learn through the knowledge of teaching that is shared between members of the teaching profession either through discussions of classroom video records or workshops. In cases where the teachers cannot share their knowledge through the above discussed methods, making the teaching knowledge public by documenting and portraying it might benefit other teachers since teachers would be able to access this written knowledge for improvement.

Loughran, Milroy, Berry, Gunstone and Mulhall (2001) envisaged PCK as a body of knowledge possessed by experienced teachers. These authors developed ways of articulating and documenting PCK with the view that PCK can be recognised and publicised. In their earlier attempts to portray PCK, Loughran, Gunstone, Berry, Milroy and Mulhall (2000) state that they used vignettes to document and portray PCK but noticed that portraying PCK through vignettes was limited in that vignettes only showed how the teacher taught the content but did not go further to articulate what the teacher knew about the content that was taught. They added that

vignettes portrayed only the happenings of the teachers' classroom but were deficient in hints of the problematic nature of either content or context. Loughran *et al.* (2000) then introduced CoRes and PaP-eRs to capture, document and portray PCK. The use of CoRes and PaP-eRs is a link between science content and pedagogy and helps to shed light on the particular approach to teaching specific content for certain reasons.

As an attempt to make teachers' topic-specific PCK explicit, Loughran, Mulhall and Berry (2004) developed and used a method to uncover, document and portray PCK that would enable the teachers' PCK to be made available to other science teachers. With the involvement of experienced high school science teachers, this method of exploring, documenting and describing teachers' PCK was developed such that it was composed of two analysis tools; Content Representation (CoRe) and Pedagogical and Professional experience Repertoires (PaP-eR). CoRe is a tool that helps to document the teachers' content knowledge and the way of transforming this knowledge through various representations and also helps to access the teachers' understanding of aspects of PCK.

Loughran, Berry and Mulhall (2006) maintain that teachers' stories on how they teach carry important information that helps other teachers to relate to and draw their own meaning from a description of a teaching or learning situation. They add that the narratives might influence the reader's knowledge of teaching as they help to make the tacit knowledge of teaching explicit. PaP-eRs display the knowledge of teaching a particular content in a particular context and give insight into the aspects of PCK in action (Loughran *et al.*, 2001). PaP-eRs link teachers' content knowledge to teachers' classroom practice and this helps to explain the choices made by the teacher to transform subject matter knowledge into the teachable form with the belief that pedagogy is shaped by content knowledge. PaP-eRs show the aspects of PCK in teaching practice provided by discussions of ideas connected to CoRe together with classroom observations. Loughran *et al.* (2004) developed and used this method to explore science teachers' PCK in teaching of a variety of specific science topics such as chemical reactions, ecosystems and forces and report that the CoRe and PaP-eR have been successful to capture, document and portray teachers' PCK in different science topics.

2. 5. Empirical studies guided by PCK

van Driel, Verloop and de Vos (1998) researched the development of PCK of experienced science teachers (more than five years of teaching experience) with respect to teaching chemical equilibrium in an in-service program in which the purpose was to develop chemistry

teachers' PCK by increasing teachers' awareness of preconceptions and difficulties in teaching chemical equilibrium. van Driel *et al.* (1998) argue that the type of knowledge that guides the teachers' practice is craft knowledge which is the wisdom of teaching growing with the teachers' experience. In agreement with Shulman (1986), van Driel *et al.* (1998) add that PCK refers to understanding of students' difficulties in learning certain topics through knowledge of students' preconceptions and shaping the teacher's subject matter knowledge in the way that its transformation will increase students' understanding. Although van Driel *et al.* (1998) call this knowledge craft knowledge; the aspects of this knowledge are the same as the categories of knowledge elaborated by Shulman (1987) as knowledge of pedagogy, students, curriculum and subject matter. The difference is that according to van Driel *et al.* (1998), these aspects of knowledge are integrated with teachers' beliefs to guide the teachers' teaching practice. The findings revealed that teachers' PCK was improved, manifested by developed knowledge of learning difficulties associated with chemical equilibrium and also developed knowledge of strategies that enable teachers to address these learning difficulties.

The relationship between subject matter knowledge and PCK was explored in student teachers compared with an experienced teacher in the teaching of isotopes (Geddis, Onslow, Beynon & Oesch, 1993). Beginning teachers seemed to transmit their subject matter knowledge with little skill of shaping the subject matter knowledge into the form that could be understood by learners while the experienced teacher showed more skills of transforming subject matter, making it easier for students to understand. To explain the teachers' PCK, Geddis *et al.* created the following categories: knowledge of students' prior knowledge, curriculum saliency, multiple different representations and effective strategies to teach isotopes. Geddis *et al.* (1993) and van Driel *et al.* (1998) agree that teaching content in a comprehensible way involves knowledge of different forms of PCK such as misconceptions held by students, the knowledge of teaching strategies to change students' misconceptions and the significance of the topic in the curriculum.

Rollnick, Bennett, Rhemtula, Dharsey and Ndlovu (2008) conducted two South African case studies designed to explore the influence of subject matter knowledge on PCK of teachers teaching the amount of substance and chemical equilibrium. The first case study was done on teaching of the mole in a high school context in two township schools and the second on teaching of chemical equilibrium in an access programme at a tertiary institution. It was found in the first case study that the two high school teachers focused on procedural ways in teaching the mole concept instead of teaching for conceptual understanding, and a suggestion was made

that this may have been due to lack of content knowledge in these teachers. In the second case study, it was found that the teacher had thorough subject matter knowledge on the topic and also showed developed PCK.

Nilsson (2008) reports the exploration of the development of PCK of four mathematics and science student teachers who participated in a project in which they were teaching physics to students aged 9–11 over the period of one year. Nilsson looked at student teachers' understanding of the components of PCK which she identifies as subject matter knowledge, pedagogical knowledge and contextual knowledge and then analysed how such understanding influenced student teachers' PCK foundation. Nilsson found that the development of PCK might have occurred from the way the student teachers understood the components of PCK. Nilsson adds that reflection contributes to the development of PCK since it helped student teachers to understand and explain the knowledge base that influences the development of PCK and indicates that student teachers often develop PCK by themselves by the time they start teaching.

Unlike Rollnick *et al.* (2008), Nilsson (2008) focused on pre-service teachers teaching physics while Rollnick *et al.* focused on experienced teachers teaching chemistry. Although the teaching experience levels of the teachers under the two studies differ, the two papers agree that the role of SMK and its influence on PCK of these teachers appears to be the same.

2.6. Teaching and Learning difficulties in radioactivity

a. Teaching difficulties

According to Lungu (2009), physics teachers who chose nuclear physics as the most difficult topic to teach mentioned: calculations, nuclear processes, nature of alpha particles, beta particles and gamma rays, and applications of nuclear physics to other fields as difficult aspects of nuclear physics to teach. Among other stated reasons that made the teachers regard nuclear physics as one difficult topic to teach, Lungu argues that the most compelling reasons were the lack of teaching materials, the abstractness of the topic and the difficulty to do experiments at high school level. As these teachers in Lungu (2009) considered calculations as difficult element of nuclear physics, Mulhall and Gunstone (2008) also agree that limited mathematics knowledge of learners can be a barrier to understanding physics because physics relationships are expressed in mathematical form which needs one to have a good mathematical background.

b. Misconceptions

Henriksen and Jorde (2001) assert that it is important to find out the prior knowledge which students have on radioactivity before instruction. Several studies have been done on students' ideas about ionizing radiation. In reviewing learners' conceptions on radioactivity, some studies (Millar, Klaassen & Eijkelhof, 1990; Millar & Gill, 1996; Pranthier & Harrington, 2001) found that learners fail to distinguish between irradiation and contamination. Anjos *et al.* (2001) assert that there are some beliefs in radiation that irradiation makes food radioactive, radiation can be removed from contaminated materials by heating or by exposing the contaminated material to chemicals and that after one half-life has elapsed; a radioactive material does not emit radiation. In a study conducted on Turkish high school students, Nakiboglu and Tekin (2006) found that learners have difficulties relating stability of the nucleus to the half-life and showed that learners believe that the nucleus with a shortest half-life is the most stable, while the shortest half-life implies least stability. Nakiboglu and Tekin also found that students' misconceptions about applications of radioactivity include students' thinking that radioisotopes can only be used in energy production because they are harmful for humans and argue that this misconception results from the media which emphasises the harmful effects of radioactivity more than uses.

These conceptions about radioactivity may cause learning difficulties in learners and teachers may be faced with challenges to teach radioactivity in such a way that would enable learners to change their conceptions about radioactivity.

2. 7. Teaching strategies in science

Pedagogical content knowledge includes knowing what teaching approaches fit the content to be taught; it also involves knowledge of teaching strategies that incorporate suitable representations in order to address learners' difficulties and misconceptions to promote understanding (Shulman, 1987). Effective teaching draws from different types of knowledge such as PCK and curricular knowledge (Schroeder, Scott, Tolson, Huang & Lee, 2007). Schroeder *et al.* (2007) maintain that teachers should identify the lesson objectives and then select appropriate strategies to achieve their lesson goals for teachers to use effective teaching strategies in their instruction.

Schroeder *et al.* (2007) examined 61 recent studies in science teaching as an attempt to provide research-based evidence of effective teaching strategies used by teachers in USA. These selected studies were all dealing with teaching strategies and students' achievement in science. The useful teaching strategies were categorised into eight categories being: questioning

strategies, manipulation strategies, enhanced material strategies, assessment strategies, inquiry strategies, enhanced context strategies, instructional technology strategies and collaborative learning strategies. Although these strategies are domain specific, they can also be useful in the teaching of radioactivity as this is also a science topic. These strategies are explained in the table below according to (Schroeder, *et al.*, 2007, p. 1445-1446).

Table 2.3: Categories of teaching strategies employed to teach science

Strategies	Description
Questioning strategies	Teachers vary timing, positioning, or cognitive levels of questions (e.g., increasing wait time, adding pauses at key student-response points, including more high cognitive-level questions, stopping visual media at key points and asking questions, posing comprehension questions to students at the start of a lesson or assignment).
Manipulation strategies	Teachers provide students with opportunities to work or practice with physical objects (e.g., developing skills using manipulatives or apparatus, drawing or constructing something).
Enhanced materials strategies	Teachers modify instructional materials (e.g., rewriting or annotating text materials, tape recording directions, simplifying laboratory apparatus).
Assessment strategies	Teachers change the frequency, purpose, or cognitive levels of testing/evaluation (e.g., providing immediate or explanatory feedback, using diagnostic testing, formative testing, retesting, testing for mastery)
Inquiry strategies	Teachers use student-centred instruction that is less step-by-step and teacher-directed than traditional instruction; students answer scientific research questions by analyzing data (e.g., using guided or facilitated inquiry activities, laboratory inquiries).
Enhanced context strategies	Teachers relate learning to students' previous experiences or knowledge or engage students' interest through relating learning to the students'/school's environment or setting (e.g., using problem-based learning, taking field trips, using the schoolyard for lessons, encouraging reflection).
Instructional technology strategies	Teachers use technology to enhance instruction (e.g., using computers, etc., for simulations; modelling abstract concepts and collecting data; showing videos to emphasize a concept; using pictures, photographs, or diagrams).
Collaborative learning strategies	Teachers arrange students in flexible groups to work on various tasks (e.g., conducting lab exercises, inquiry projects, discussions)

Schroeder *et al.* (2007) concluded that a combination of teaching strategies would be more effective than using one strategy to teach science and added that the teachers' PCK should enable the teacher to select strategies that would better help to achieve goals of instruction.

Teachers in developing countries employ different teaching approaches when teaching science (Lewin, 1992). Lewin (1992) asserts that science teachers use methods such as question and answer, small group practical work and assess students using multiple choice questions.

According to Lewin, the mentioned methods are dominating in developing countries even though the extent to which they are used varies from country to country and from one region to the other. The common approaches engaged by teachers in developing countries include traditional teaching approaches in which teachers are authoritative in classrooms, telling learners the concepts that are important and giving directions on how the experiments should be carried out (Shumba, 1999). In South Africa, Stoffels (2008) found that teachers used text book approach in their teaching. The other approaches used involve teacher demonstrations which minimally engage learners. These approaches are engaged in large extent in classroom such that in some countries, they are dominant approaches. As Lesotho is one of the developing countries, these teaching approaches might be the same approaches used by Lesotho physics teachers to teach radioactivity.

According to Stoffels (2008), subject matter knowledge and intensified work load influence teachers' approaches to teaching. In the areas in which teachers had lack of subject matter knowledge, Stoffels found that teachers used raw material from the text book without modification in their classrooms. The training that teachers get at the tertiary level also influences the way teachers approach their teaching (Lewin, 1992). The tertiary level, especially at the degree level at which teachers are trained concentrates more on teaching content and pedagogy is given a small amount of time (Lewin, 1992). The other influential factors are the conditions in which teachers work such as lack of resources in schools. Although Lewin (1992) sees resource constraints as one of the influencing factors shaping teachers' approaches of teaching science, Stoffels (2008) showed that resource constraints do not have an impact on how teachers approach science teaching. This was shown in the study of two teachers who taught in schools which were different in terms of resources. One teacher was teaching in a moderately resourced school while the other was teaching in a well resourced school but the two teachers seemed to use same approaches while teaching science.

Qhobela (2008) argues that physics learners have a problem of understanding physics topics and the physics register and these problems are compounded by English as a language of learning and teaching. This is in agreement with Johnstone and Selepeng (2000) who contend that some learners are faced with two problems in learning science, the problem of language used as a medium of instruction and the language of science. Basotho students are not an exception in this problems since they are studying science in English and expected to understand the language used in physics. Oyoo (2010) argues that irrespective of the learners' linguistic background, both technical and non-technical words used in science context are a

source of difficulty of science. There is a need to explain the words that are used in science context which have a different everyday meaning for students to differentiate the words in context. Oyoo (2010) found that experienced physics teachers were giving more explanations of the technical words when teaching than the beginning teachers were. While Oyoo (2010) argues that the language of instruction appears to cause problems of hindering understanding in physics learning, Rollnick (2000) suggests that there are strategies that can be used to teach science for English second language learners. The example is code-switching that bridges the gap between the second language and the language of science helping learners to develop conceptual understanding. Fakudze and Rollnick (2008) maintain that code-switching can be used to detect learners' misconceptions for the teacher to direct teaching to develop correct scientific conceptions. They clarify that the use of two languages to represent what is taught offers better opportunities for students to access knowledge.

2.8. Teaching strategies in radioactivity

Lungu, (2009) investigated the teaching strategies that were used by Malawian physical science teachers to teach nuclear physics. The findings revealed that teachers used multiple teaching strategies to teach nuclear physics. The teaching strategies employed included the use of an analogy of two identical magnets and two metals of different masses to explain the behaviour of charged particles in electric field and this was a macroscopic analogy which does not explain the microscopic phenomenon of the charged particles behaviour. Teachers also used decay equations and symbols to involve students in finding solutions of changes in nucleon numbers and proton numbers. In addition, the teachers used diagrams and examples. Lungu (2009) indicated that teachers mostly used teaching strategies that transmitted procedural content knowledge such as solving equations and involving calculations than teaching for conceptual understanding.

As a way of teaching radioactivity for understanding, Millar *et al.* (1990) suggest a teaching sequence that may help teachers. Millar, Klaassen and Eijkelhof (1990) claim that radioactivity should be taught in such a way that concepts are taught from a macroscopic level to the microscopic level. The suggested sequencing is as follows: phenomenological orientation, qualitative macroscopic treatment, quantitative macroscopic treatment and microscopic treatment. Phenomenological orientation means relating the topic to real world background to link what is taught to students' experiences. At the macroscopic level, learners' experiences on radioactivity are investigated to build on concepts such as the penetrating power of radiation from different sources, different types of radiation emitted by radioactive sources being; alpha

particles, beta particles and gamma rays, distinguishing between radioactive matter and radiation and distinguishing between contamination and irradiation. Millar *et al.* (1990) show that the last stage in the teaching of radioactivity should be the microscopic treatment in which the model at atomic level is required to clarify questions such as: "What actually happens to a radioactive source when radiation is emitted, what happens when radiation is absorbed" (Millar *et al.*, 1990, p. 341).

Crossier, Cobb and Wilson (2000) contend that radioactivity may be taught for understanding by providing more content on radioactivity through the use of a virtual laboratory. The virtual laboratory is claimed to be important for learners to see how radiation is emitted by radioactive materials. A suggestion was made that the use of virtual laboratory should be preceded by instruction to develop learners' knowledge of terminology in radioactivity and concepts that would enable learners to pick relevant knowledge from the laboratory.

2.9. Conclusion

The literature reviewed in this study suggested that PCK which is central to teaching results from the blending of different types of the knowledge base for teaching, which teachers draw their practice from. The Model for Rollnick *et al.* (2008) used in this study deems PCK as an amalgam of four knowledge domains for teaching being: knowledge of subject matter, knowledge of students, general pedagogical knowledge and knowledge of context. Since it is difficult to communicate between teachers about the knowledge of teaching they possess, the idea of capturing, documenting and portraying teachers' PCK is useful to avail the teachers' knowledge about teaching the topic of radioactivity to both experienced and beginning teachers. The literature has highlighted what teachers consider difficulties in teaching the topic of radioactivity, students' misconceptions around the topic and gave insights into the strategies that teachers use to address learning difficulties.

The studies reviewed above on the teaching of radioactivity focused on how radioactivity could be taught for understanding but there are not many studies providing knowledge on how teachers transform their subject matter knowledge of radioactivity into knowledge that can be understood by learners. It is therefore the purpose of this study to make two physics teachers' PCK on teaching radioactivity explicit through finding out how they teach radioactivity and to understand their PCK better. The focus will be on the identification of certain teaching strategies specific to the teaching of radioactivity. This study will add more on the limited literature where

the teachers' knowledge is made explicit for access to other teachers in the similar discipline and context.

The literature which has been discussed has provided the starting point for the next chapter, which discusses the research method and design of this study.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

In chapter 2 I reviewed the literature on PCK and on the teaching of radioactivity. In this chapter I elaborate on how the research has been carried out; looking at the research design, its rationale, the methods and instruments that I used to collect data and the discussion on gaining access to schools and teachers. I also discuss how trustworthiness was ensured in this study.

3.2. Design

A qualitative case study approach within an interpretive paradigm was used to guide this research project to explore in-depth physics teachers' PCK. Opie (2004) and Merriam (2009) mention that a qualitative case study is an exhaustive study of a certain phenomenon, where a phenomenon is studied in detail to provide more thorough explanations of the processes and relationships related to that phenomenon.

The case study approach also has disadvantages. The case study approach does not allow for generalizations because it focuses on a particular situation, therefore the results of a case study cannot be generalized to other situations (Descombe, 2007). However Descombe argues that the results of a case study can also be applied to situations of the similar characteristics as the one under study, as in this case, the teaching of radioactivity that is a challenge to many physics teachers (Lungu, 2009).

A case study helps researchers to explore a certain phenomenon in its context using different data collection methods (Baxter & Jack, 2008). I chose a case study approach because it was most suitable to help me explore how physics teachers teach radioactivity by exploring the teaching strategies that they used in their classroom settings being their context. A case study therefore provided the best scope for answering my research questions.

Golafshani (2003) argues that a case study allows multiple data collection methods and these methods enable validity through triangulation (Descombe, 2007). I therefore decided to use the case study approach in my study to ensure validity through the use of multiple data collection methods which I discuss below.

3.3. Data collection methods and instrumentation

3.3.1. Interview

I used interviews as one of my strategies to collect data. Opie (2004) asserts that an interview is a suitable instrument for eliciting information from the respondents' ideas, so in this study the interview helped me to access teachers' ideas about teaching radioactivity, the strategies they intended to use and reasons for choosing certain methods when teaching radioactivity. There are different types of interviews and below I discuss the types of interviews together with the one that has been used in this study.

3.3.1.1. Semi-structured interview

I used semi-structured interviews in this study. Both Opie (2004) and Descombe (2007) agree that semi-structured interviews provide more data because of the flexibility that respondents have on giving answers. Additionally, the interviewer has less control over the answers and the interviewee can say as much as she/he can. I used this type because it allowed me to go deeper into finding more information from the interviewees through the use of probing and follow-up questions which could help to provide more understanding of what the interviewee was saying (Descombe, 2007; Opie, 2004). Opie (2004) points out that even though semi-structured interviews are flexible; they bring issues of researcher bias in that the researcher may interpret answers given by the interviewee according to his/her values and beliefs and these answers may deviate from what the interviewee meant, especially where there is misunderstanding of the interview questions. The other limitation of interviews is that the interviewees may give answers that they think would please the interviewer especially when they have close relationship with the interviewer (Descombe, 2007).

There are other types of interviews such as structured and unstructured interviews. Structured interviews are used in studies that involve large samples to generalize the results (Opie, 2004). Breakwell (1995) argues that structured interviews do not enable people to reveal information which they think is important because they constrain the respondents within the chosen answers that have been suggested by the researcher and do not allow freedom for expressing their ideas. This type of interview would not be suitable in my study because I would miss important information from teachers that I am not aware of. For example, the teacher could have different answers from the answers suggested by the researcher which could be missed by restricting the number of answers for a question. My study was looking for emergent features in the process of teaching radioactivity therefore structured interview was not suitable.

Unstructured interviews yield large amounts of data which require a lot of time for analysis (Opie, 2004). In addition, the analyses of these require more expertise to handle. Opie has also advised that this type of interview is not suitable for use by novice researchers because of time constraints and practical difficulty to analyse; therefore unstructured interviews were also not suitable for this study.

I used semi-structured pre-observation interviews with teachers in this study. I adapted the prompts in the CoRe from Loughran, Mulhall and Berry (2004) into the interview schedule. Loughran *et al.* (2004) involved experienced science teachers in their study to examine ways of capturing and portraying science teachers' PCK. Science teachers were grouped and engaged in activities to state what they would consider as main ideas and how they would help their students understand in teaching a particular science topic. Teachers' discussions resulted in what was agreed upon as main ideas in the topic and the main ideas were discussed in terms of a series of prompts. Loughran *et al.* (2004) called the main ideas together with the prompts collectively as Content Representation, CoRe.

I have adapted the original prompts in Loughran *et al.* (2004) by changing some words to suit the teaching of radioactivity because originally, the prompts have been used in the teaching of science in general. The prompts have been used to capture science teachers' PCK, so they helped me to communicate with the participant teachers about their PCK. I have converted the prompts that were written in the form of statements into questions. Questions 1, 4, 5, 6, 7, 8 and 9 were originally written as statements in the CoRe but I have converted them into interview questions (refer to appendix 1 for the interview schedule). For example, the original prompt for question 1 was: what you intend the students to learn about this idea. For the purposes of this study, this has been converted to: what do you think are the main ideas that you intend to teach Form Es about radioactivity? For original prompts, refer to (Loughran *et al.*, 2004, p. 376) or appendix 14.

3.3.2. Observations

3.3.2.1. Video recorded classroom observations

Another strategy that I used was video recorded classroom observations. Classroom observations are a suitable method for collecting data because a researcher is able to access first hand information rather than the second hand information that a researcher gets in interviews (Descombe, 2007). Opie (2004) argues that video recording is good for giving information on non-verbal activities. Since I was interested in the ways the teachers teach, video

recording enabled me to watch both the verbal and the non-verbal activities engaged in by the teachers. Video recording may bring in technical problems such as poor sound quality (Opie, 2004); to address this problem I used the video camera together with voice recorders.

Although observations are good at providing the first hand information about the processes as they happen, the people observed may change their behaviour because of the presence of the observer (Descombe, 2007; Opie, 2004). I have addressed this limitation by observing several lessons so that the teachers could get used to the presence of the observer in the classroom.

3.3.2.2. Field notes

I also used field notes as another method of collecting data. Opie (2004) asserts that field notes can be used to record the observed behaviour, conversations or discussions involved by people under study. In this study I used field notes to record aspects of PCK which were shown by the teacher in the classroom. According to Opie, field notes help the researcher to focus on certain aspects of behaviour. In this study, field notes helped me to record particular areas of interest in the ways the teachers under study taught which helped me to focus on the portrayed aspects of PCK. I also used field notes to record behaviour that could not be captured by the video recorder such as students showing confusion when a particular content area was taught and students' satisfaction after being given explanations.

Field notes can be biased and inaccurate if made a long time after observation (Opie, 2004). In this study I wrote notes immediately after observing the class to avoid inaccuracy and bias. I would have written the notes while I was observing but because I was operating the video camera I did not. I could not video record the classroom and write field notes simultaneously.

3.3.3. Diagnostic test

3.3.3.1. Description of the development of the diagnostic test

The aim of the test was to elicit the teachers' subject matter knowledge on radioactivity. According to Shulman (1987), a teacher should have a broad knowledge of subject matter in order to help students understand concepts by engaging various ways of clarifying concepts and principles to students of diverse abilities and characteristics in different contexts. Testing the teachers' subject matter knowledge would be important in this study because subject matter knowledge is the one that helps the teacher to communicate important ideas of the discipline with learners (Shulman, 1986). Since I was also exploring PCK in the teaching of radioactivity, it was also important to test teachers' subject matter knowledge because subject matter

knowledge is one of the components of PCK (Cochran, DeRuiter, & King, 1993) and it is the only knowledge domain (Rollnick *et al.*, 2008) for teachers that can be directly tested.

It is best to use diagnostic tests that have been researched and available in the literature but none were available, so I used a selection of questions from a well known text book. The questions that have been used in this test were taken from Nelson Physics by Storen and Martime (2004). The questions have been used as revision questions by a second year Honours students' physics lecturer to test students' understanding of radioactivity. I have selected some of the questions to cover different aspects of radioactivity as explained in the table below (refer to appendix 2 for the diagnostic test questions). The questions were selected such that they were in line with the syllabus that the teachers under study were teaching (refer to appendix 21) except questions 2 (c) and 3 where the knowledge of the cause of the behaviour of charged radioactive radiation in both electric field and magnetic field and on fusion and fission was not included in the syllabus. These questions were important for this study to see if the teachers had more knowledge than that required by the syllabus on the topic as Bishop and Denley (2007) argue that having extended subject matter knowledge is crucial because it enables the teacher to explain concepts even if learners ask questions which go beyond what is being discussed. Furthermore, Bishop and Denley (2007) indicate that broad subject matter knowledge makes teaching effective unlike when a teacher is unable to engage and interact with learners because of lack of knowledge. The diagnostic test consisted of five questions as shown in the table below.

Table 3.1 Diagnostic test description

Question	Description of what was tested
1	Two sub questions testing the knowledge of the atomic structure as this is a pre-requisite for the topic of radioactivity.
2	Three sub questions testing the knowledge of characteristics of three types of radioactive radiation and the cause of the behaviour of charged radioactive radiation in electric and magnetic fields.
3	Knowledge of fusion and fission.
4	Knowledge of half-life calculations
5	Understanding of safety in storage and handling radioactive materials.

I submitted the diagnostic test questions and a marking memorandum to an experienced physics lecturer at Marang Centre for Maths and Science Education to ensure both face validity and content validity (Satori & Pasini, 2007) and to identify misconceptions that would come in the answers to questions that I provided (refer to appendix 2). After getting the feedback that the questions could be used as diagnostic questions and that there were no misconceptions emerging out of the answers I suggested, I asked the first year Honours chemistry lecturer at Wits to give me some time to pilot the diagnostic test in his classroom. I chose his students because they were experienced physical science teachers whom I assumed had a general knowledge on radioactivity because they had also been studying the topic. I explained the purpose of piloting the study to the chosen sample and told them that their comments would be very important to help me change questions for clarity for the sample in my study.

I had allocated 20 minutes for answering the questions and most of the respondents completed in about 15 minutes and only a few took about 20 minutes. I decided not to change the allocated time because people differ in the rate of answering questions. I made no changes after piloting the study because I did not get comments stating that I should change the questions or stating that the questions were not clear. I used a memorandum together with a rubric (attached in appendix 2) for classifying responses as: correct, partially correct, incorrect and no response.

3.4. Selection of participants

3.4.1. Sample

I selected two high school physics teachers teaching physics at Form E level which is the last year of senior secondary level in Lesotho equivalent to Grade 12. The names that I have used to refer to teachers are pseudonyms. Mr Victor was a 44 years old male who had a diploma in science education and a bachelor of science in mathematics education. He had taught integrated science, physics, chemistry and mathematics for a total of nineteen years at the time of this study. The other teacher, Ms Grace was a 24 years old female teacher who held a diploma in science education as her teaching qualification. At the time of this study, she had three years of teaching experience, teaching integrated science at junior secondary level, mathematics and physics at senior secondary level.

Mr Victor was my physics high school teacher whom I regarded as very competent and because I knew him, I thought he would easily give me access to interview and observe his classroom. Ms Grace had been my work colleague and took over my teaching post when I left for further study and because we helped each other in terms of school work and we were used to working

together during my school holidays in the previous year, I thought it would be easy for her to allow me to work with her in this study. I selected these qualified teachers so that this study could benefit both other qualified teachers and unqualified teachers who will be able to access knowledge of how other teachers taught radioactivity.

These teachers agreed to participate after I had explained to them the purpose of my research, how the confidentiality would be ensured and that they could withdraw from the study at any time. I chose these two teachers purposively. Mr Victor had taught physics for a long time and has been producing constantly good COSC results in physics. According to van Driel *et al.* (1998) PCK is accumulated through experience and I assumed that the Mr Victor had therefore developed PCK which is worthy of portrayal and could give a suitable comparison between him and the Ms Grace who taught physics for a shorter time. This was not to say that the beginning teacher had no PCK.

3.4.2. Schools

The selected teachers were both teaching in schools in Maseru. The schools' location was convenient for me since I live in Maseru so I had a place to stay while I was collecting data. The names of the schools that I used are pseudonyms to keep anonymity. Tebellong High School, where Ms Grace was teaching, was about two kilometres south of the city centre while Paballong High School, Mr Victor's school was about two and half kilometres in the same direction. I was easily able to reach the schools because they were on the taxi route. The two schools were separated by a short distance allowing me to walk from one school to the other within a short period of time.

Both schools were day schools. In Tebellong High School there were about 63 learners in the class and in Paballong, there were about 35 learners. There were libraries in both schools but in both cases teachers mentioned that the books in the libraries were too old to provide useful additional information to students. There were also science laboratories with running water and electricity but in both schools, teachers mentioned that there was a lack of suitable equipment for the teaching of radioactivity. For example, there were no radiation detecting instruments such as Geiger Muller tubes. In this way these schools had similar problems to the majority of schools in the country regarding a lack of resources (Qhobela, 2008). The two selected schools followed the same type of combined science syllabus being physics and chemistry, they were also both poorly resourced and that would enable me to provide a fair comparison between the two teachers' PCK. The discrepancy in class size could have impact on the teachers' PCK but

as Shulman (1987) indicates, a teacher should have knowledge of educational context as a knowledge base for teaching. In this case, each teacher was expected to know how to teach in a small class and in a big class size which contributes to the PCK of the teacher.

3.5. Negotiation of access to do research

3.5.1. Permission to conduct research in schools

Access to conduct research was sought in stages. Ethics clearance was firstly sought from The University of Witwatersrand School of Education. I then asked for permission to conduct the study from the Ministry of Education and Training in Maseru, school principals, teachers, students and finally parents/guardians.

Ethics clearance to conduct this study was first sought from The University of Witwatersrand School of Education, by submitting an ethics application form to the Human Research Ethics Committee of The University of Witwatersrand School of Education for the permission to do my study. The ethics application stated the objectives of my study. I was given an approval to carry on with my study (see appendix 3).

I submitted a letter asking for permission to do research in the schools to the Ministry of Education and Training (MOET) in Maseru, Lesotho (see appendix 4). The letter introduced me, stated the topic and aim of my research project and the ethical considerations about my research to guide the Ministry to give permission for my study to be carried in the two schools in Maseru. I also submitted an informed consent form to the MOET (refer to appendix 5). I delivered the letter and the form in person to the Ministry and the consent was given on the same day.

I submitted the letter requesting permission (see appendix 6) and the informed consent form (see appendix 7) to the school principals. The letter introduced me, stated my research topic, aim and also the ethical considerations about my study to inform the principals about this study so that they could agree or disagree for this study to be carried out at their schools. I stated in the letter that the research was not going to affect the way teaching was carried out and that the school principal had the discretion to grant me permission to interview and observe the teacher and also that the name of the school and that of the participant teacher was to be kept anonymous. I delivered the letter and the form in person to the schools and in one school where I had been a teacher, I got the permission on the same day of delivery and in the other school, I

had to wait for about two months before the principal took the decision to give me permission. This was after I revisited the principal and explained to her again about my research. .

The difference in difficulty to gain access in these schools was caused by the fact that in one school where I easily got access I had served as a physics teacher for about three and half years and I was on good terms with the principal. In the other school, I was only known by the physics teacher and the principal needed to be convinced that the research was to be carried for academic purposes and for the benefit of science education only.

3.5.2. Permission to conduct research in classrooms

I approached the two teachers individually at their schools and requested them to participate in my study, stating verbally the topic, aim, research methods and the ethical considerations that I would involve in my study and they both gave verbal permission. During the second visit after gaining permission from the principals, I gave the two teachers the information sheets (see appendix 8) stating the aim of my study and formally invited them to participate. The teachers were informed that their participation was voluntary and that they would have the option to withdraw from the study at any time if they did not wish to continue. I informed the teachers that their names would be kept anonymous and that the study was being conducted for purposes of improving the teaching of physics in Lesotho schools. I also told them that the material was going to be used for research purposes only. The information sheets also described the methods that I would use to collect data. I also gave teachers the informed consent forms (refer to appendix 9) and they agreed to participate in my study.

I visited learners' classrooms with the permission of the principals and physics teacher in both schools to introduce myself a few days prior to data collection. I explained verbally that I was a researcher and I was going to observe their classroom without interfering with the way they learned. I stated the purpose of my study and the methods of data collection that I was going to involve. I then gave learners the information sheets (see appendix 10) and consent forms (see appendix 11) for permission. I stated in the sheet that the observations were not going to affect their performance and that they were not forced to participate in my study. Although I was not expecting learners' refusal to give permission, if the learner did not give permission, I planned to organise the seating arrangement with the teacher such that the video would not capture the learner whose permission has not been granted. The other option was the arrangement with the teachers under study for remedial classes. I left the information sheets and the informed

consent forms with learners for them to read and to return the consent letters the following day if permission was granted. All learners agreed to participate in my study.

I gave minor learners' parents/guardians the information sheets (see appendix 12) stating the aim of my study and informing them that I would be observing the learners' classroom for research purposes only and requested to be allowed to involve their children in my study. There were about 7 minors in one school and about 11 in the other. The information sheet stated to parents/guardians that the observations were not going to affect the learners' performance and that learners were not forced to participate. I indicated how the learners whose permission was not granted were catered for so that their learning would not be affected by this study. This would not affect my study adversely because my focus was mainly on the teacher's activities.

I told minor learners verbally that both the information sheet and the consent form were written in English. I then suggested that if the learners had parents/guardians who could not read English they should come to see me so that we could discuss what we could do to enable parents/guardians access the information on the letters but there were no cases of parents who could not read English because in both schools, students came from families of working parents and guardians. I also gave the parents' consent form (see appendix 13) to sign as an agreement to allow me carry on with the study. Both the information sheet and the informed consent form were given to learners so that they reached the parents/guardians and the parents' consent forms were also brought back by learners. All parents/guardians gave their consent.

3.6. Data collection sequence

3.6.1. The interview

I met the two teachers in their schools a day prior to the interview. I handed over to them the interview schedule together with the schedule for demographic information (included in appendix 1). I left the interview schedule and the demographic information questions with the teachers for them to read for understanding so that they could ask me some questions for clarity where necessary to avoid answering questions without understanding but still accepting that people may have different meanings for one question (Opie, 2004). I also asked the teachers to give me a suitable time that would not interfere with their classes for interviews which they did referring to their time tables. I reminded the teachers that I was going to use voice recorders (refer to appendix 15 for the consent) and I asked the teachers to choose quiet places that would not be disturbed by noise.

I visited the teachers the following day in their respective schools for interviews. One teacher had chosen the library which was not in use because learners were in class while she had a free period. The other teacher had chosen a science laboratory which was also not in use because we did the interview during study time at that school. Before the interview began, I asked the teachers to ask questions if they needed explanations about the questions they were going to answer and there were no questions. Opie (2004) mentions that the interview should begin with structured questions that make respondents comfortable to answer so I chose to start the interview with structured questions that required the demographic information from the teachers to make them feel comfortable with questions that I thought would be easy to answer.

I interviewed the two physics teachers individually prior to classroom observations at the schools where the teachers are working. The interview lasted for about 15 - 20 minutes. I used probing questions such as; "what else?", "what do you mean by that?", and other questions to follow-up what the interviewees said and to give more explanation of the answers which were not clear to me. As Marshall and Rossman (2006) point out, follow-up questions can be involved to clarify what people mean by the information they are giving. If there was a question which I noticed that the teacher did not understand its meaning, I would put the question in other words to help the teacher understand during the interview. For example, one teacher did not understand the following question: what specific strategies would you use to ascertain student's conceptions or misconceptions of these ideas? I had to explain that the question asked about ways of finding out students' conceptions and misconceptions.

I audio-recorded the interviews and then gave interviewees a chance to listen to themselves on playback so that they could change the information they had given or add more on what they had already said. The teachers did not change their ideas; instead they added more information to clarify what they meant in their responses. I later transcribed the audio-recorded interviews (see appendix 16 for an example of audio record transcripts). I used two voice recorders to avoid loss of data due to battery failure and also charged batteries fully before the interview. I had used the two voice recorders previously in interviews in my Honours research project so I knew they were trustworthy.

3.6.2. Administering the diagnostic test

I informed the two teachers that the test was given to find out their SMK (subject matter knowledge) on radioactivity and I was not going to allocate marks on the test but I was interested in the ways they would answer. Teachers' SMK was worth testing because Cochran,

DeRuiter and King (1993) argue that subject matter knowledge is important for it enables the teacher to represent content in different ways. They add SMK enables teachers to help students of different characteristics understand content in different contexts so this would help me relate teachers' PCK to their SMK.

I gave the diagnostic test to the teachers before classroom observations began. Each teacher was given 20 minutes to answer the questions individually in their respective schools. I waited for them to answer questions and then collected their responses. No reference to text books was allowed because this test was meant to evaluate the teachers' knowledge of the topic they taught.

3.6.3. Classroom observations

I also video recorded (see appendix 17 for consent) the lessons that I observed. Table 3.2 shows the number of lessons observed per teacher and the time taken.

Table 3.2: Video recorded classroom observations

Teacher	Number of lessons	Time taken
Mr Victor	3 double lessons	80 minutes per lesson
Ms Grace	6 single lessons and 1 double lesson	40 minutes per lesson 80 minutes

The lessons were supposed to be 40 minutes long but the time decreased to about 35 minutes due to the distance walked between classes and the staffrooms. Students already knew that I was going to use a video camera because as I have mentioned, I had already told them during my introduction. I had intended to ask another person to help me capture the lessons but the two teachers under study did not feel comfortable with the second person being brought into their classrooms so I decided to operate the video camera as I was observing. I regulated my movement in the classroom such that there were no distractions caused and where I needed to be close to the chalk board, I moved along the classroom wall so that I did not prevent students from seeing what was written on the board.

I was provided with time tables by the teachers and I walked between the two schools for observation which was very strenuous. Both teachers did not seem to be comfortable with my presence the first day of observation but learners in both situations seemed to be happy with my presence. Mr Victor mentioned in our informal after class discussion that it was not easy to

teach in my presence because he assumed that I had more knowledge on radioactivity because of the level of my education. He also mentioned that the fact that I was his former student made him feel like I would question his knowledge on radioactivity. I explained to him that I had not come to judge him but to study the way he taught and that I wanted to learn from him. This conversation helped him open up in the next lessons because of the established trust between us. I also engaged in an after class informal discussion with Ms Grace where she mentioned that she thought she was not going to be affected by my presence in the classroom but she found it strange to be observed by the teacher whom she had substituted. I explained again the purpose of my study to her, told her that I was not going to be judgmental in the way she was teaching and that my main interest was to learn from her. She asked me about how I used to introduce radioactivity while I was teaching and I told her. The discussion made her more comfortable and helped her build trust in me. After that lesson we had a friendly relationship such that we talked every day after class and that increased her comfort with my presence in her classroom.

I kept the classroom video episodes on DVDs (digital video discs) and memory sticks to avoid loss of data. I chose lessons for analysis that I thought would yield rich aspects of PCK and would allow me to compare the two teachers' PCK. For instance, I chose the lessons in which the two teachers were teaching similar content for easy comparison of the approaches they used. I also looked in details for any other emerging aspects of PCK in the video records. After watching the video records, I gave copies to the two teachers for them to watch having highlighted my areas of interest according to the criteria discussed above to avoid spending time watching everything on the video record as doing so would interfere with their work schedules. I then transcribed the highlighted areas of interest in video episodes (refer to appendix 18 for examples of video record transcripts). I only transcribed the video episodes in the areas that I chose for analysis to avoid the long time taken to transcribe.

I also wrote field notes at the end of the observed lesson because as I have mentioned previously, I could not write notes while observing since I was operating the video camera. Examples of the field notes are provided in appendix 19.

3.6.4. Post observation discussion of lessons

I went back to the teachers at their schools for discussions and clarification about what has been manifested as their PCK through the strategies they engaged in teaching. I explained to the individual teachers that we were going to watch together the areas in the video records that I

have selected as my areas of interest and that I would stop the video where I needed to pose a question or an explanation from the teacher. I also stated that where the teacher felt like commenting on the way she/he taught, she/he should tell me to stop the video so that we could discuss that particular action. I discussed the teaching practices of the teachers while watching with them individually the classroom video episodes from the video clips to allow the teachers explain their decision making in the lesson and the reasons associated with the decisions they made during their teaching, this is referred to as “video stimulated recall” (Bishop & Denley, 2007, p. 7). Teachers also made comments about why they taught the way they did and how they could have taught their lessons if they were going to teach in my presence again. The discussions were audio recorded and then later transcribed (see appendix 20). Data collection ended with post observation discussion of lessons. I thanked the teachers and the principals for their corporation during data collection.

3.7. Validity and reliability

In qualitative research, reliability and validity are referred to as trustworthiness (Letts, Wilkins, Law, Bosch & Westmorland, 2007). According to Letts *et al.*, trustworthiness refers to the quality of both findings and data and is said to have four components being; credibility, transferability, dependability and confirmability. Credibility includes different methods of data collection (Anfara, Brown & Mangione, 2002) and it was addressed in this study through the use of multiple data sources such as interviews, classroom observations, field notes and post observation discussions with teachers. I have triangulated video records with field notes. Credibility also includes member checking which is done by verifying data with participants. In this study, I listened to the tape recorded interviews with the teachers to allow them remove any of their responses that they felt were not meaning what they meant and to add more where they felt there was a need to do so. I have given transcripts to participants to verify the written information and as I mentioned previously, I revisited them for discussion of areas that I would analyse in video clips. I have also ensured credibility by providing my data collection trail (Opie, 2004). To ensure transferability, I have given a thorough description of my sample and the context so that the findings of this study can be transferred to another situation (Letts *et al.*, 2007). As Letts *et al.* point out; dependability has been addressed in this study by giving an explanation of the methods of data collection, the process of data collection and analyses to ensure consistency. I also addressed confirmability by checking with participants about ideas developed during data analysis and interpretation (Anfara *et al.*, 2002).

3.8. Data analysis

As mentioned in chapter 2, section 2.4, Loughran, Mulhall and Berry (2004) employed two methods of collecting data (interviews and classroom observations) that would enable the teachers' PCK to be captured. The method for documenting and describing teachers' PCK was developed such that it was composed of two analysis tools; Content Representation (CoRe) and Pedagogical and Professional experience Repertoires (PaP-eR). The CoRe is a tool that helps to document the teachers' content knowledge and the way of transforming this knowledge through various representations and also helps to access the teachers' understanding of categories of PCK. The PaP-eR links teachers' content knowledge to teachers' classroom practice and it is a narrative that helps to explain the choices made by the teacher to transform subject matter knowledge into the teachable form with the belief that pedagogy is shaped by content knowledge. I have used CoRes and PaP-eRs as my tools for data analysis (see appendix 14 for a blank CoRe).

I also categorised the interview data; video clips transcripts, field notes and data from discussions with teachers into categories of the manifestations of PCK from Rollnick *et al.* (2008), in the teaching strategies used by the teachers to teach radioactivity. More detailed data analysis process will be discussed in next chapters.

3.9. Conclusion

In this chapter I have described the design and methods involved in this study. I also provided the discussion of ethics considerations and how the access to conduct the study has been gained. I as well detailed how the study was actually conducted. In the next chapter I will present data analysis process and the findings of this study.

CHAPTER 4: CAPTURING AND PORTRAYING PHYSICS TEACHERS' PCK

4.1. Introduction

This part of results analysis presents CoRes and PaP-eRs as analysis instruments used to capture and portray the PCK of the two teachers teaching radioactivity. These instruments have been used to answer question 1 and 3 of my research questions: How can the PCK of the two teachers be captured and portrayed?

And

What is the role of experience in the manifestation of PCK of two physics teachers?

PCK is tacit knowledge of teaching that is unique to individual teachers; while it is difficult to communicate this knowledge between teachers, Loughran, Mulhall and Berry (2006) argue that there is a need for concrete examples of PCK where teachers teach specific topics. The need for these examples of teacher knowledge arises because this is the way that can help other teachers access the hidden knowledge of how to teach specific topics.

In this chapter I present the portrayal of PCK of two physics teachers teaching radioactivity. I used CoRes (Content Representations) and PaP-eRs (Pedagogical and Professional-experience Repertoires) to document and portray these teachers' PCK. The CoRe represents the teacher's understanding of different aspects of PCK in a certain area of teaching such as: important ideas, areas of difficulty, students' prior conceptions, and particular procedures to be engaged to address learning difficulties together with ways of testing understanding (Loughran, Mulhall & Berry, 2004). The PaP-eR is a narrative that describes the teachers' actual practice in teaching content in a particular context. The context in this study means the "social, political, cultural and physical environmental contexts" (Cochran, DeRuiter & King, 1993, p. 267). These two analysis tools help to make the teacher's PCK explicit and to portray the teacher's knowledge of teaching a particular topic, refer to chapter 2 for details.

4.2. CoRes (Content Representations)

In this study the CoRe illustrates the understanding that the two physics teachers have about radioactivity and what they view as important to consider in teaching this topic. The CoRes have been constructed through interviewing teachers whereby the questions used in the interview schedule were taken from the prompts of the CoRes constructed by Loughran *et al.* (2004) as

mentioned in chapter 3 and I have used the interview outcomes as the depiction of PCK of these teachers. I have also used classroom observations which were video recorded to identify aspects of teacher's practice that could be suitable to be included in different prompts in the CoRe. This data was used to complement the interview data.

The CoRe is made up of big ideas of the topic under discussion, in this case being radioactivity. Under these big ideas is the demonstration of the individual teacher's conceptualisation of how to teach these ideas and these illustrations are formed from the prompts that are found in the rows of the CoRe, see section 4.3 below. The method and purpose as used in this study is different from the (Loughran *et al.*, 2004) approach.

Loughran *et al.* (2004) used the CoRe to represent PCK of a group of experienced teachers with a view to portray expert teachers' practice but in this study I have used the CoRe to document the PCK of Mr Victor, an experienced physics teacher and that of Ms Grace, a beginning physics teacher to see if there are any distinct differences in PCK between an experienced and beginning teacher teaching the same topic. The big ideas were agreed upon by the experienced science teachers in Loughran *et al.* but in this study, I inferred the final big ideas from the interview and classroom observations but decided initial ideas from interactions as discussed below.

Looking at the physics section content in the combined science syllabus for 2010 (see appendix 21); my supervisors and I came up with four possible big ideas that might emerge out of data analysis. The big ideas were:

1. Radiation is emitted when unstable isotopes disintegrate.
2. There are different types of radioactive radiation.
3. Different radioactive substances have different half-lives.
4. Radioactive substances can be both dangerous and useful.

I got the big ideas for the two teachers under study from the combination of looking at the curriculum prescription and data. Determining big ideas was part of my data analysis. During data analysis, I found that the first and the second big ideas combine to form one big idea while the last two big ideas remained unchanged and the number of big ideas was reduced to three as shown in Table 4.1 below. My inference of the big ideas from the data was validated by my supervisors as a check on dependability of the data analysis. Coming up with widely different big ideas was unlikely because the two teachers taught the same curriculum at the same level.

I constructed the CoRe such that the applicable information for each teacher is placed in the same CoRe for easy comparison so that similarities and differences can be easily seen. The CoRe for these two teachers is shown in Table 4.1. In the CoRe, B stands for both teachers', V represents Mr Victor's and G denotes Ms Grace's information.

4.3. CoRe for teaching radioactivity

Table 4.1 CoRe for teaching radioactivity: A comparison between Ms Grace and Mr Victor.

Big Ideas	Big Idea A Radioactive radiation is emitted when the nuclei of unstable isotopes disintegrate	Big idea B Different radioactive substances have different half-lives.	Big Idea C Radioactive substances can be both dangerous and useful
What you intend students to learn about this idea?	Atoms are composed of electrons, protons and neutrons. (B) Unstable isotopes disintegrate, releasing different types of radioactive radiation. (B) There can be changes in the nucleon number and proton number of an unstable isotope as the isotope decays depending on the type of decay. (B) Stable isotopes do not easily disintegrate. (G)	Atoms of radioactive substances decay randomly but the time it takes for half of the atoms to decay can be calculated knowing the half-life of a substance. (B) Graphs involving half-life are used to determine how stable a radioactive substance is. (G) Activity and half-life have a different meaning in physics from everyday language. (V)	Radioactivity is both useful and dangerous. (B) Safety precaution should be taken against radioactive substances to avoid radiological accidents. (B)
Why is it important for students to know this?	They will use these ideas during examinations and in their future work places. (B) In radioactivity, one idea complements another; the knowledge of these ideas will help learners understand the topic of radioactivity as a whole. (V)		To help students understand that radioactivity has both advantages and disadvantages. (V) Students need to know that radioactivity is useful in the production of electricity. (V)
What else you know about this idea that you do not intend students to know yet.	Why stable isotopes do not disintegrate. (G)	Knowledge of half-life equation, $N = N_0 e^{-\lambda t} \Rightarrow T_{1/2} = \frac{\ln 2}{\lambda}$ that can confuse learners at this level. (V)	Fusion and fission. (G) The in-depth concepts on how radioactive materials are used in industry and medicine. (G) The Einstein's Mass-Energy equation $E=mc^2$. (V) The knowledge on how fission and fusion can be used in the production of electricity in detail. (V) The detailed concepts on how radioactivity can be used in genetically modified food

Big Ideas	Big Idea A Radioactive radiation is emitted when the nuclei of unstable isotopes disintegrate	Big idea B Different radioactive substances have different half-lives.	Big Idea C Radioactive substances can be both dangerous and useful
			production. (V)
Difficulties connected with teaching this idea.	Difficulty for students to understand physics words. (B) Some students do not have text books. (G) Reliance on what is written in the text books. (V) Students' lack of mathematics knowledge. (V) Experiments cannot be done because of safety reasons; radioactive substances cannot be manipulated in the lab. (V) Students do this topic for the first time at this level. (V)		
Knowledge about students' thinking which influences your teaching of this idea.	Students have misconceptions such as; radioactive radiation cannot penetrate through water. (G)	Students think that after one half-life, the half-life of a substance becomes shorter. (V) Students think that the most radioactive substance (the least stable substance) is the one that has a long half-life. (G)	Students think that irradiated food is radioactive. (V) Students think that when radioactive substances are used in medicine they will cause more damage to body cells. (G) The misconceptions that students come to class with resulting from reading text books and magazines such as: electricity generated from nuclear power stations is radioactive. (G)
	Students think that radioactivity is a difficult topic to understand. (G)		
Other factors that influence your teaching of this idea.	Lack of resources such as computers and internet facilities. (B)		

Big Ideas	Big Idea A Radioactive radiation is emitted when the nuclei of unstable isotopes disintegrate	Big idea B Different radioactive substances have different half-lives.	Big Idea C Radioactive substances can be both dangerous and useful
Teaching procedures (and particular reasons for using these to engage with this idea).	Teaching procedures Lecture, use of diagrams, explanations, discussions, questioning, use of graphs Use of text books. (B) Narrating history on discovery of radioactivity and naming of types of radiation. (B) Storytelling referring to radiological accidents that happened. (G) Providing a scenario for students to analyse. (G) Individual class presentation. (G) Description of experiment on penetration power. (V) Reading definitions from prepared notes. (V) Use of analogies. (V) Small group class presentations. (V) Reasons These methods are helpful in the situation where there is lack of resources, diagrams help learners to visualise what is happening. For example, to visualise nuclear reactions and the arrangement of neutrons and protons in the nucleus. (B) Lack of resources. (B) Storytelling increases students' attention and makes the lesson more interesting. (G) To make students interested and keep them engaged in learning. (G) Presentations engage students, students find more information knowing they are going to present. (G) Students do not have prior knowledge on radioactivity so these methods would be helpful for them. (V) Radioactive materials can harm students if they would be allowed to handle them in the laboratory, so these methods are helpful to avoid accidents. (V) These help students to be able to find things for themselves and to enable them to ask questions to people who can help them. (V)		
Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of response)	Assignments. (B) Questions asked and answered orally, giving reasons for answers. (B) Use of questions from a text book. (B) Quiz. (V) Activities done in class by students on the board. (V) Exercises given to students to solve in small groups. (V) Investigating learners' understanding of uses of radioactivity and the impact on the environment through a case provided. (G) Giving exercises on the board to be solved by students on the board. (G)		

NOTES: B, both teachers, V, Mr Victor, G, Ms Grace.

4.4. Discussion of the CoRe for teaching radioactivity

The CoRe represents the PCK of each teacher since it includes the knowledge of what the teacher intends to teach at a certain level of students, why that content has to be taught and how to teach it (Mulhall, Berry & Loughran, 2003). Below I discuss the two teachers' PCK as it has been represented in the rows of the CoRe.

4.4.1. What you intend students to learn about this idea.

According to Shulman (1986), one of the aspects of PCK is the knowledge of content which is important because it is the one that enables the teacher to be aware of central and peripheral concepts in a discipline for the teacher to organize concepts and to know which concepts need to be emphasised. The two teachers had common intentions about what content had to be taught in the topic of radioactivity with slight differences that are shown on the CoRe. The CoRe indicated that Ms Grace included stable isotopes and graphs that are used to compare the stability of radioactive substances determined from half-lives of different substances as important content to teach while Mr Victor did not consider this content. Instead Mr Victor considered the explanation of the physics words such as activity and half-life as important to differentiate the physics explanation from daily language of learners (Oyoo, 2010). The way the teacher perceives the content to be taught is important as this might be manifested in the actual teaching and it also provides a framework for teaching the topic per teacher that leads to observable differences when the two teachers teach the topic. Although Mulhall *et al.* (2003) argue that inexperienced teachers lack knowledge of being specific about what they intend students to know in a particular topic, in this study, both Mr Victor and Ms Grace had clear intentions about teaching radioactivity.

4.4.2. Why is it important for students to know this?

Geddis, Onslow, Beynon and Oesch (1993) assert that teaching content in a comprehensible way involves knowledge of different forms of PCK of which one of them is the significance of the topic in the curriculum. Both teachers seemed to have similar goals in the teaching of radioactivity that students will need the concepts taught for examination purposes and that they will use the concepts in their work places. Mr Victor also believed that teaching the selected ideas in radioactivity would help students to understand radioactivity as a whole and that students will be able to understand the uses of radioactivity such as the production of electricity. Mr Victor indicated that students focus more on the dangers of radioactivity (Brown & White, 1987) and pointed out that they need to be taught about uses of radioactivity to understand its

advantages. So the two teachers were aware of the importance of the topic for examination purposes and how the topic will be useful when students leave school for work or for further education. Although Millar *et al.* (1990) pointed out the need for teaching radioactivity at schools for learners to take part in public debates involving radioactivity, neither teacher mentioned the importance of teaching this topic for development of scientifically literate citizens who could partake in debates.

4.4.3. What else do you know about this idea that you do not intend students to know yet?

Teachers decide what to include or exclude in their teaching for them to make their learners understand and to avoid learners' confusion (Loughran *et al.*, 2006; Geddis & Wood, 1997). In this study the two teachers selected what they did not want their learners to know at the level they were teaching in order to avoid learners' confusion. Mr Victor pointed out the complete half-life equation, in depth concepts on how radioactivity is used in genetically modified food production and the Einstein's Mass-Energy equation, as knowledge that can confuse learners at their level. Ms Grace on her part considered the knowledge of why stable isotopes do not disintegrate and detailed concepts on how radioactive materials are used in industry and hospitals as the knowledge that can confuse learners. Although the two teachers selected the content that they did not want their students to learn, there were differences in what they deemed not important to teach. This prompt illustrates the knowledge that the teachers had about the topic beyond what was to be taught even though it does not suggest that the teacher who selected little content material to leave out does not have a deep understanding of the topic as for some teachers it is not easy to communicate what they know about the topic (Rollnick *et al.*, 2008).

4.4.4. Difficulties connected with teaching this idea.

The similarities that are noticeable in the CoRe include both teachers' awareness of language problems in physics that makes it difficult for students to understand physics and has also been mentioned by Qhobela (2008) who indicated that learning in a second language hinders the understanding of physics in Basotho learners. Mr Victor was also concerned about the lack of students' prior knowledge in the topic, the lack of mathematical knowledge (Lungu, 2009; Mulhall & Gunstone, 2008) and the safety precautions against radioactive substances that prevent students' experimenting with the radioactive substances (Lungu, 2009). Ms Grace's other concern was on the shortage of text books in her class.

4.4.5. Knowledge about students' thinking which influences your teaching of this idea.

Shulman (1986) and van Driel, Verloop and de Vos (1998) point out the knowledge of preconceptions that students bring to class in teaching certain topics as one important aspect of PCK because this knowledge helps the teacher to shape the teachers' subject matter knowledge in the way that the transformation to students will increase understanding. Ms Grace mentioned one misconception during the interview that students think that electricity generated from the nuclear power stations is radioactive. Mr Victor did not mention any misconceptions in the interview but through discussions he engaged in with students, he was able to identify misconceptions. Both teachers seemed to be aware of students' misconceptions because they were able to identify them during their classroom practice and applied teaching strategies that were intended to help students understand. The letters at the end of the stated misconception show the initial of the teacher who identified the misconception. The identified misconceptions were:

1. Radioactive radiation cannot penetrate through water. (G)
2. After the first half-life, the half-life of a substance becomes shorter. (V)
3. The least stable radioactive substance is the one that has the long half-life (Nakiboglu & Tekin, 2006). (G)
4. Radiated food is radioactive (Anjos, Facure, Lima, Gomes, Santos, Brage, Okuno, Yoshimura and Umisedo, 2001). (V)
5. When radioactive materials are used in medicine, they will cause more damage to body cells. (G)
6. Electricity generated from power stations is radioactive. (G)

Ms Grace also mentioned that students come to class having a conception that radioactivity is a difficult topic to understand.

4.4.6. Other factors that influence your teaching of this idea.

These teachers were both concerned about the lack of computers and internet facilities in their schools and they both believed that the knowledge that students get from the classroom only is limited and the presence of computers and internet facilities would enable students to get more information in radioactivity.

4.4.7. Teaching procedures (and particular reasons for using these to engage with this idea).

The common methods that would be useful in teaching radioactivity according to the two teachers include: lecturing, use of diagrams, explanations, discussions, questioning, and use of text books. Both teachers believed that these methods would help learners understand especially in their schools where there is lack of resources. Although Ms Grace did not mention this in the interview, she showed that she regarded storytelling, individual class presentations and providing a scenario as useful procedures for teaching radioactivity in classroom practice because she believed that they made students interested and kept them engaged in learning. Mr Victor preferred use of small group presentations, narration of history, use of analogies and involving graphs to teach radioactivity as suitable to situations (like his) where there is lack of resources and help to avoid radiological accidents in the laboratory.

4.4.8. Specific ways of ascertaining students' understanding or confusion around this idea.

Loughran *et al.* (2006) indicate that teachers use different ways to monitor their learners understanding and to see how effective their teaching was. These teachers valued the same methods of ascertaining students understanding such as assignments, oral questions and solving problems that involve calculations. Both teachers mostly used formative assessment to ascertain their learners' understanding.

4.4.9. General comment on the CoRe and difference between the teachers

The CoRe for both Mr Victor and Ms Grace gives an understanding of how both teachers approach the teaching of radioactivity. The CoRe highlights the content that both teachers regarded as important to teach, why they view that content important, the difficulties associated with teaching the topic, strategies used and the reasons for using such strategies. The content of the Core has shown that both Mr Victor and Ms Grace had some common views towards the teaching of radioactivity but they also had differences in the way they conceptualised the teaching of this topic.

The first three prompts of the CoRe as discussed in sections 4.4.1., 4.4.2 and 4.4.3 show the differences in the content that the two teachers regarded as important for including in their teaching, why the content is important and what the teachers did not want their students to know at their level of education. The mentioned differences suggest that the two teachers might have a different approach of teaching radioactivity even if they were teaching the same syllabus.

The difficulties about teaching of radioactivity in section 4.4.4, the knowledge about students' thinking in section 4.4.5 and the knowledge about other factors that influence teaching in section 4.4.6 show how much the teacher knew about the challenges around teaching. There would be expected differences in the strategies engaged by Ms Grace and Mr Victor. For example, Mr Victor would employ teaching strategies that cater for his students' lack of prior knowledge and poor mathematical background while Ms Grace would focus on the strategies that would enable students learn without text books.

The CoRe has captured and documented the PCK of the two teachers but not their actual practice; below I present the PaP-eRs for both teachers to show their actual classroom practice.

4.5. Construction of the PaP-eRs

To reiterate, PaP-eRs are descriptions of the teachers' actions or practice in the teacher's teaching context (Loughran, Mulhall & Berry, 2004). PaP-eRs therefore help to make aspects of PCK explicit in a particular teacher's work. The PaP-eRs are related to the CoRe and are illustrative of the actual teachers' practice which helps to make the tacit knowledge of the teacher clear. Loughran *et al.* (2004) constructed PaP-eRs from what they have observed in classrooms and the discussions with a group of science teachers. In this study, I constructed the PaP-eRs from video recorded classroom observations, field notes and the post observation discussions with the two physics teachers. I provide a narrative of the teachers' practice that helps to reveal aspects of PCK as the two teachers teach 'half-life' as a particular content area in radioactivity. The narratives include examples of the teachers' and learners' extracts from the video record transcripts and the snap shots from the video records. I have indicated the sources of the extracts by writing letters in brackets, for example, (VRTV) indicates the extract from the video record transcript for Mr Victor and (VRTG) indicates the extract taken from the video record transcript for Ms Grace. In each PaP-eR, the initial for the teacher's name has been used to indicate where the teacher was talking. S indicates students talking in chorus and S1 or any S with a number indicates an individual student talking. The words in bold in the quotations indicate the Sesotho words that were used by the teachers.

4.6. Mr Victor's PaP-eR on Radioactivity: Teaching about half-life

To reiterate, this PaP-eR has been developed using the video record transcript that was meant to capture the teacher's approaches to teach 'half-life' a sub-topic in radioactivity; this was to provide insight into the way this teacher articulated his knowledge of teaching half-life. In this class students dealt with half-life for the first time and this sub-topic was taught within a double period (80 minutes). When this sub-topic was taught, students had already been taught other sub-topics in radioactivity such as: the structure of an atom, unstable isotopes, how radioactivity was discovered, names of 3 types of radioactive radiation, detection of radioactive radiation, characteristics of alpha particles, beta particles and gamma rays and the meaning of radioactive decay where words such as disintegration and decay of atoms have been dealt with.

Part 1: Introducing half-life

Mr Victor began the lesson by telling learners that the class was going to deal with activity and 'half-life' and asked learners if they have ideas on what the two words: 'activity' and half-life mean, asking learners to explain the words from their everyday use. He allowed learners to use a dictionary to find the English meaning of the word activity. Learners looked for the word and one learner read the dictionary definition:

S1: Something that you do because you (inaudible) (reading from the dictionary).

After that, Mr Victor told students that he would give them the definition for activity in radioactivity and that he wanted learners to say if there is any link between the physics definition and the everyday meaning of the word.

V: Activity is the number of decays of a radioactive source per second (reading from the board). It is sometimes also called rate of decay. Is there any relation to the English definition?

Students concluded that activity has a different meaning in physics from everyday use. Mr Victor emphasised that some of the words used in everyday communication have a different meaning when used in physics, stating that:

V: So you see some of the words we use in English do not have any relation to the words we use in radioactivity, here it is the rate of decay (emphasising). Ok, and you know when you talk about the rate, it is something against time. (VRTV)

He then reminded learners of the meaning of the word 'rate' referring to concepts that are taught in physics such as power being the rate of doing work and 'activity' being the rate of disintegration and explained that "activity is the number of decays per second which also means the number of disintegration per second".

Mr Victor asked learners to explain half-life according to their understanding. The following is his interaction with students as he gave the meaning of half-life.

V: What is coming in your brains when you see half-life, half-life, that word, the compound word, what can you say, what is your idea?..

S3: I think it means something that is incomplete.

V: ...incomplete, what comes into you is something that is incomplete. Can you explain to me what is incomplete about half-life?

S3: I mean something that is half-way.

S4: Something in the middle. (VRTV)

Mr Victor seemed to be concerned about everyday language that learners used and the physics language used in class and wanted to make clear distinctions between these languages. Where it was possible for him to relate learners' language to the physics language, Mr Victor built on that and linked the physics meaning of a word to the learners' language. For example, Mr Victor gave an explanation of 'half-life' from his notes and then used the word 'middle' to clarify half-life indicating that when the object is full, then at half-life, one part from the middle will be gone and the other part will remain.

*V: We are dealing with the definition: half-life is the time taken for a radioactive sample to fall to half its original value... I want us to use middle, let us make our own definition so that we understand. Time taken for the radioactive substance to fall to half, it means when something is going to the middle, it means it will be half, half **hakere** (isn't it so)?*

(VRTV)

According to Mr Victor, the reason for involving the word 'middle' was to make students understand because this was the word they had used.

Part 2: Explaining half-life

Mr Victor drew a horizontal line on the board and then bisected the line to show the middle part of the line; he then stated that if the line was a radioactive substance, half-life would mean the

time taken for one part of the line being one half to go away and then the other part being the other half will remain.

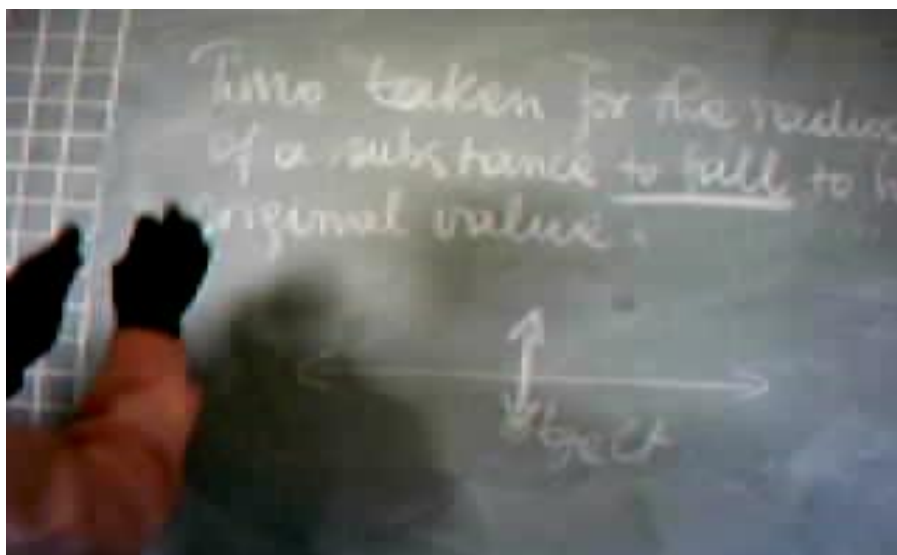


Figure 4.1: A line used to represent a radioactive substance

Another example that Mr Victor used to explain half-life was an example that involved bread. He gave the following example:

V: So what I am trying to say is assume you have 10 grams of bread, ok; you have your bread... Now after a certain time, let's say after 10 minutes, this bread after every ten minutes, like it or not is going to go to its middle part. I want to use the middle part so that you understand. Every ten minutes this bread is going to be divided by two, (emphasising) that means after ten minutes does it mean we have the full bread? (VRTV)

Mr Victor asked students to say what mass of bread will be left after every 10 minutes. At this stage Mr Victor did not say where the other half goes but he later asked students to say where the other half goes and students mentioned that the other half has decayed or disintegrated. While students gave answers like "half, the half will be halved", Mr Victor drew diagrams of portions of bread that would be left after every 10 minutes on the board. He then asked students to relate the given example with the definition of half-life which was written on the board as: half-life is the time taken for a radioactive substance to fall to half its original value. He mentioned that the original mass of the bread stand for the original value of a radioactive substance which is the value when decay time equals zero; because after every 10 minutes, the remaining value

of bread is halved, 10 minutes represents half-life of a substance. He also gave barium-139 that has a half-life of 86 minutes an example of a radioactive substance and explained that the same thing as happened with bread would happen to barium-139 i.e. after every 86 minutes the remaining quantity would be halved.

Mr Victor emphasised that each radioactive substance has a half-life different from others; he then asked students to find examples of radioactive elements from their text books and to state in each case the corresponding half-life. These were some of the examples which were given by students:

S6: Radium-226, its half-life is 1600 years.

S8: Potassium-40 has half-life of 1500 million years. (VRTV)

Although Mr Victor used various methods to explain half-life, one student seemed to have a misunderstanding about half-life; the students seemed to think that when a quantity of a radioactive substance decreases, the half-life also decreases.

S12: Sir if one half remains and another half is being halved, is this half-life going to be the same or is it going to change from something to something?... Sir, I am saying is that half-life going to remain at 1600 years? (VRTV)

The student referred to the half-life of radium-226 in this question. Mr Victor engaged a demonstration to explain to the student that half-life will remain the same even if the quantity of a radioactive sample decreases. He asked students to give him a piece of paper. Students gave him a full page and then he asked learners to assume that half-life of that paper was 2 days and then he asked them to say what would have happened to the paper at the end of 2 days. Students answered that the paper would be halved. Mr Victor tore the paper into halves and threw one half away and then asked what would happen to the remaining paper after 2 days. As students answered that the paper will be halved, Mr Victor indicated that the process will continue until the paper was finished. This demonstration was done so that the students would see that the quantity of a radioactive material is halved only after the time that is called half-life of a material. As well it was to highlight that the remaining sample has to wait for the half-life which is a time that does not change with the remaining sample of the radioactive sample.

Part 3: Examples involved in half-life

Mr Victor informed learners that they were going to represent half-life of a material using a decay curve. Then Mr Victor involved students in a discussion on the following question that was written on the board:

V: What quantity of a radioactive material will you have after every half-life of the material if you begin with 1 whole of the radioactive material? (VRTV)

As students gave answers, he plotted the answers against the number of half-life; that is against the first half-life, the second and the third and then joined the points to form a decay curve. The curve is shown below.

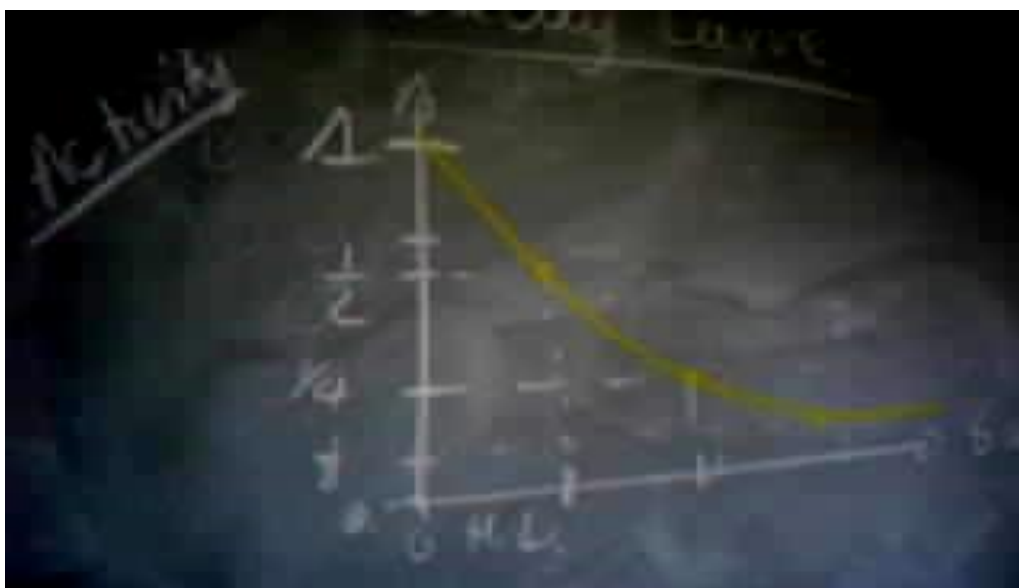


Figure 4.2: Representation of half-life of a material using a decay curve

Mr Victor drew another decay curve of a radioactive substance on the square board and wrote the question to be answered in class by looking at the decay curve. The example of the curve is shown on the snap shot below.



Figure 4.3: A decay curve of a radioactive substance

From this curve students were asked the following questions by Mr Victor:

V: What will be the count rate after 20 hours? Before we can go and answer this question, let me ask, what is the original amount here? What is the half-life of this substance? (VRTV)

Mr Victor asked individual students to answer the two last questions about the original amount and the half-life of a substance and also asked students to give reasons for the answers they gave. As shown in the graph, students answered that the original amount was 2000 and that the half-life was 5 hours, taking 1000 to be half of 2000 corresponding to 5 hours in the graph.

Thereafter Mr Victor asked students to find the solution for the first question in small groups. The answers that were given by students from their different groups are:

S17: 125

S18: 125

S19: After 10 hours it was 500, after 15 hours it was 250 and after 20 hours, this 250 was halved and it was 125. (VRTV)

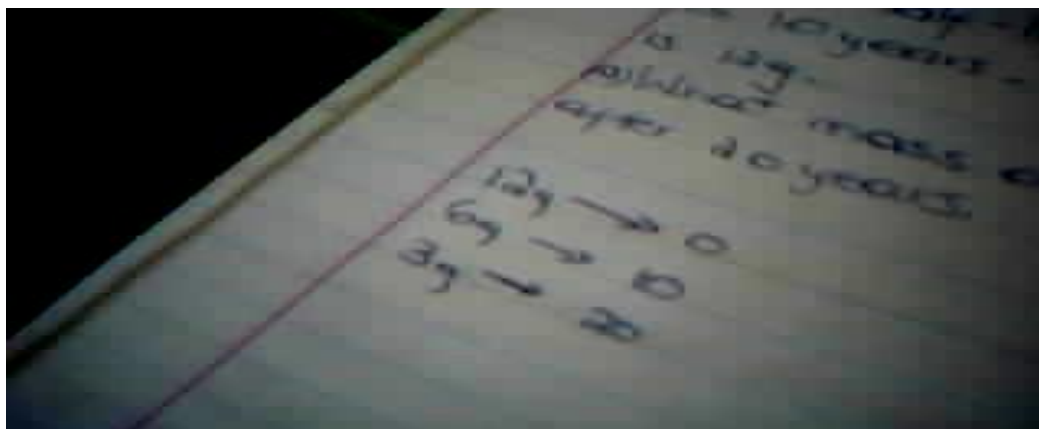
125 was the correct answer since the original amount of the substance was 2000.

The other example that was done in the form of a question involved students in simple calculations. The answers were found individually where students solved the question and gave

answers showing how they got the answer and one student was given a piece of chalk to solve the question on the board. The following question which was written on the board was asked by Mr Victor:

The half-life of a certain radioactive isotope is 10 years; the original value of the isotope is 12g. What mass of this radioactive isotope remains after 20 years? (VRTV)

These students used simple half-life calculations to find the answers; an example of the ways they used to get answers is shown by the picture below.



This is shown in the following table:

12g	→ 0
6g	→ 10
3g	→ 20

Figure 4.4: An example of answers given by students

Different students gave their answers and explained how they got their answers. Below are examples of the given answers and reasoning.

S20: 3g

S21: 6g

S21: I said $12g \div 2 = 6g$

S22: (solving the problem on the board) 12g is the original value; this value goes to half after 10...Because 10 is half-life... after 10 years we divide this value by two. ($12g \div 2 = 6g$). After another 10 years we divide 6g by 2. ($6g \div 2 = 3g$).

S23: 12g is the original value. We know that after 10 years this original value will be halved, and the half of 12 is 6. And then after the other 10 years, this 6 is going to be halved, the answer is 3g. (VRTV)

The correct answer was 3g. Mr Victor asked those learners who got the answer correct to help one learner who got the answer wrong; S21, missed how calculations are done because she went outside while Mr Victor was teaching.

4.7. Radioactivity PaP-eR for Ms Grace: Teaching about half-life

Ms Grace introduced half-life after teaching about the atomic structure, characteristics of three types of emission, detection of radioactivity and the meaning of radioactive decay. This subtopic was taught over one period (40 minutes). This PaP-eR has been constructed from a video record that was captured while Ms Grace was teaching and I was observing.

Part 1: Introducing half-life

Ms Grace introduced the concept of half-life by asking learners to say what they understand about half-life and while students were giving answers in a chorus, Ms Grace wrote a question on the board that read:

Assume we have 1 whole of a radioactive substance, and assume the half-life of a substance is 10 minutes. What is going to happen here (pointing on the board) when the time is zero? What is the amount of the remaining substance? (VRTG)

Ms Grace explained half-life through an example before she let students answer the question on the board. She explained that a radioactive substance has atoms and these atoms decay. She mentioned that:

*G: If you have a radioactive substance, that substance has atoms, **joale liatom tsena** (so these atoms), when the substance decays, may be half of the atoms decays and the other half remains, half of the remaining also decays, and the other half remains meaning when you have 10, 5 decays, the other 5 remains, half of 5 decays, how much will be left?*

S: 2.5

*G: 2.5 and half of 2.5 also decays let's say after 2 minutes, after another 2 minutes, the other half decays, **ebe joalo joalo ho fihlela half ea ntho e nyane e sala** (it continues until half of a small quantity remains). That is a half-life of a radioactive substance,*

meaning it is the time taken for a radioactive material to fall to half its original value.

(VRTG)

Ms Grace used the above example to introduce learners to half-life where she indicated that it is the time it takes for half of the atoms of a radioactive substance to decay and after every half-life, the remaining quantity of a radioactive substance is halved. She used the local language of students in her explanation and then switched back to explaining in English.

Part 2: Explaining half-life

Ms Grace went back to the board where she wrote the question on the board and asked students for the answer:

G: (Repeating the question on the board) assume we have 1 whole of a radioactive substance, and assume the half-life of a substance is 10 minutes. What is going to happen here (pointing on the board) when the time is zero? What is the amount of the remaining substance?

S: 1 whole

G: After 10 minutes?

S: (giving different answers) it is still 1 whole, it is half, it is 1.5, nothing happens.

G: It is $\frac{1}{2}$

S: (speaking at the same time) no, madam, why $\frac{1}{2}$? Yes, it is $\frac{1}{2}$. How?

G: After 20 minutes?

S: $\frac{1}{4}$ (in chorus)

G: After 30 minutes?

S: $\frac{1}{8}$ and after 40 minutes $\frac{1}{16}$ and then $\frac{1}{32}$ after 50 minutes. (VRTG)

The chorus responses that were different seemed to indicate that some students did not understand what was done in the classroom to find the answers and Ms Grace did not try to explain to those who seemed lost on how the answers were found but because of the answers that she wrote on the board, some students seemed to follow from the written answers what was happening. Ms Grace then told students that they can represent their calculation in the form of a graph called a decay curve. The calculations that were done and the graph drawn from the calculations are shown on the pictures below.

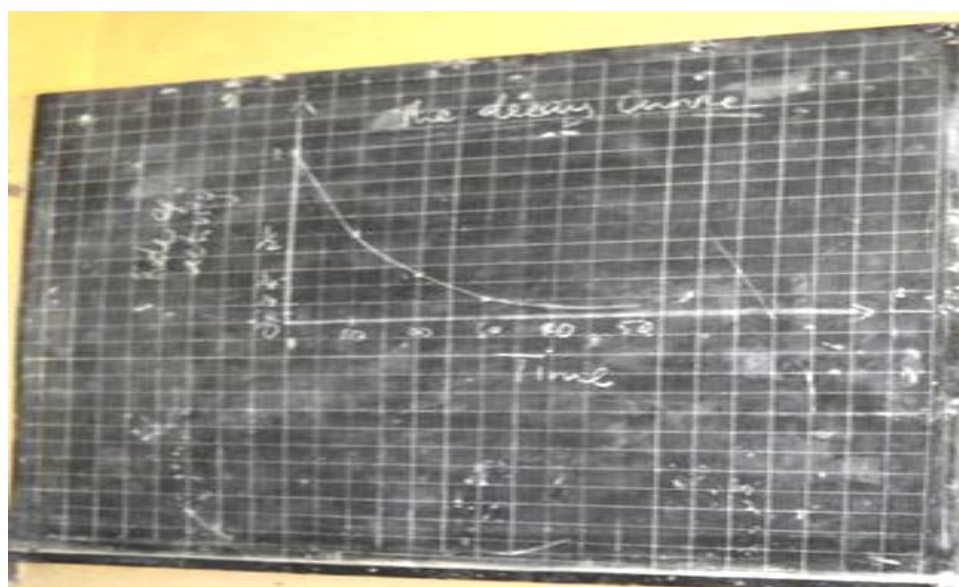
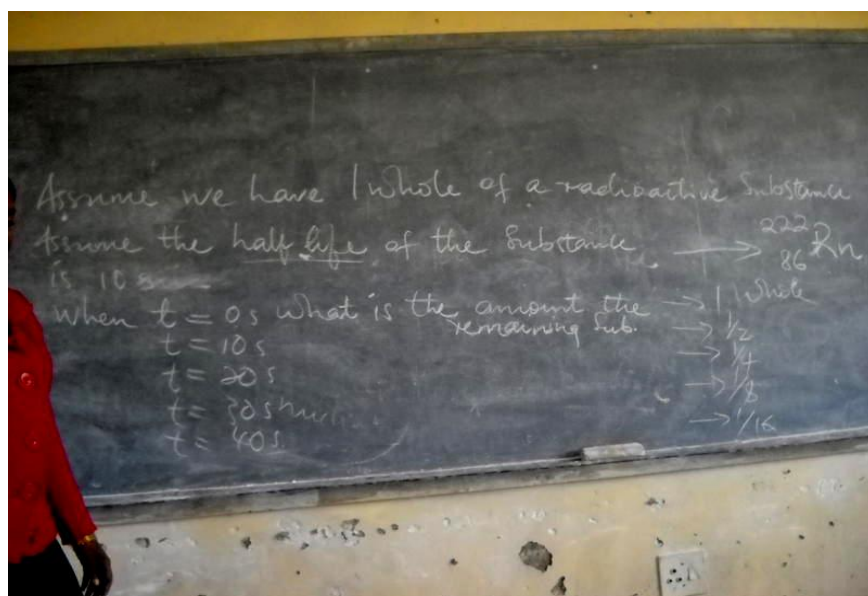


Figure 4.5: A decay curve representing half-life

Ms Grace emphasised that a decay curve has to look like this one which has been drawn on the board.

Part 3: Examples involved in half-life

Ms Grace drew 3 decay curves with different shapes on the square board and asked learners which of the three decay curves represented the most radioactive substance, which is the

substance with the shortest half-life. Students gave their answers individually, giving reasons for their answers.

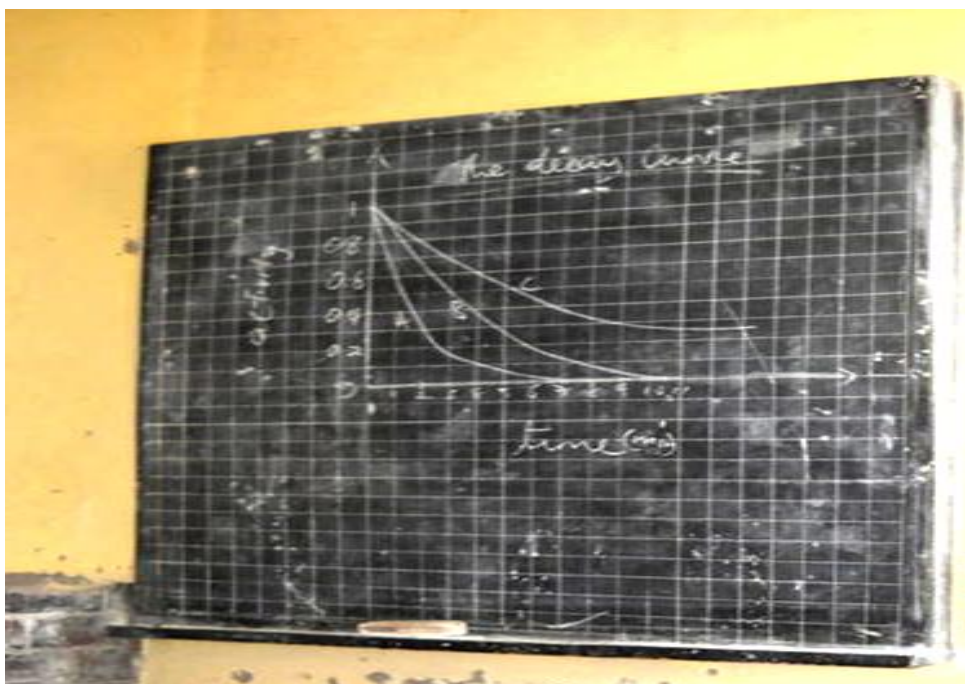


Figure 4.6: 3 decay curves

S7: Madam, I can say it is C because it takes a long time to decay, meaning it will decay and decay and decay again and again and again).

S1: Madam I can say it's A, because it takes a short time to decay. (VRTG)

From the students' responses and the drawn curve, Ms Grace explained that the substance that took a shorter time to decay was the one that is most radioactive. Explaining this using the curves where she showed by different half-life of the substances which was the most radioactive substance, indicated by the shortest half-life it has.

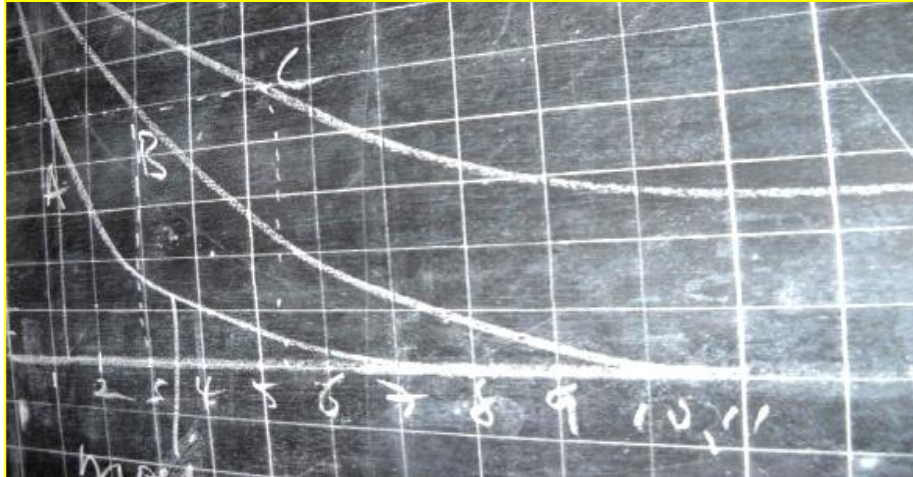


Figure 4.7: Vertical lines corresponding to half-life of the substance

The dotted horizontal lines indicate half of the original quantity of the radioactive material and the vertical dotted lines labelled A, B and C, indicate the half-life of each radioactive material. And through these, Ms Grace explained that the substance with the shortest half-life is the most radioactive. Ms Grace concluded the lesson by indicating that the most radioactive substance can be determined by looking at the half-life of different substances where the shortest half-life indicates the most radioactive substance. By the most radioactive substance she referred to the substance that took a shorter time to decay.

4.8. Discussion of the PaP-eRs for Mr Victor and Ms Grace

The discussion of PaP-eRs will be based on the aspects of PCK that have been portrayed by the two teachers under this study. The identified aspects of PCK in these PaP-eRs were: awareness of language difficulties in teaching radioactivity, ways of explaining half-life and teaching procedures engaged to address students' misconceptions.

1. Awareness of language difficulties in teaching radioactivity

Awareness of difficulties associated with teaching a certain topic is one important aspect of teachers' PCK (Loughran, Mulhall & Berry, 2006). In the teaching of radioactivity, the two teachers under study mentioned language problems as one of the difficulties that lead to students misunderstanding of physics words (see table 4.3.). In their teaching, Mr Victor and Ms Grace seemed to have been aware of the language problems that their students might have been facing.

Loughran *et al.* (2006) point out that knowledge of language difficulties is one feature of teachers' PCK that forms the teachers' knowledge of students that influence the teaching of a particular idea in the topic. Johnstone and Selepeng (2000) argue that some learners are faced with two problems in learning science, the problem of language used as a medium of instruction and the language of science. Basotho students are not an exception in this problem since they are studying science in English and expected to understand the language used in physics. The teachers in this study were aware of this language difficulty and addressed it in different ways. On one hand, Mr Victor began the class with the explanation of words that students were going to meet in class being 'activity' and 'half-life' and engaged students to find the meaning of the words where at the end he clarified the words' meaning in the context of physics (Oyoo, 2010). He did this to show the difference between words used in daily life of students and how the same words were used in radioactivity. On the other hand, Ms Grace used some Sesotho words to explain half-life after which she switched back to English. This approach is referred to as code-switching and it is used to bridge the gap between the second language and the language of science helping learners to develop conceptual understanding (Rollnick, 2000). By being aware that language hinders students' understanding, these teachers used these different approaches to avoid problems caused by misunderstanding the language used in physics, particularly in radioactivity.

2. Ways of explaining half-life.

Mr Victor used different representations to teach half-life. The representations he used included: analogies such as a line drawn on the board and the bread portions drawn on the board to represent what happens to the substance after half-life, demonstration of half-life using a sheet of paper, examples on calculations and explanations using graphs. Shulman (1986) asserts that PCK comprises the teachers' use of different ways of representing content that make it easier to understand by learners. Looking at the variety of ways of representing the content taught by Mr Victor, it shows that Mr Victor had developed rich PCK on teaching radioactivity. Loughran, Mulhall and Berry (2006) argue that the knowledge of teaching a particular content in the way that leads to students' understanding develops over time with experience, the different ways that Mr Victor engaged to teach this sub-topic, showed that Mr Victor had developed the knowledge of teaching this sub-topic.

The analogies that Mr Victor used were macroscopic and enabled learners to visualise what was meant by half-life. Radioactivity happens at microscopic level and it would have been

necessary for Mr Victor to explain what happens at microscopic level; that is at atomic level after demonstrating to learners what is meant by half-life as Millar *et al.* (1990) suggested that the teaching sequence should be from the macroscopic to microscopic level. Even though there seemed to be no bridge between the analogies used and the microscopic concept of half-life, Mr Victor's students did not seem to have problems doing calculations on half-life.

Ms Grace did not use analogies at all but used explanations that involved graphs and some examples on calculations. There were no observable varieties of representations as exhibited by Mr Victor in Ms Grace's teaching of half-life. Ms Grace used an example about the atoms of a radioactive substance decaying and simple calculations to explain half-life where there was a confusion of learners on how the answers were found while other learners followed what Ms Grace was doing. This indicated that some learners were struggling to understand the meaning of calculations while others showed that they understood. The approach to Ms Grace' teaching, involving calculations is similar to that of student teachers in Geddis, Onslow, Beynon and Oesch (1993) who began the teaching of isotopes through calculations, this is one way of transmitting teachers' knowledge to students without helping them to understand concepts. While Henriksen and Jorde (2001) maintain that it is important to find out the prior knowledge which students have on radioactivity before instruction, Ms Grace did not consider students' prior knowledge and poor mathematical background (Mulhall & Gunstone, 2008) of students to be the difficulties in the teaching of half-life, so the approach she was using suggests that she did not cater for students with poor mathematics background and lack of prior knowledge. The difference in the approaches used by Ms Grace and Mr Victor might be due to the different years of teaching experience that the two teachers had as van Driel, Verloop and de Vos (1998) argue that PCK develops through experience, so Mr Victor could have accumulated different ways of teaching half-life over the time he taught this topic.

3. Teaching procedures engaged to address students' misconceptions

According to Shulman (1986), pedagogical content knowledge incorporates prior knowledge of students of a particular age and the knowledge of teaching strategies which can be helpful in assisting learners to understand the subject being taught through overcoming and transforming learners' preconceptions if they are in the form of misconceptions. One student in Mr Victor's class had a misconception that half-life changes after the radioactive substance falls to half its original value. To address this misconception, Mr Victor engaged a demonstration with a sheet of paper to illustrate that half-life of a substance does not change with the remaining quantity of

a substance. More difficulties with teaching radioactivity appeared as Mr Victor engaged this demonstration. The demonstration with a piece of paper involved a macroscopic process where the paper was torn to indicate the remaining part until the smallest paper that could not be seen by students and that could not be torn further remained. Mr Victor stated that the process happens 'until the paper gets finished' and this statement was a misconception that came through while Mr Victor was trying to address another misconception (see page 56). The use of this demonstration may have aided understanding because students could see how the concept of half-life relates to exponential decrease in the quantity of a radioactive substance. This showed Mr Victor's knowledge of demonstrations that applied to the topic. However, the teacher did not point out the limitations of this demonstration, that at microscopic level, the atoms do not 'get finished'.

In Ms Grace's class, some students had a misconception that a substance that has a longer half-life is the one that decays quickly. This was also found by Nakiboglu and Tekin (2006) who mentioned that learners have difficulties relating stability of the nucleus to the half-life and showed that learners believe that the nucleus with a shortest half-life is the most stable while the shortest half-life implies least stability. Ms Grace used the graph of different radioactive substances to explain the relationship between the stability of a radioactive substance and the half-life of a material.

4.9. Conclusion

The CoRe and PaP-eRs helped me to show the teachers' intentions and identified important aspects to be looked at in the teaching of radioactivity by these two teachers. The CoRes and PaP-eRs have been helpful to represent the teaching knowledge of the two physics teachers and these instruments have helped me to document differences of how these two teachers seemed to conceptualise the teaching of radioactivity based on how they actually taught the topic in class. The different approaches engaged by these two teachers indicated that there is a difference between a beginning teacher and an experienced teacher in the way they approached their teaching. The experienced teacher, Mr Victor has used similar approaches to Ms Grace who is a novice teacher but there were more distinctive differences such as Mr Victor's use of analogies and in teaching which were lacking in Ms Grace's teaching. One of the strategies that Ms Grace used; using three different curves to differentiate between radioactive substances with different half-lives cannot be ignored since they might promote conceptual understanding in half-life.

CHAPTER 5: TEACHERS' SUBJECT MATTER KNOWLEDGE AND MANIFESTATION OF PCK IN TEACHING RADIOACTIVITY

This chapter is divided into two sections, section 5.1, ascertaining teachers' subject matter knowledge and section 5.2, the manifestation of PCK in teaching radioactivity. I investigated teachers' subject matter knowledge through a diagnostic test that tested teachers' subject matter knowledge on the topic of radioactivity to see how their subject matter knowledge lead to the strategies that they employed in teaching the topic. As mentioned previously, among other domains which make up the teachers' PCK according the model of Rollnick *et al.* (2008), SMK is the only domain that can be accessed directly using a diagnostic test, so the test was given to ascertain teachers' SMK in radioactivity.

5.1. Subject matter knowledge: Ascertaining teachers' subject matter knowledge

5.1.1. Introduction

Different authors argue that subject matter knowledge is important in teachers' PCK. For example, Shulman (1986) argues that for teachers to teach any subject, they must have the knowledge of content in that subject. This means that content knowledge is the basic requisite for teachers to teach. Cochran, DeRuiter and King (1993) also consider subject matter knowledge as one of the essential ingredients that form teachers' PCK. Teachers have a tradition of using teacher-centred methods and this becomes even more common where teachers lack subject matter knowledge (Gess-Newsome, 1999). In this section, I present the results of the diagnostic test that I gave the two teachers under study to test their subject matter knowledge on radioactivity.

5.1.2. The diagnostic test

As mentioned before, the diagnostic test was composed of five questions that were selected from a well known text book (Storen & Martime, 2004), to cover the subject matter knowledge on the topic of radioactivity (see Appendix 2 and Table 3.1). I analysed the test referring to the memorandum that I had prepared. As stated in previously I used the memorandum together with the rubric (refer to appendix 2) to categorise teachers' responses into correct, partially correct, incorrect and no response. To validate my classification, I gave the teachers' responses to my colleague who is also a physics teacher to see if she could come up with the same classifications I made and she did come up with the same classifications except for question 1 (a) where I classified the response for Mr Victor as incorrect because of the electrons that he

included in the diagram. My colleague suggested that we classify the question as correct because the nucleus components were correctly shown in the diagram which was the content that the question was looking for and we agreed on the classification of the question as correct despite being technically incorrect. The diagnostic test was meant to ascertain teachers' subject matter knowledge on the topic of radioactivity. The analyses of the diagnostic test are presented next.

5.1.3. Results of the diagnostic test

Question 1

(a) Carbon has an atomic number of 6. One isotope of carbon has a nucleon number of 12 and another isotope has a nucleon number of 14. Draw the nuclear structure of these isotopes, showing clearly the difference(s) between the diagrams.

Responding to question 1 (a), Ms Grace drew only the nucleus of the carbon isotopes leaving out the electrons, which was technically correct while Mr Victor drew both the nucleus and the electrons.

Radioactivity involves atoms and subatomic particles and the knowledge of the nuclear structure is a prerequisite in radioactivity which was expected to be known by both teachers. Mr Victor included electrons while the question was looking for the nuclear structure that involves only protons and neutrons. This might have been the case because Mr Victor could not have read the question carefully enough. However he showed the requisite content knowledge on the nuclear structure, so both answers were classified as correct.

(b) Why is each of these isotopes electrically neutral?

Both teachers answered this question correctly by providing the similar response that: "The number of protons is equal to the number of electrons" but did not enlarge on the response by suggesting that the number of neutrons does not affect electrical neutrality. This response was classified as correct.

Question 2

(a) What are three types of natural radioactivity?

Answer: Alpha particles, beta particles and gamma rays.

(b) Which of these three radiations²:

i. Has the greatest penetrating power?

Answer: Gamma rays

ii. Is deflected the most by a magnetic field?

Answer: Beta particles

iii. Is most easily absorbed?

Answer: Alpha particles

iv. Has the strongest ionising power?

Answer: Alpha particles

v. Is not deflected by a magnetic field?

Answer: Gamma rays

vi. Is deflected most by electric field?

Answer: Beta particles

Both teachers gave similar correct responses to question 2 (a) and (b).

The teachers' correct answer to questions 2 (a) and (b) showed that they had a basic knowledge of the characteristics of the three types of radioactive radiation.

Question 2 (c)

(c) Why are some of these radiation types deflected by both electric and magnetic fields?

Question 2(c) presented a greater challenge to both teachers. Ms Grace did not attempt an answer while Mr Victor's response was partially correct. Ms Grace's decision to provide no response for the question could suggest that she had no idea on the question; maybe because of the way she had learned the concept, maybe she did not learn the concept at all in her training. Mr Victor's answer was: "because some they have charges."

The partially correct response given could not suggest whether Mr Victor understood the concepts underlying the deflection of some of radioactive radiation in magnetic or electric fields. This was a question that needed conceptual understanding of the behaviour of types of

² Radiation in this study refers to radioactive radiation

radiation in magnetic and electric field and the explanation would involve what actually causes some radiation to be deflected while some is not. This could suggest the depth of knowledge of Mr Victor around this concept, that his content knowledge was not deep enough maybe because of the content he learned in his training to be able to explain the behaviour of radiation in magnetic and electric fields.

Question 3

Why would nuclear fusion be a safer reaction for society than nuclear fission?

The expected answer was:

Nuclear fusion produces low radioactive waste while nuclear fission produces high radioactive waste. If the fusion reaction goes out of control, the reaction automatically stops as it cools down but with fission reaction, if it goes out of control, a nuclear meltdown can happen which can release highly radioactive particles in the environment.

Ms Grace did not attempt to respond to the question.

Mr Victor's answer: Fusion is the basis for our life by allowing the sun to keep on burning, atoms are brought together, and the reaction is slow and less radioactive.

Although Mr Victor attempted to answer the question, his answer does not clearly answer the question. The part of the answer that states that fusion is less radioactive indicates that Mr Victor was aware of the radioactive waste produced by the two reactions even though he did not use precise words to respond to the question but involved a vague term "less radioactive". This response could suggest that Mr Victor might be aware of the advantages of nuclear fusion over nuclear fission even though his understanding seemed to be superficial on the two processes, fission and fusion. This question is not within the syllabus that the two teachers teach, so their failure to give correct or accurate responses might be because they prepared within the sphere of the content they were teaching and have forgotten about other content that they did not teach. It does mean that their knowledge of the topic does not stretch beyond what they have to teach.

Question 4

A radioactive element has a half-life of 20 days, what mass of an element remains after 80 days if the original mass was 4.0g? Please show your reasoning.

Mr Victor's answer: 0.25g

Reasoning: 4.0g $\rightarrow$ 0

2.0g $\rightarrow$ 20days

1.0g $\rightarrow$ 40days

0.5g $\rightarrow$ 60days

0.25g $\rightarrow$ 80days

Ms Grace's answer: 1.0g

Reasoning: 20days $\rightarrow$ 4.0g

40days $\rightarrow$ 2.0g

80days $\rightarrow$ 1.0g

Mr Victor got question four correct showing reasoning by successive calculations while Ms Grace got the question incorrect and the reasoning provided by the calculations show that Ms Grace did not do the correct calculations. Ms Grace began her calculations with the full mass after 20 days, it seems she thought that after one half-life has elapsed, the mass remains unchanged and the mass would then change after the second half-life, which could suggest that she had a misconception about half life, or maybe she had forgotten how to do the problem. The other mistake contributing to the incorrect answer was the omission of 60 days in her calculations, showing that at the time of the diagnostic test she either did not understand the concept of half-life or she did not prepare well.

Question 5

Why are radioactive materials kept in lead containers?

Mr Victor's answer: Because lead is a good absorber of ionising radiation.

Ms Grace's answer: It reduces their penetrating strength.

Both the answers given to this question were not completely answered, I classified them both as partially correct because their answers need to be complemented to be correct, for example, Mr Victor stated that lead is a good absorber of ionising radiation but did not say anything about what lead does to gamma-rays. Ms Grace stated that lead "*reduces their penetrating strength*" but there are radioactive radiations which are completely stopped by lead not only reduced by

lead. The teachers should have stated that lead has a high density and is able to stop both alpha and beta radiation and it reduces gamma radiation.

5.1.4. Discussion of teachers' diagnostic test

Ms Grace had one question incorrect and two unanswered. The question that Ms Grace got incorrect was the question that involved half-life calculations. Ms Grace had however solved similar kinds of questions correctly in the observed class, so the fact that she got the question incorrect in the diagnostic test cannot be taken to indicate that she did not know how to do calculations. Perhaps she made mistakes while solving the question, having had problems with mathematical calculations, or that when she went to class she had prepared well in time to get questions correct. This could also suggest fragile subject matter knowledge for Ms Grace that she needed to revisit her content before solving some problems.

Ms Grace did not attempt two questions and this leads to the assumption that she did not have any idea on the questions. This can be argued despite the fact that the questions that she did not attempt were not within the syllabus that the two teachers were teaching, a teacher should have a broader knowledge of subject matter on the teaching subject than the students (Shulman, 1987); I therefore share the argument that even the knowledge that goes beyond what the teacher teaches is crucial for effective teaching (Bishop & Denley, 2007). I expected that Ms Grace would have knowledge about the questions so that when the students asked questions out of the syllabus content, the teacher could be able to answer.

The two teachers were able to answer most of the questions correctly that were within the syllabus they were teaching. The questions that were either partially correct or unanswered were not in their syllabus or the syllabus did not require them to go deeper into explaining the fundamental concepts like question 3 which Mr Victor answered partially and Ms Grace did not attempt.

Mr Victor attempted all questions. The questions that he answered partially correctly suggest that he had some ideas around the concepts, this is also evident from the CoRe in answers to prompt 3 and besides his training; this could be attributed to his level of experience compared to Ms Grace who was a beginning teacher. Mr Victor could have come across similar questions from students in his teaching.

Table 5.1: Categorisation of teachers' responses

Question	Sub-question	Part of sub-question	Mr Victor's response	Ms Grace's response
1	a		correct	correct
	b		correct	correct
2	a		correct	correct
	b	(i)	correct	correct
		(ii)	correct	correct
		(iii)	correct	correct
		(iv)	correct	correct
		(v)	correct	correct
		(vi)	correct	correct
	c		partially correct	no response
3			Partially correct	no response
4			correct	incorrect
5			partially correct	partially correct

Looking at the way these two teachers answered the diagnostic test, it seems that both of them had required knowledge of the content that they were expected to teach according to their curriculum. This knowledge is limited and it could result in the difficulty to answer questions if students asked questions beyond their curriculum. Ms Grace seemed to have insufficient knowledge as she needed to revisit the content before teaching as evidenced by her incorrect answer on question 4 in the test, but her correct work with the class. The number of partially correct responses could suggest a lack of depth of knowledge for both teachers and the number of no responses could suggest that the teacher had no idea around the question. These indicated a difference between the subject matter knowledge for Ms Grace and Mr Victor that Mr Victor had better subject matter knowledge than Ms Grace and this contradicts Hoz, Tomer and Tamir (1990)'s finding that the level of experience has no effect on subject matter knowledge.

5.2. Manifestation of PCK in teaching radioactivity

In this section the manifestations of PCK as shown in the teaching strategies employed by Lesotho physics teachers are discussed with regard to the knowledge domains that generated

the displayed knowledge of teaching the topic of radioactivity. In particular, this section attempts to answer the following research questions:

- How is the PCK of the two teachers manifested in their teaching of radioactivity?

And

- What is the role of experience in the PCK of two physics teachers?

To answer these two questions, multiple sources of data were used to draw results on teaching strategies that teachers used and the reasons for using those strategies. Results were extracted from interviews, video recorded classroom observations, field notes and post observation video episodes discussions with teachers. The additional sources of data focused on in this chapter are the interview transcripts and post observation discussion transcripts for the teachers. Table 5.2 gives the details of the abbreviations I have used. I used excerpts selected from these sources to illustrate some points emerging out of data; in all cases, abbreviations in brackets have been used to indicate the sources of data. The same abbreviations that have been used in section 4.4 have been used here to refer to video record transcripts for the two teachers.

Table 5.2: Abbreviations used to indicate sources of data

Abbreviations used	Description of data source
ITG	Interview transcript for Ms Grace
ITV	Interview transcript for Mr Victor
PODTG	Post observation discussion transcript for Ms Grace
PODTV	Post observation discussion transcript for Mr Victor

The manifestations of PCK in the teaching strategies used by the teachers who participated in the study are discussed below in terms of the categories as outlined in Rollnick *et al.* (2008)'s model and the reasoning for using such strategies are inferred referring to knowledge domains that are considered in the model. Manifestations refer to observable practices that the teachers engaged to teach concepts.

5.2.1. Manifestation of PCK in teaching strategies

Below, I discuss the teachers' PCK, with reference to their knowledge of teaching strategies that were visible in the classroom: representations, assessment, curriculum saliency and topic specific instructional strategies together with the knowledge base domains that produced the

manifestations. In this study, teaching strategies are viewed as the actions or representations of the subject that are engaged in by the teacher to help learners understand the concepts; these actions therefore are manifestations of teacher knowledge in teaching radioactivity.

5.2.1.1 Representations

As discussed in section 2.2, page 13, representations of subject matter refer to the analogies, illustrations, examples, explanations and demonstrations used by the teacher to make subject matter understood by learners (Rollnick *et al.*, 2008; Shulman, 1986). Discussions of how the two physics teachers who participated in the study used representations during their teaching of radioactivity now follow.

(a) Analogies

Lungu (2009) reports that one of the difficulties to teach radioactivity is the topic's abstract nature. In trying to help learners understand, one teacher used an analogy to make the content easier to understand. Mr Victor used an analogy with an onion to represent the effect of released radioactive radiation when an unstable isotope disintegrates. He wanted to show that radioactive radiation that is released cannot be seen but the effects can be observable.

V: Let's consider onion to be an unstable isotope, like isotopes break, let's say when you cut onion it breaks releasing that vapour, you cannot see the vapour but the effects of the vapour you can feel. What is released when isotopes break?

S: radiation.

V: we said substances which are radioactive release radiation, now what is radiation?

S3: The sending of energy in the form of waves.

V: Good now, we cannot see this radiation with our naked eyes but we can feel the effects of radiation. (VRTV)

Mr Victor used an analogy with an onion which is not radioactive but used it to symbolise a radioactive isotope to help learners understand that even though this radiation is emitted during decay; they cannot see it occurring but can only observe the effects of that radiation. Onions are commonly used as food in students' everyday life, so Mr Victor chose to use the example of an onion knowing it was familiar to students and the effects of cutting it were well known to students. This indicated his knowledge of transforming content taking into consideration students' context. Ms Grace did not use any analogies in her teaching.

(b) Illustrations

One of the illustrations that Mr Victor used was a diagram that showed how different types of radioactive radiation were deflected by the magnetic field.

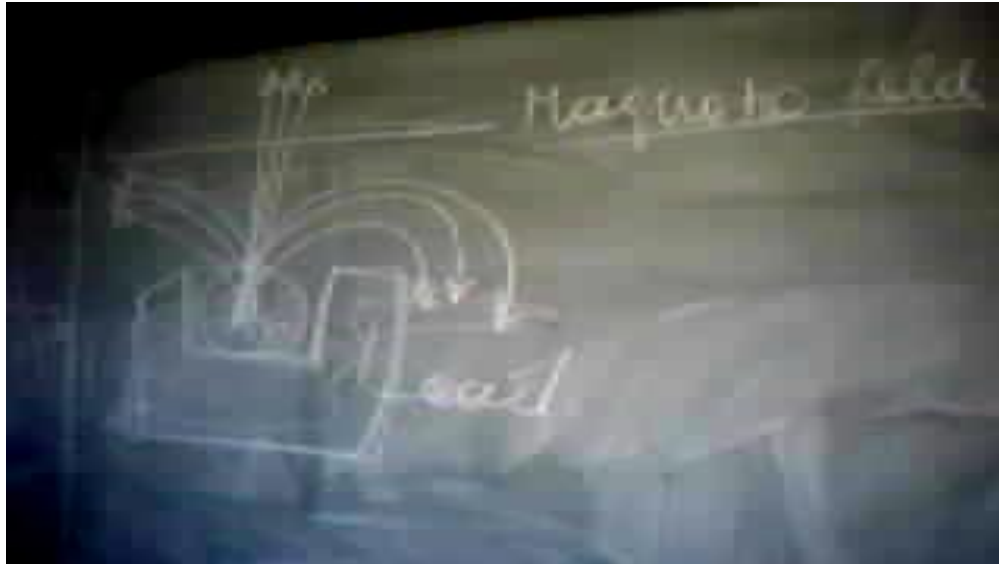


Figure 5.1: deflection of radioactive radiation in magnetic field

Mr Victor was showing how different types of radioactive radiation were affected when passed through a magnetic field. The three different directions of the radiation on the diagram showed that some radiation is deflected while some is not. Mr Victor used the same diagram to explain that different types of radiation behave differently in magnetic field depending on the charge they have, like he did with answering this question in the diagnostic test, he did not go beyond explaining why the charged radiation was deflected in magnetic field. Mr Victor chose to use a diagram together with verbal explanation to clarify this concept drawing from his general pedagogical knowledge that helped him choose this strategy, knowledge of students, knowing how best his students would learn this concept and his content knowledge (Rollnick *et al.*, 2008).

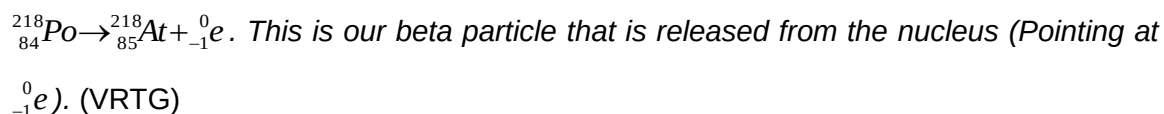
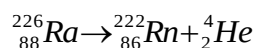
Ms Grace also used diagrams to show the instruments used to detect radioactive radiation and how they are used. The instruments she drew on the board included a spark counter and the gold leaf electroscope; she also asked learners to look up diagrams of the other instruments in their text books. She also used the diagram to show the difference in penetrating powers of different types of radiation. Drawing from her general pedagogical knowledge, knowledge of

students and her content knowledge, Ms Grace used pictures to clarify concepts in radioactivity with her belief that students learn best when they see and that diagrams help learners understand better than when the teachers use verbal explanations only.

(c) Explanations

The nature of radiation types was dealt with before the radioactive decay by both teachers. Both teachers revised with learners the nature of the alpha particles, beta particles and the gamma rays and they related the differences in their nature to changes in the parent nuclide's nucleon number and atomic or proton number. In explaining how different types of radioactive decay take place and their effects on the nucleon number of the parent nuclide, both participant teachers used specific examples to represent different types of decay.

Some of examples used by Ms Grace:



Some examples used by Mr Victor

Activity:

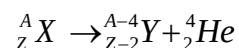
- (a) *What is the nature of alpha-particles, beta-particles and gamma-rays?*
- (b) *What effect would the emission of each type of radiation have on the nucleon number and proton number of the parent nuclide?*

Take examples of:

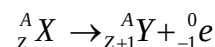
1. *Radium-226 emitting alpha-radiation*
2. *Carbon-14 emitting beta radiation*
3. *Cobalt-60 emitting gamma radiation (Field notes Mr Victor)*

They started with specific examples of radioactive decay before they moved to general equations. Below are the general equations they used to explain alpha, beta and gamma decay. In these equations X denoted the parent nuclide while Y symbolised the daughter nuclide.

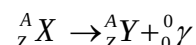
The equation that indicated alpha decay



The equation that indicated beta decay



The equation that indicated gamma emission



These teachers did not seem to be only interested in using equations to teach about radioactive decay but they seemed to use their knowledge of content to link conceptual aspects in radioactivity such as the nature of radiation to explain the changes in the daughter nuclides resulting from the emission of radiation through equations as indicated in the examples above. This approach is also indicative of the teachers' knowledge of students and general pedagogy, knowing how to simplify the content such that students could easily understand.

(d) Demonstrations

Mr Victor used a sheet of paper to demonstrate how the mass of a radioactive substance decreases after each half-life but that the half-life of a substance remains unchanged for a given substance. He demonstrated this using a sheet of paper which he successively tore into halves after the assumed time that was considered to be the half-life of that paper. He did this to show students that even when a small quantity of a radioactive substance is left, for the quantity to fall to half of its remaining value, the same time that was considered to be the half-life does not change. Students seemed to understand after this demonstration. Ms Grace did not involve demonstrations in her teaching.

The knowledge of students' learning difficulties encountered in learning in radioactivity could have guided Mr Victor to employ more methods of teaching half-life. He considered their poor mathematics background as a barrier to understanding half-life (Mulhall & Gunstone, 2008). He stated that "If a student does not know mathematics, it is going to be difficult for that student to understand half-life" (ITV). Knowing that it would be difficult for students who did not know mathematics to perform half-life calculations, he engaged strategies such as drawing a loaf of

bread and dividing it into halves where students were able to see where the answers like half of half is a quarter and half of a quarter is one eighth through the drawing on the board. Although the demonstrations used were macroscopic, they were meant to explain what happens at microscopic level. They were helpful to increase students' understanding but there was no link between the demonstrations and the microscopic level concepts of half-life such as half-life being a random process, meaning it cannot be determined which half of atoms were going to decay and the demonstrations cannot explain that the atoms never get finished in the process of decay. Although these demonstrations did not have a link to microscopic level of the concepts they were helpful because calculations involved in half-life at the level of these students involved successive halving, which these demonstrations were addressing.

5.2.1.2. Assessment

In the pre-observation interview Mr Victor, mentioned that he would use tests, quizzes, and activities in the form of question and answer to evaluate students' understanding. Below is the extract that shows how Mr Victor indicated how he would assess students' understanding.

V: I will be giving them tests, I will be giving them maybe a quiz to find out if they are able to do it. And sometimes, sometimes I always go for activity, it means immediately after a subtopic, their series of questions are always elaborate and I give to students to answer which will help me to see whether they try to get what we taught about. (ITV)

During the actual lesson, Mr Victor used assignments, solving exercises on the board, individually or in small groups, and oral questions. Some of the assessment methods that Mr Victor mentioned such as quizzes and tests were not observable in his classroom practice during observation but these assessment strategies could have been used later in his teaching.

Examples of the questions used by Mr Victor and the answers given by students are given in section 4.5 part 3, where students solved questions in small groups, individually or giving the solution on the board.

On her part, Ms Grace had mentioned that she would use different kinds of questions to ascertain students' understanding. "Giving them questions... Assignments then when we discuss them in class, they are able to see that where they are wrong and where they are right" (ITG). In the observed lesson Ms Grace varied her methods of assessment. She used exercises written on the board as well as from the text book. Examples of the exercises are shown in

section 4.6 part 2 and part 3 together with students' answers where they answered in chorus and individually.

Both teachers used formative assessment in the form of oral questions which were more dominant over other methods of assessment. They also gave students assignments which were presented in class even though the presentations differed. Mr Victor had students in small groups to do the oral presentation of the given assignment on uses of radioactivity. The assignment question read "Discuss uses of radioactive materials in agriculture, medicine and in industry" (VRTV). Mr Victor involved collaborative learning strategy (Schroeder, Scott, Tolson, Huang & Lee, 2007) to assess his students after a given time of students' discussion. Ms Grace involved individual oral presentations for the similar assignment with a question that read "Find out the uses of radioactivity in industry and medicine. Find out the dangers of radioactivity. Suggest safety precautions that should be taken against radioactive materials" (VRTG). The different strategies were employed based on each teacher's knowledge of general pedagogy, selecting what strategy would best help learners to understand.

Although Ms Grace seemed to have used certain strategies for different reasons, her class was noisy most of the time. Students were answering questions in chorus, they could not wait for her to choose them, they were talking at the same time and this resulted in a lot of noise in that classroom. Ms Grace indicated that she should not have let her students answer through chorus responses because that method of assessment contributed to the noisy class. She mentioned this while watching her video record episode in the words:

G: (Listening to the noise made by students as they answer questions in a chorus) *I think I may want to approach it in a manner that they raised up their hands individually, quietly, it would have been better, the lesson is distractive.* (PODTG)

This was an issue of the knowledge of classroom management techniques that Ms Grace was apparently not aware of while teaching but she recognised how distracting the method was especially because she was teaching a big class. In contrast to Ms Grace's class, Mr Victor's class was smaller in size but he did not allow chorus responses in his class, students most of the time raised up their hands and waited for him to pick them to answer. There was minimal noise in his class indicating that he was more skilled in class management that denotes his knowledge of general pedagogy and his strategy for assessment seemed to have worked towards reducing noise.

5.2.1.3. Curricular saliency

Both teachers included re-teaching the structure of the atom when beginning the topic of radioactivity even though this topic had been handled earlier in students' studies. Even though Ms Grace did not mention this during the pre-observation interview, she included this in her teaching. Mr Victor showed the reason for beginning with this concept although it is not strictly part of radioactivity content in the syllabus:

V: ...we have to talk about the atom... you cannot talk about for instance... radioactive decay if a student does not know what is a proton, what is mass number, so you see those ideas they complement each other, so I think all the ideas there are very important. (ITV)

Mr Victor indicated how important it was for him to include teaching about the atomic structure and he mentioned the relationship between the structure of an atom and radioactive decay. The understanding that Mr Victor had about the interrelationship of the knowledge about the structure of an atom and radioactive decay which is informed by his knowledge of subject matter helped him to include the atom in his teaching. He also related the rate of decay to other concepts in physics such as power; being the rate of doing work, which could not be easily done by a teacher lacking content knowledge in physics. This also reflects his knowledge of the curriculum, which is contextual knowledge.

Both Mr Victor and Ms Grace were able to state the ideas that were important to include and exclude in the teaching of radioactivity considering the importance of the topic in examinations, further education and for application in future work places. The following excerpt is an example of what Mr Victor said about what he considered important to include in the teaching of radioactivity.

V: ... you can also include something that you know but that is not in the syllabus and you guide them (students) by giving them some further information that you think they will need when they are in the university or in their working places... I was teaching about the modification of DNA and the effects of radioactivity on genetically modified food, we are not allowed to teach that, the syllabus does not allow us to teach that... so you should tell the students its importance like the uses... (PODTV)

Mr Victor showed that when teaching radioactivity there is some important content that though omitted in the syllabus, needs to be taught for the future benefit of students whether at work

places or at universities. Having a broader knowledge of subject matter might have helped Mr Victor to include some of the concepts he thought would be important for students to know which would be difficult if he did not have such knowledge.

Ms Grace did not have evidence of what she would include in her teaching though not covered in the syllabus but she mentioned what she considered has to be omitted in the teaching of radioactivity.

G: ...I do not think it is important for them to know why stable isotope does not break and I think also such things as what, em! Fission and fusion, it is not required in their syllabus for them to know. (ITG)

Mr Victor referred to some content in radioactivity that he considered important to omit in his teaching as well as the content that needs to be taught superficially around the topic of radioactivity. He stated that some concepts such as the Einstein Mass-Energy equation ($E = mc^2$) do not need to be taught at all at this level, but the process of generating electricity in the nuclear power station needs to be taught but not in detail.

The two teachers were clear on what was important to be included or excluded in their teaching of radioactivity; this helped them to decide where they should be detailed or not in teaching certain concepts. Their knowledge of subject matter and the knowledge of what is best for students at the level they were teaching helped them to sequence the content they taught, to select the content they deemed important in the topic and to explain concepts in a way that helped students to understand.

Curricular saliency is seen through the teachers' understanding of what has to come before and after the topic being taught (Rollnick *et al.*, 2008; Geddis & Wood, 1997), hence is a pointer to the knowledge that the teacher has on how the topics are interrelated and how important the topic is. In addition, curricular saliency is also evident in the teachers' knowledge of what is to be included or omitted while teaching the topic.

5.2.1.4. Topic specific instructional strategies

The teachers in this study similarly appeared to have a repertoire of a broad range of teaching strategies. These strategies differed according to the class of the teacher.

The two teachers used similar and different procedures for teaching radioactivity. The similarities and differences in the procedures the two teachers used for teaching radioactivity

were described in section 4.3. Most of the topic specific strategies that were exhibited in the teachers' observed classroom practice were not mentioned in the pre-observation interviews. Ms Grace for example had mentioned in the pre-observation interview that she would use "lecture method and diagrams" (ITG) but additional methods were observed were during her teaching as has been presented in section 4.3. Similarly, Mr Victor also used more methods than those he had mentioned. Lecture method and to let learners find information through questioning were his planned strategies to teach radioactivity; in his actual teaching however, a variety of other methods of teaching radioactivity were evident. He mentioned that:

...they (students) can ask questions and they try to, as a teacher you will try to help them... I cannot run away from lecturing because there are things whether you like it or not the teacher should talk, so lecturing also is going to be involved... I think the two methods to me... that's the only easy way. (ITV)

This indicates that depending on the context and general pedagogical content knowledge, a teacher is able to involve a variety of strategies in a classroom situation to suit the content being taught.

Table 5.3 displays Ms Grace's teaching strategies she used and the reasons for using such strategies.

Table 5.3: Ms Grace's teaching strategies and her reasons for using them

Content covered	Teaching strategies	Reasons for using the strategy
Half-life	Storytelling followed by a discussion.	To increase students interest and to capture students attention.
Safety precautions against radioactive materials and uses of radioactive materials	Scenario followed by questioning and discussion	To find misconceptions that students have about uses of radioactive materials.

Ms Grace narrated the story about the radiological accident that happened in Brazil where people came into contact with a radioactive material leading to death and hospitalisation of others. She mentioned in her story that after a number of years, some plants that grew in the

place of the accident were still contaminated with the radioactive material. She then involved a class into a discussion through asking questions such as:

G: Explain why the radioactive material was still observed in the area after a long time after the accident happened. (VRTG)

Ms Grace gave her reasons for using the chosen strategies as stated “They (referring to students) like to listen to stories so it captures their attention” (PODTG). In this extract Ms Grace shows her knowledge of students, knowing what makes them listen in class and choosing the strategy that she knew would make them listen attentively. Ms Grace also used a scenario as one of her teaching strategies. She read the scenario she prepared for the students. The scenario read:

Load shedding³ has been a concern for several years in Lesotho due to shortage of electricity. The government of Lesotho has decided to prevent load shedding through generation of electricity in nuclear power station. A nuclear power station generates electricity though the use of radioactive materials from which other radioactive materials are produced. There should be people working in this power station. The government wants your opinion whether they should build a power station in your country to address the issue of load shedding. State whether the government should carry on with the issue of building a nuclear power station or not, giving your reasons. (VRTG)

This type of strategy where the teacher engages students in a problem-based learning related to the students’ environment is referred to as enhanced context strategy (Schroeder, *et al.*, 2007). The discussions followed Ms Grace’s scenario in the form of individual students raising their points for or against the building of the nuclear power station. Ms Grace knew that through the strategy she used, her students would be able to talk and through their talking she could identify the alternative conceptions they had about radioactive materials.

Ms Grace used this method before she gave students an assignment to find out about the uses of radioactive materials and the safety precautions that should be taken when handling the radioactive materials. In the pre-observation interview she mentioned that students come to class with certain misconceptions that come from media and the books they read. In this lesson Ms Grace was able to detect some misconceptions that students had about radioactive materials and their uses. The identified misconceptions were:

³ Load shedding means the cutting of electric current in some places due to the shortage of electricity supply while usage is high.

1. Electricity generated from nuclear power stations is radioactive.
2. Radioactive radiation cannot pass through water.

These misconceptions were mentioned by students during class discussions. Ms Grace knew that her students would easily talk through engaging a scenario and as she intended to get some misconceptions she got them through using these strategies. The strategies used by Ms Grace show her application of integrated knowledge of students, subject matter, context and general pedagogy (Cochran *et al.*, 1993).

Mr Victor indicated in the pre-observation interview that amongst other content covered in radioactivity, students become more interested in the discussion of uses of radioactivity. He mentioned that:

V: ... you talk about radioactive decay, you talk about half-life, you talk about isotopes but when it comes to the uses, that is where they are more interested. (ITV)

This is indicative of Mr Victor's awareness of students' interests around the topic of radioactivity. Knowing the students' curiosity in uses of radioactivity he engaged students into small group presentations about the uses of radioactivity in order for them to be able to gather more information on their own. Mr Victor stated that:

V: If they go and read about the uses themselves, they will know more than myself... it means it's going to help them understand more and to read more. Through discussions, they will bring more information than when it comes from me... (PODTV)

Mr Victor chose presentations that required reading for preparation as a strategy to deal with uses of radioactivity, through this strategy he knew that his students would best learn the content, knowing where their interest lies in the topic.

Mr Victor explained that the students lack prior knowledge in some concepts such as half-life because they do the topic for the first time at Form E level and he added that he used the lecture method most of the time in concepts that he knew were new to students, e.g. where students lack prior knowledge of such concepts such as half-life. He indicated that:

V: They will come from form A, from primary, they have never been taught about half-life, they don't know anything so...we also have to lecture somehow at some point because it's something new to them... (ITV)

He showed that the knowledge of students' lack of prior knowledge in some concepts made him choose lecturing over other strategies. By lecturing Mr Victor was referring to telling students the concepts in the topic being taught and this was where the teacher did most of the talking while students listened.

Although Mr Victor did not talk about students' misconceptions in the pre-observation interview, the methods he used to tackle students' misconceptions came up during his teaching about half-life and uses of radioactive materials. The misconceptions that came up are shown in Table 5.4 and the teaching strategies that Mr Victor used to address such misconceptions.

Table 5.4: Mr Victor's strategies used to address misconceptions

Content covered	misconceptions	Strategy used	reason
Half-life	Half-life decreases as the activity decreases	Demonstration and questioning	To tackle students' misconception
Uses of radioactive materials	Irradiated food becomes radioactive	Small group presentation followed by lecturing	To address students' misconception

Mr Victor opted for these strategies to deal with misconceptions that came up from students through questions that were asked in class while he was teaching half-life and while the class was presenting uses of radioactivity. Mr Victor was able to change his teaching strategies immediately when he identified students' misconceptions, showing that he was aware of misconceptions that might come even though he did not mention them in the interview. This also indicates his ability to change his teaching strategies to suit the demands of the learning process.

Both Ms Grace and Mr Victor were concerned about the lack of resources in their schools and they indicated that the lack of resources limited the strategies that they could use to teach radioactivity. They both mentioned how this condition affected their teaching methods.

V: ... you know if there were computers that we would use here, it would be easier, the radioactive materials even if they are there in the lab, you cannot just do experiments with them because they might harm students but through computers they (students) could see what is actually happening. It is quite difficult without computers. (ITV)

G: ...if we had maybe overhead projectors, it would be easier for them to see some of the equations without wasting time writing them on the board. Some diagrams are

difficult to put on the board so if we had projectors it would be much easier for them to see different instruments we use to detect radioactivity. (PODTG)

As so far discussed, the teachers' employment of varied strategies that enabled their students to understand suggested their knowledge of how to counter the challenges of their teaching context, lack of resources in this case. The use of analogies that involved materials which were available in students' daily life and this was observable in Mr Victor's teaching was additional piece of evidence to this as well as drawing from learners' everyday experiences such as load shedding by Ms Grace. The use of diagrams drawn on the board or referred to in text books to help students understand also showed the two teachers' knowledge of their teaching context.

5.3. Conclusion

In this chapter I have given insights into subject matter knowledge of the two physics teachers, their PCK with regard to teaching strategies that they used together with their reasons for using such strategies. Mr Victor and Ms Grace taught similar content and there were as many similarities as there were differences in their PCK when teaching radioactivity. These similarities and differences were revealed through the framework used to explore their PCK. The model of Rollnick *et al.* (2008) has helped me to describe the teachers' manifestations in their classroom practice and their opinions about teaching radioactivity from interviews and post observation discussions. This model has also helped in relating classroom practice to domains of knowledge that generated such practices.

In the next chapter I give a summary of the findings of the study, reflect on the study and suggest recommendations based on the findings in the study.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1. Introduction

This study was done to explore the two physics teachers' PCK teaching the topic of radioactivity at high school level in Lesotho and to shed light on the nature of these teachers' PCK on this topic. This study sought to answer the following research questions:

1. How can the PCK of the two teachers be captured and portrayed?
2. How is the PCK of the two teachers manifested in their teaching of radioactivity?
3. What is the role of experience in the PCK of two physics teachers?
4. What is the SMK of two physics teachers of different experience?

In chapter 4 and 5, I presented results to address the above questions. In this chapter, I reflect on the study, present the summary of the results and draw conclusions and recommendations from the results. The limitations and directions for future research are also discussed.

6.2. Summary of research

The study sought to investigate the PCK of two teachers, Mr Victor and Ms Grace teaching the topic of radioactivity at Form E level. Both teachers were qualified physics teachers with differing experience. Mr Victor had 19 years experience while Ms Grace had 3 years experience in physics teaching. With greatly differing number of years of experience between these teachers, the study also sought to investigate the role of experience in the PCK of these two teachers. I used CoRes (Content Representations) to capture and document the expressed teachers PCK and PaP-eRs (Pedagogical and Professional experience Repertoires) to relate the teachers PCK documented in the CoRe to their practice. I also used the model of Rollnick *et al.* (2008) to analyse the teachers' knowledge of teaching the topic. This model indicated how the teachers' PCK was produced from the teachers' knowledge domains.

6.3. Reflection on the study

The CoRe helped to portray how the teachers conceptualised the teaching of radioactivity and the PaP-eRs made the tacit knowledge of teaching this topic explicit because of the narration of the teaching process that they illuminated. Through the use of these instruments, it was possible to compare and contrast the PCK of these teachers.

I adapted the method of Loughran *et al.* (2004) for capturing, portraying and documenting the two teachers' PCK. Unlike Loughran *et al.* whose CoRes were constructed by number of

experienced science teachers working together to come up with the big ideas around the topics they were working on, this study involved only two teachers; one experienced and another a beginning teacher. I constructed the CoRe using data gathered through interviews and class observations. I inferred the big ideas in the topic of radioactivity looking at what the teachers viewed as important in helping to understand this topic as a whole. The big ideas shed light on how the teachers framed this topic. I did not allow the two teachers to come up with big ideas they agreed upon as Loughran *et al.* (2004) did because in this study I was interested in these teachers' similarities and differences in their PCK so their agreement on big ideas would not yield results that would allow me to differentiate the way they conceptualised PCK on teaching radioactivity. The CoRe allowed me to capture and record what each teacher denoted as aspects of PCK. I have constructed the CoRe such that the two teachers' responses are placed in the same CoRe for easy comparison so that similarities and differences can easily be seen. CoRe and PaP-eRs brought to light the links between knowledge of content and teaching contexts of the two teachers in this study. The CoRe and PaP-eRs also helped to portray the holistic overviews of the teachers' PCK related to the teaching of radioactivity that can be accessed by both experienced and novice teachers to develop their PCK.

There was one question in the interview schedule which one teacher did not understand. The misunderstanding was on the following question: what specific strategies would you use to ascertain student's conceptions or misconceptions of these ideas? I had to explain the question using simpler words to help the teacher understand. This suggested that the interview questions should be written in more simple English especially when the interview is done to people who speak English as a second language. Another possibility would be to rephrase the question in Sesotho. However an advantage of the interview situation is that it is possible to rephrase the question immediately and clarify. The questions I used in the interview were in fact the prompts of the CoRe. If I could have just given these teachers the CoRe to complete, then the teacher who did not understand one question could have been stuck and I could have not got the response I was looking for and lost important data which could have negatively affected the results of the study.

The diagnostic test served to access the teachers' subject matter knowledge. Question 4 of the diagnostic test only required that teachers should use their basic knowledge of calculations on half-life but since teachers are expected to know more than they teach (Bishop & Denley, 2007), I should have added a question that would require teachers to use their deeper knowledge on calculations. For example, I could have asked a question that asked about the remaining mass

after 600 days of a radioactive substance of 1g, with a half-life of 20 days so that I could see if the teachers were able to solve the problem using methods other than a step by step calculation such as a formula. This would have determined if they had deeper subject matter knowledge. These two teachers used successive halving to solve this question, which is the method they used in their classroom practice and the method does not suggest whether the teacher had a deeper knowledge on this concept or not but Mr Victor showed that he possessed the knowledge of using the half-life equation.

The model of Rollnick *et al.* (2008) has helped me to describe the teachers' manifestations in their classroom practice and their opinions about teaching radioactivity from interviews and post observation discussions. The way these teachers considered some or all of the four knowledge domains was exhibited in their way of teaching radioactivity. This model helped to show the well developed PCK when the teacher had integrated the four knowledge domains and the poorly developed PCK when one or more of the knowledge domains were not considered. This model has also helped in relating classroom practice to domains of knowledge that generated such practices.

In the first day of video recorded classroom observations, the two teachers felt insecure due to my presences in their classroom even though they had allowed me to observe them. I had to re-establish the issue of trust between us by reminding them of the aim of my study that I wanted to learn from them not to judge the way they teach. This issue of insecurity could have made these teachers change their behaviour (Descombe, 2007) and I might have lost some of the important data such as flexibility in the teaching strategies that a comfortable teacher could have displayed that would enrich their portrayed PCK. Although video records served to access the teaching process, some of the words could not be heard from the video records and the voice recorders that I used helped me to get the inaudible words but they too failed at times and the words could not be heard which contributed to the lost data.

6.4. Discussion of findings

6.4.1. CoRe

The CoRe was constructed with big ideas emerging from the interview and the teaching processes under the topic of radioactivity (refer to section 4.2, page 43 for the process of determining big ideas and section 4.3 page, 45 for big ideas). The big ideas are similar for both teachers since these teachers taught the similar syllabus at the same level. Under these big

ideas was the illustration of the individual teacher's conceptualisation of how to teach these ideas and these illustrations were formed from the prompts that were found in the rows of the CoRe. This analysis instrument was used to address research questions 1 and 3.

The CoRe indicated some differences in the choice of what each teacher wanted the students to know about the topic of radioactivity. Ms Grace included stable isotopes and graphs that are used to compare the stability of radioactive substances determined from half-lives of different substances as important content to teach while Mr Victor did not consider this content. Instead Mr Victor considered the explanation of the physics words such as activity and half-life as important to differentiate the physics explanation from daily language of learners (Oyoo, 2010).

Both Mr Victor and Ms Grace had common clear intentions about the concepts they wanted to their students to know in radioactivity with slight differences in their selected concepts. Unlike Mulhall, Berry and Loughran (2003) who state that beginning teachers have no clear intentions of what they want their students to know, Ms Grace showed thought through intentions of the content she would like to cover. The two teachers' selection of the content was with regard to the importance of the content to both the present and the future life of students. Both teachers mentioned that the content was important for students to know for examination purposes and for further education or work places. For Mr Victor who stated that students' focus was on disadvantages of radioactivity (Brown & White, 1987; Nakiboglu & Tekin, 2006) he also wanted to teach some concepts to help students understand that radioactivity is also helpful in their life.

Both Mr Victor and Ms Grace were able to identify concepts they would omit in their teaching considering the level of their students. They were able to select the content that they did not consider important. The knowledge of points of difficulties in a certain topics is considered an important aspect of PCK (Shulman, 1987). Both teachers were aware of the learning difficulties resulting from the language of instruction (Qhobela, 2008). Mr Victor also pointed out that both lack of prior knowledge and mathematical knowledge (Mulhall & Gunstone, 2008) make it difficult for students to learn this topic. He also added that difficulty to do experiments (Lungu, 2009) also contributes to learning difficulties in this topic. These teachers were concerned about the lack of resources that they viewed as limiting factor in the way they would teach this topic because this lack of resources brings about lack of flexibility to vary teaching strategies. Mr Victor showed more awareness of learning difficulties than Ms Grace and this could be linked to his level experience as he might have encountered some of these difficulties in his teaching over the years of service.

6.4.2. PaP-eRs

The PaP-eR for each teacher teaching half-life as a subtopic of radioactivity was constructed mainly from the video recorded classroom observations. When dealing with this topic both teachers attempted to address the language problems but not in a similar approach. Ms Grace used the local language of learners to explain the process of half-life after which she returned to the use of English as a medium of instruction. This code-switching that she engaged was meant to help students to understand as Rollnick (2000) asserts that this method can be used to bridge the gap between the second language and the language of science helping learners to develop conceptual understanding. Mr Victor looked at technical words used in radioactivity such as activity and half-life and explained the difference between the daily use of the words and their scientific meaning. Ms Grace did not attempt to differentiate between the daily meaning and scientific meaning of the words. This is in agreement with Oyoo (2010) who states that experienced physics teachers engage in explanation of these technical words more than beginning teachers do.

The other difference between these teachers was the use of different representations used to transform the teachers' subject matter knowledge to the form that could be understood by students. Mr Victor engaged a variety of representations while Ms Grace used fewer representations.

6.4.3. Teachers' PCK in the teaching of radioactivity

The common representations used by both teachers included illustrations and explanations. Illustrations were done through diagrams that were either drawn on the board or taken from text books to clarify some concepts. Explanations were strengthened by use of equations or symbolic representations (Treagust, Chittleborough & Mamiala, 2003) and graphs. Differences between Mr Victor's and Ms Grace's approach were revealed through the representations they used to teach half-life. Mr Victor made extensive use of analogies and a demonstration while these were not observed in Ms Grace's teaching. With his knowledge that half-life calculations require the knowledge of mathematics hence that students with poor mathematics background would find it difficult to perform calculations, Mr Victor engaged some analogies that enabled students to perform half-life calculations before exercises from text books were given. This indicated how his knowledge of points of difficulties within this topic in students at that level of education being the knowledge of students informed his teaching strategies. Ms Grace used exercises that involved calculations to teach half-life and some of her students were struggling

with calculations indicating that they did not understand what had been done in class. There was no evidence of students struggling to do half-life calculations observed in Mr Victor's class. As mentioned in chapter 1, both of the classes they taught were mixed ability classes but the different teaching approaches used seemed to have comparatively contributed to the ease and difficulty in doing calculations. This shows a great difference between the strategies used by these two teachers. Ms Grace in this subtopic apparently seemed to be oblivious to consider students' poor mathematical background and she assumed that her students would be able to do calculations. The approach she was using could have been influenced by her own poor subject matter knowledge around this content as evidenced by her difficulty in answering the questions in the diagnostic test. This is a reasonable claim on the fact that in the diagnostic test, Ms Grace got the question on half-life calculations wrong. She did not change her approach to explain further even when some students asked how the answers were found as they were performing half-life calculations. Mr Victor integrated his knowledge of subject matter, knowledge of students, knowledge of context and general pedagogical knowledge to select and vary the manifested representations in his teaching that resulted in his well developed PCK which lead to his students' understanding. Ms Grace selected the strategy which indicated that subject matter knowledge and knowledge of students were missing in her integrated knowledge domains which was manifested in the struggles that her students experienced.

Some of the effective strategies that Ms Grace used but were not used by Mr Victor cannot be overlooked. The manifestation of storytelling and a scenario employed as teaching strategies indicated her knowledge domains of general pedagogy, context and knowledge of students as these strategies were chosen knowing how best her students could learn through them. She was able to select the relevant content to students' life and used the strategies that would make learning interesting to students.

Some of the strengths that these teachers had around teaching the topic could not be ignored. The teachers engaged specific examples before they could use general equations to teach the concept of radioactive decay. These teachers did not seem to be only interested in using equations to teach about radioactive decay but they seemed to use their knowledge of content to link abstract aspects in radioactivity and this was indicative of their more transformed subject matter knowledge unlike other teachers in Lungu (2009) who quickly moved to general equations before they could prepare students to understand. These teachers began with specific examples to show the changes in nucleon number and proton number for different elements before they could use general equations.

6.5. Summary of Findings

The aim of this study was to portray the two teachers' PCK on teaching radioactivity through finding out how they teach radioactivity and to understand their PCK. The other aim was to find out the role of experience in the PCK of the two physics teachers. This was done on the teaching of radioactivity at Form E on learners of age range (16-18). This section presents the main research findings and tries to answer the research questions of the study.

6.5.1. Research question 1

How can the PCK of these teachers be captured and portrayed?

The CoRe and PaP-eRs served as important tools that allowed me to write down each teacher's practice and they helped me to make the teachers' PCK explicit instead of being implicit.

The CoRe was constructed from the big ideas in the topic of radioactivity that I inferred from how the two teachers conceptualised this topic. The first three prompts of the CoRe documented each teacher's knowledge of content around the topic of radioactivity. They illustrated the selection of content that the teacher would like students to learn and the reasons for selecting the content. The other prompt helped to record what the teacher deems not necessary for students to know. These prompts shed light on the curricular saliency. Through the CoRe, the curricular saliency as being expressed by the teachers was recorded. The CoRe was also able to articulate the teachers' knowledge of points of difficulties together with the knowledge of students' thinking that influence the teaching of the topic. The CoRe also highlighted the teachers' knowledge of teaching strategies and methods of assessment.

The PaP-eR helped to document the teachers' knowledge of teaching in practice. That is how the teachers applied their PCK to their teaching context, to the students they taught and to address learning difficulties through the teachers' observable approaches.

These analyses instruments served as important to articulate the teachers' PCK and help to make the tacit knowledge to be explicit so that other teachers can access it in written form.

6.5.2. Research question 2

How is the PCK of the two teachers manifested in their teaching of radioactivity?

The PCK of these teachers was manifested in the teaching strategies that they selected to this topic. In chapter 4, section 4.3 and in chapter 5 section 5.2, I indicated the teaching strategies that were used by the two physics teachers. There were common strategies that were used by both teachers and these strategies are: lecture method, use of diagrams, explanations, discussions, oral questioning, use of graphs and use of text books. The other strategies used were explanations involving equations. These strategies were not used in isolation but they were combined at some point depending on the learning requirements of the class either being the learning difficulties, students' misconceptions or lack of resources. The selected strategies showed the teachers' awareness of the context they were working in; their knowledge of students and their ability to select a suitable variety of strategies manifested in the teaching process. The strategies they used were indicative of their knowledge of general pedagogy. The teachers' employment of varied strategies that enabled their students to understand suggested their knowledge of how to counter the challenges of their teaching context. This indicated the teachers' knowledge of effective ways of teaching this topic as Schroeder, Scott, Tolson, Huang and Lee (2007) assert that teaching strategies become more efficient when they are combined. Assessment was mostly done in oral questioning but the teachers also had other methods of assessment such as assignments, solving exercises on the board or in exercise books. The knowledge of methods of assessment and the choice of questions to assess students is drawn from the teachers' knowledge of subject matter and curriculum demands being the knowledge of context (Rollnick et al., 2008).

Although these teachers used some common strategies in their teaching, there were some strategies that were not common to both teachers. Mr Victor used analogies and demonstrations to address learning difficulties and these were not observed in Ms Grace's classroom. He also explained the difference technical words used in daily English language. The other strategy used by Mr Victor was small group presentations. He included the narration of history to teach about the discovery and naming of different types of radioactive radiation. Mr Victor showed more awareness of students' difficulties than Ms Grace and this informed his choice of using different representations in his classroom.

Ms Grace used a scenario for students to analyse and involved students in individual presentations. She also employed storytelling relating to radiological accident. Ms Grace showed her knowledge of students, knowing what makes them listen in class and choosing the strategy that she knew would make them listen attentively which indicates her PCK applied to

the choice of teaching strategies. The strategies used by both teachers showed their application of integrated knowledge of students, subject matter, context and general pedagogy.

The teachers' knowledge of subject matter and the knowledge of what is best for students at the level they were teaching helped them to sequence the content they taught, to select the content they deemed important in the topic and to explain concepts in a way that helped students to understand. This was indicative of their conceptualisation of the importance of the topic of radioactivity in the curriculum they were teaching which Geddis, Onslow, Beynon and Oesch (1993) refer to as curricular saliency. This curricular saliency enables the teacher to decide what to teach based on the knowledge of context and the motivation for teaching what the teacher deems important to include or exclude (Geddis *et al.*, 1993). Although Geddis *et al.* argue that the ability to select the important content to be taught lacks in novice teachers, Ms Grace was able to articulate her knowledge of what to include and what to omit.

6.5.3. Research question 3

What is the role of experience in the PCK of two physics teachers?

The ability for Mr Victor to select available materials in students' life such as an onion and a loaf of bread used as analogies to explain half-life concepts suggested his awareness of how relevant materials can be used to clarify abstract concepts in radioactivity. Onions are commonly used as food in students' everyday life, so Mr Victor chose to use the example of an onion knowing it was familiar to students and the effects of cutting it were well known to students. This indicated his knowledge of transforming content taking into consideration students' context. There was no evidence of Ms Grace's use of relevant materials to use as analogies. The ability to select locally available resources to help students understand which was observed in Mr Victor's classroom could be attributed to his level of experience.

The knowledge of points of difficulties such as the language of instruction that Mr Victor paid attention to when explaining technical words, students' lack of mathematical knowledge and prior knowledge seemed to be the one directing Mr Victor's choice of teaching strategies. Ms Grace paid no attention to students' difficulties mentioned above when teaching radioactivity. With a few years of teaching experience, Ms Grace might not have realised how the mentioned learning difficulties could hinder students' understanding.

Mr Victor related the rate of decay to other concepts in physics such as power; being the rate of doing work, which could not be easily done by a teacher lacking content knowledge in physics.

This also reflects his knowledge of the curriculum, which is contextual knowledge. Having a broader knowledge of subject matter might have helped Mr Victor to include some of the concepts he thought would be important for students to know which would be difficult if he did not have such knowledge. Although Hoz, Tomer and Tamir (1990) argue that content knowledge does not improve with experience, Mr Victor exhibited a broader knowledge of subject matter that was manifested in the ways he taught radioactivity as an experienced physics teacher.

6.5.4. Research question 4

What is the SMK of two physics teachers of different experience?

Looking at the general way the teachers answered the diagnostic test, there were weaknesses on their subject matter even though Mr Victor proved to have better subject matter knowledge than Ms Grace that could have resulted from his training or from his level of experience. The common weakness they showed was on the questions that required the knowledge beyond the syllabus they taught being: question 2 (c) and question 3 of the diagnostic test. This could imply that the teachers' content knowledge was limited, only enough to teach what was in the syllabus and this could pose problems of flexibility (Bishop & Denley, 2007) in the teaching strategies they use to teach the topic.

When teaching half-life calculations, both teachers used successive halving to show the remaining mass of a radioactive substance after a number of half-lives. In their response to the diagnostic test on the question on half-life calculations, Mr Victor got the answer correct while Ms Grace got it incorrect, but both teachers were able to solve exercises of this type correctly in class and this suggests that Ms Grace needed to revise the concepts before working out the problem, which is indicative of her fragile subject matter knowledge. Mr Victor had deeper knowledge around this concept and this was shown by the way he answered the question that was asked by one student that went beyond the method of using successive halving to solve half-life calculations. He wrote the half-life equation on the board to show how the student could solve the problem that went beyond successive halving but immediately rubbed it off because he said the equation was not used at the level of students.

The response to this question required a teacher to use the subject matter knowledge beyond the knowledge required by the syllabus which Bishop and Denley (2007) argue that it is important for the teachers to have extended knowledge and this would be problematic if Mr

Victor did not know the equation that could be used. This is indicative of the importance of subject matter knowledge as a teacher's knowledge domain.

6.6. Limitations of the study

This study followed a case study approach and it was done on two teachers; one experienced teacher and one novice teacher and the teachers were teaching only one topic in physics, being radioactivity, therefore the teaching strategies I identified are not useful in a universal sense but refer to the teaching of radioactivity. These results could not be generalized although they may be insightful to teachers teaching in the similar context to the context of teachers in this study. A larger sample of both experienced and novice teachers could have illuminated a richer understanding of PCK similarities and differences between the experienced and beginning teachers.

Due to time constraints, I only had two weeks to complete my data collection and I could not observe Mr Victor finish the teaching of radioactivity. This time constraints had limited the PCK manifestations that I could have observed in Mr Victor's teaching because he might have manifested more of his knowledge in those lessons that he finished the topic.

Being a novice researcher, it was difficult for me to probe further on some interview questions and I noticed as I was analysing that some important data were missing. For example, I could not follow up one teacher to give examples of students' thinking that students come to class with, such as misconceptions on the topic of radioactivity.

6.7. Recommendations

This study provides an illustration of specific examples of the teaching process in the topic of radioactivity and these examples are documented and described in full. These examples may be of significant value to teacher educators by serving as sources of specific ideas about teaching radioactivity and teacher educators can incorporate these specific instances into their teaching to prepare student teachers using research based instances.

Stoffels (2008) showed that the lack of resources does not impact on teachers' approaches but the lack of subject matter knowledge does. The teachers in this study showed that they had limited subject matter knowledge that is enough to teach within the content prescribed in the syllabus so; this implies that teachers should be exposed to programmes that increase their

subject matter knowledge, to enable them to be equipped with more knowledge that could increase effective teaching.

The demonstrations used by Mr Victor seemed to be helpful in helping students understand. Such demonstrations may be helpful especially to teachers who teach students who have a poor mathematical background but they should be used together with the links to indicate the actual microscopic processes in the concept of half-life to teach for conceptual understanding.

Documented PCK should be made available to teachers who teach physics but who are not physics specialists in order for them to transform their subject matter effectively. Novice physics teachers need to be exposed to the literature on learning difficulties in physics, how to diagnose these difficulties and how to address them. The Ministry of Education and Training in Lesotho should expose teachers to the findings of research on PCK so that teachers could access knowledge on different teaching strategies engaged to address learning difficulties. This may also equip teachers with skills so that the knowledge for teaching could be improved.

Teacher educators in Lesotho could introduce CoRes to student teachers to raise their awareness of the kind of components of the CoRe which serve as PCK in the topics they would be teaching. This could also be beneficial if used by both experienced and beginning teachers in teaching physics and other topics in different subjects, so the Ministry of Education and Training in Lesotho could introduce teachers to CoRes through workshops.

Since the knowledge of teaching certain topics is not static (Cochran *et al.*, 1993) but develops and changes with time, Mr Victor seemed to agree with Cochran *et al.* (1993) by indicating that teaching knowledge of both content and pedagogy develops with time. This was in the words:

V: I cannot say I know this... every year I have to read. I cannot have the same notes for every student but the methods can be the same. Maybe there is the information I did not give last year and I discover when I am preparing that I did not give this last year so this year I decide that let me give them this. So sometimes if you are a teacher and you don't do the reading, you will find that your teaching cannot improve because it is not changing... if you see the way I taught in those days in the 1990s and today is quite different, there are changes I did because keeping on doing something, you end up changing the method because, you can see this year they have passed well here, what can I do where they have not passed well... (PODTV)

This suggests that the PCK for teaching a certain topic also develops with the experience the teacher has if the teacher is willing to reflect and improve. The Ministry of Education and Training in Lesotho should expose teachers to workshops where teachers share their knowledge of teaching certain topics and where teachers discuss the findings and of research to reflect and improve their teaching. Teachers should also be encouraged to discuss the teaching strategies they use when teaching certain topics so that their PCK could improve as the results of this study show that there were points where the beginning teacher showed strengths in her teaching; this implies that experienced teachers can learn from beginning teachers as much as beginning teachers can learn from them.

6.8. Directions for further research

This study focuses on the PCK in teaching radioactivity looking at important aspects of PCK that emerged during the teaching of this topic, involving an experienced teacher and a novice teacher. A similar study should be done but with a larger sample to get clear differences between the PCK of experienced and beginning teachers and more understanding of the teachers' PCK in this topic.

Teachers in this study were communicating less of their teaching knowledge in the interview but more of what they knew was found through classroom observations and this adds to the claim that the knowledge for teaching is tacit (Loughran, Milroy, Berry, Gunstone & Mulhall, 2001). Studies like this one could benefit both experienced and novice science teachers to access this hidden knowledge of teaching and may be beneficial to help novice teachers modify their teaching approaches and build on what other teachers do. Further research is therefore required to articulate PCK in the teaching of other topics in physics and other subjects with teachers of different levels of experience.

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APPENDICES

Appendix 1: Interview schedule

Demographic information

a) Details of experience:

- i) How many years have you been in the teaching service?
 - ii) Which subjects have you taught?
 - iii) Which grades have you taught?
 - iv) What schools have you taught?
 - v) What is your current position in the current school?
 - vi) How long have you been in this current position?
- b) What are your highest teaching qualifications?

Interview schedule

Questions

1. What do you think are the main ideas that you intend to teach Form Es about radioactivity?
2. Why do you think it is important for students to know these ideas?
3. What else do you know about these ideas that you do not intend students to know yet?
4. What are the difficulties connected with teaching these ideas?
5. What knowledge can you share about students' thinking that influences your teaching of these ideas?
6. Are there any other factors that would influence your teaching of these ideas?
7. What teaching procedures would you employ?
8. Why would you use these procedures?
9. What specific strategies would you use to ascertain student's conceptions or misconceptions of these ideas?

Appendix 2: Diagnostic test

Questions on Nuclear and radioactivity physics

Question 1

- a. Carbon has an atomic number of 6. One isotope of carbon has a nucleon number of 12 and another isotope has a nucleon number of 14. Draw the nuclear structure of these isotopes, showing clearly the difference(s) between the diagrams.

- b. Why is each of these isotopes electrically neutral?

Question 2

- a. What are three types of natural radioactivity?

- b. Which of these three radiations:

- vii. Has the greatest penetrating power?

- viii. Is deflected the most by a magnetic field?

- ix. Is most easily absorbed?

- x. Has the strongest ionising power?

- xi. Is not deflected by a magnetic field?

- xii. Is deflected most by electric field?

c. Why are some of these radiation types deflected by both electric and magnetic fields?

Question 3

Why would nuclear fusion be a safer reaction for the society than nuclear fission?

Question 4

A radioactive element has a half-life of 20 days, what mass of an element remains after 80 days if the original mass was 4.0g? Please show your reasoning.

Question 5

Why are radioactive materials kept in lead containers?

Memorandum for the diagnostic test

Question 1

c. Carbon has an atomic number of 6. One isotope of carbon has a nucleon number of 12 and another isotope has a nucleon number of 14. Draw the nuclear structure of these isotopes, showing clearly the difference(s) between the diagrams.

A diagram of a nucleus with 6 protons and 6 neutrons for carbon-12

A diagram of a nucleus with 6 protons and 8 neutrons for carbon-14

d. Why is each of these isotopes electrically neutral?

The charged particles in the isotopes being electrons and protons are equal in number so the resultant charge on the isotope is zero, making the isotope neutral.

Question 2

- d. What are three types of natural radioactivity?

Alpha-particles, beta-particles and gamma-rays

- e. Which of these three radiations:
xiii. Has the greatest penetrating power?

Gamma-rays

- xiv. Is deflected the most by a magnetic field?

Beta-particles

- xv. Is most easily absorbed?

Alpha-particles

- xvi. Has the strongest ionising power?

Alpha-particles

- xvii. Is not deflected by a magnetic field?

Gamma-rays

- xviii. Is deflected most by electric field?

Beta-particles

- f. Why are some of these radiation types deflected by both electric and magnetic fields?

Alpha particles are positively charged while beta particles are negatively charged so they are deflected because they are attracted to the oppositely charged plates that produce the electric field. Charged particles moving in magnetic field experience a magnetic force that is considered as the centripetal force that makes them move in circular paths.

Question 3

Why would nuclear fusion be a safer reaction for the society than nuclear fission?

Nuclear fusion produces low radioactive waste while nuclear fission produces high radioactive waste. If the fusion reaction goes out of control, the reaction automatically stops as it cools

down but with fission reaction, if it goes out of control, a nuclear meltdown can happen which can release highly radioactive particles in the environment.

Question 4

A radioactive element has a half-life of 20 days, what mass of an element remains after 80 days if the original mass was 4.0g? Please show your reasoning.

0.25g

Reasoning by calculations: 4.0g → 0

2.0g → 20days

1.0g → 40days

0.5g → 60days

0.25g → 80days

Question 5

Why are radioactive materials kept in lead containers?

Lead has a high density and it is able to stop both alpha and beta particles but reduces gamma radiation.

The rubric for classifying responses of the diagnostic test

Correct	Partially correct	Incorrect	No response
The question is fully answered as asked and a correct response is given.	Part of the answer is correct but the answer is not complete or the completing statement is incorrect.	The answer is completely incorrect	No answer has been given.

Appendix 3: Approval for Ethics clearance

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa
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STUDENT NUMBER: 384786
Protocol number: 2010ECE47C

31 August 2010

Mrs. Maselise Ratlali
P O Box 542
MASERU
LESOTHO

Dear Mrs. Ratlali

Application for Ethics Clearance: Master of Science

I have a pleasure in advising you that the Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate has agreed to approve your application for ethics clearance submitted for your proposal entitled:

Exploring PCK in the process of teaching radioactivity; the teaching strategies involved by Lesotho physics teachers

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

Yours sincerely

M Matsie Mabeta
Matsie Mabeta
Wits School of Education

Cc Supervisor: Dr. S Oyoo (via email)



Appendix 4: MOET letter asking for permission

University of the Witwatersrand Wits School of Education

Ministry of Education and Training
Maseru
Lesotho

Dear Sir/Madam

Request for permission to conduct research in your school

My name is Maselise Ratlali. I am a researcher studying Master of Science in science education in the School of Education at the University of the Witwatersrand. I am carrying out a study *on exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers*. My research will benefit the institutions where it is conducted, as well as the Lesotho educational system in improving the teaching and learning of physics.

This is my request for permission to conduct my study at high schools in Maseru. The study will involve my direct classroom observations and an interview with a Form E physics teacher. The interview will be audio recorded and the classroom observations will be videotaped. I intend to use the video-tape for the purpose of simulated recall for teachers' and researcher's classroom practice discussions. The teacher will be able to easily answer the questions watching the video clips to help him/her explain his/her practice in teaching. Giving permission in this study is entirely voluntary, no harm is envisaged, and all information collected from teacher and students will be treated as confidential and names not known.

My research results will be presented in my research report may be presented at a conference and/or published in an academic journal. In order to maintain anonymity and confidentiality, all names I use will be pseudonyms.

I will provide you with a summary of my research results on completion if you would like me to.

Yours sincerely

Maselise Ratlali

Signature: _____

Phone number: 0027733344899/ 62007688

Date: _____

Appendix 5: MOET consent letter

University of the Witwatersrand
Wits School of Education

Ministry of Education Informed Consent Form for Conducting Research in schools

Research Topic: Exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers.

I _____ from the Ministry of Education in Lesotho, give permission to Maselise Ratlali of the University of Witwatersrand to conduct the study on *exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers*. I understand that the study will involve interviews and observations. I also understand that no harm will result from the teachers' and students' participation in this study, and that the study is being conducted for purposes of improving the teaching of physics in our schools. This permission is on condition that the material will be used for research purposes only.

This consent does not oblige the teachers and students to participate and I understand that they may withdraw from the study at any time.

I understand that the real names of the schools and students will not be used in the transcripts. I also understand that the names of the participating teachers and those of the people they will refer to in the interview will be kept confidential.

I understand that the results of the study will be presented in the research report, may be presented at a conference and/or published in an academic journal.

Name: _____

Signature: _____

Date: _____

Appendix 6: Principal letter requesting permission

University of the Witwatersrand

Wits School of Education

The Principal

Dear Sir/Madam

Request for permission to conduct research in your school

My name is Maselise Ratlali. I am a researcher studying Master of Science in science education in the School of Education at the University of the Witwatersrand. I am carrying out a study *on exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers*. My research will benefit the institution where it is conducted, as well as the Lesotho educational system in improving the teaching and learning of physics.

This is my request for permission to conduct my study at your school. The study will involve direct classroom observations and an interview with a Form E physics teacher. The interview will be audio recorded and the classroom observations will be videotaped. I intend to use the video-tape for the purpose of simulated recall for teachers' and researcher's classroom practice discussions. The teacher will be able to easily answer the questions watching the video clips to help him/her explain his/her practice in teaching. Giving permission in this study is entirely voluntary, no harm is envisaged, and all information collected from teacher and students will be treated as confidential and names not known.

My research results will be presented in my research report may be presented at a conference and/or published in an academic journal. In order to maintain anonymity and confidentiality, all names I use will be pseudonyms.

I will provide you with a summary of my research results on completion if you would like me to.

Name: Maselise Ratlali

Signature: _____

Phone number: 0027733344899/ 62007688

Date: _____

Appendix 7: Principal consent letter

University of the Witwatersrand

Wits School of Education

Principal's Informed Consent Form for Conducting Research in Science classrooms

Research Topic: Exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers.

I _____, the principal of _____ give permission to Maselise Ratlali of the University of Witwatersrand to conduct the study on *exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers*. I understand that the study will involve interviews and observations. I also understand that no harm will result from my teachers' and my students' participation in this study, and that the study is being conducted for purposes of improving the teaching of physics in our schools. This permission is on condition that the material will be used for research purposes only.

This consent does not oblige the teacher and students to participate and I understand that they may withdraw from the study at any time.

I understand that the real name of my school will not be used in the transcripts. I also understand that the names of the participating teachers and those of the people they will refer to in the interview will be kept confidential.

I understand that the results of the study will be presented in the research report, may be presented at a conference and/or published in an academic journal, but the name of my school and that of the teacher and students will remain unknown.

Name: _____

Signature: _____

Date: _____

Appendix 8: Teachers' information sheet

University of the Witwatersrand
Wits School of Education

Teacher's Information Sheet

Dear sir/madam

Request for your participation in my study

My name is Maselise Ratlali. I am a researcher studying Master of Science in science education in the School of Education at the University of the Witwatersrand. I am carrying out a study on *exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers*. My research will benefit the institutions where it is conducted, as well as the Lesotho educational system in improving the teaching and learning of physics.

This letter is my request to you to consider for participating in this study. The aim of the study is to identify teaching strategies used by Lesotho physics teachers to teach radioactivity. The study is also to find out why teachers use those strategies.

The study will involve my direct observations in your classroom and an interview. I will audiotape the interview and videotape the classroom observations. The video-taping will be for the purpose of simulated recall for teachers' and researcher's discussion of the teacher's classroom practice. You will be able to easily answer the questions while watching the video clips to explain your practice in teaching. Participation in this study is entirely voluntary, no harm is envisaged, and all information will be treated as confidential. You will be able to withdraw from the study at any time.

The results of the study will be presented in a research report, may be presented at a conference and/or published in an academic journal but your name and the people you refer to during interview and observations will be kept anonymous.

I will provide you with a summary of my research results on completion if you would like me to.

I am inviting you, as a high school physics teacher, to participate in this study.

Yours sincerely

Maselise Ratlali

Signature: _____

Phone number: 0027733344899/ 62007688

Date: _____

Appendix 9: Teachers' interview consent letter

University of the Witwatersrand

Wits School of Education

Teacher's interview Consent Form

Research Topic: Exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers.

I, _____ agree to participate in this study to be conducted by Maselise Ratlali of the University of Witwatersrand on *exploring PCK in the process of teaching radioactivity: the teaching strategies employed by Lesotho physics teachers*. I understand that no harm will result from my participation in this study, and that the study is being conducted for purposes of improving the teaching of physics in our schools. I understand that the material will be used for research purposes only.

I further agree to being interviewed as part of the study. I understand that everything I say will be kept confidential by the interviewer and my real name will not be used in the transcripts. In addition, the names of any persons I refer to in the interview will not be revealed.

I understand that my actual words may be used in the research report as quotes, but they will be reported such that my identity is not known. I understand that the results of the study may be presented at a conference and/or published in an academic journal, but my name will remain unknown.

I have voluntarily given my consent to be interviewed and I understand that I can withdraw from the study at anytime.

Name: _____

Signature: _____

Date: _____

Appendix 10: Learners' information sheet

University of the Witwatersrand

Wits School of Education

Learners' Information Sheet

Dear student

Request to conduct research in your classroom

My name is Maselise Ratlali. I am a researcher studying Master of Science in science education in the School of Education at the University of the Witwatersrand. I am carrying out a study on *exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers*. My research will benefit the institutions where it is conducted as well as the Lesotho educational system in improving the teaching and learning of Science.

I will involve 8 classroom observations which I will video record. I intend to use the video tape for the purposes of simulated recall and to capture teaching in the classroom settings. The video records will enable teachers to easily answer the questions watching the video clips to help them explain their practice in teaching. The video clips will be watched by the researcher and supervisors only and then stored in my institute's safe storage after analysis and then later destroyed.

I am asking for permission to conduct my study at your school in your classroom. Giving permission in this study is entirely voluntary, no harm is envisaged, and all information collected from students will be treated as confidential and names not known. Your refusal to participate will not result in the loss of marks.

The study results will be presented in my research report may be presented at a conference and/or published in an academic journal. In order to maintain anonymity and confidentiality, all names I use will be pseudonyms.

Yours sincerely

Maselise Ratlali

Signature: _____

Phone number: 0027733344899/ 62007688

Date: _____

Appendix 11: Learners' consent letter

University of the Witwatersrand

Wits School of Education

Learners' Informed Consent Form for Conducting Research in Science classrooms

Research Topic: Exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers.

I _____, the student of _____ give permission to Maselise Ratlali of the University of Witwatersrand to conduct the study in my classrooms at my school on *exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers*. I understand that no harm will result from my participation in this study, and that the study is being conducted for purposes of improving the teaching of physics in our schools. I give permission for the material to be used for research purposes only.

I am not forced to give permission to the researcher for observation and video recording and understand that I may withdraw from the study at any time. I also understand that my refusal to participate will not result in loss of marks.

I understand that the results of the study will be presented in the research report, may be presented at a conference and/or published in an academic journal, but the name of my school and my name will remain unknown.

Name: _____

Signature: _____

Date: _____

Appendix 12: Parents' information sheet

University of the Witwatersrand

Wits School of Education

Parent's Information Sheet

Dear Sir/Madam

My name is Maselise Ratlali. I am a researcher studying Master of Science in science education in the School of Education at the University of the Witwatersrand. I am carrying out a study on exploring PCK in the process of teaching radioactivity; strategies employed by Lesotho physics teachers. My research should not only benefit the institutions where it is conducted, but also the Lesotho educational system in improving the teaching and learning of Science.

I am asking for permission to conduct my study at your child's school in his/her classroom. I will involve 8 classroom observations which I will video record and take field notes. I intend to use the video tape for the purpose of simulated recall for teachers' interviews. Teachers will easily answer the questions watching the video clips to help them explain their practice in teaching. The video clips taken in classroom will be transcribed and kept in my institution's safe storage and then destroyed after five years and they will only be watched by the researcher and the supervisors.

I would like to make it clear that giving permission in this study is entirely voluntary, no harm is envisaged, and all information collected from students will be treated as confidential and names not known. Refusal for permission will not result in the child's loss of marks.

My research results will be presented in my research report. Part or all the results of this study may be presented at a conference and/or published in an academic journal. In order to maintain anonymity and confidentiality, all names I use will be pseudonyms.

Name: Maselise Ratlali

Signature: _____

Phone number: 0027733344899/ 62007688

Date: _____

Appendix 13: Parents' consent letter

University of the Witwatersrand

Wits School of Education

Parent's Informed Consent Form for Conducting Research in Science classrooms

Research Topic: Exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers.

I _____, the parent/guardian of _____ give permission to Maselise Ratlali of the University of Witwatersrand that my child may be involved in the study *on exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers*. I understand that no harm will result from the participation of my child in this study and that the study is being conducted for purposes of improving the teaching of physics in schools. I give permission for the material to be used for research purposes only.

I am not forced to give permission to the researcher for observation and video recording the lessons and understand that my child may withdraw from the study at any time. I understand that my refusal to give permission will not result in my child's loss of marks.

I understand that the results of the study will be presented in the research report, may be presented at a conference and/or published in an academic journal, but the name of my child's school and the name of my child will remain unknown.

Name: _____

Signature: _____

Date: _____

Appendix 14: Content Representation

From Loughran *et al.* (2004)

Prompts/Questions	Big Idea A	Big idea B	Big Idea C	Big idea D
What you intend students to learn about this idea.				
Why is it important for students to know this?				
What else you know about this idea that you do not intend students to know yet.				
Difficulties connected with teaching this idea.				
Knowledge about students' thinking which influences your teaching of this idea.				
Other factors that influence your teaching of this idea.				
Teaching procedures (and particular reasons for using these to engage with this idea).				
Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of response)				

Appendix 15: Voice recorder consent letter

University of the Witwatersrand

Wits School of Education

Teacher's audio-recording Consent Form for Conducting Research

Research Topic: Exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers.

I, _____ agree to participate in this study to be conducted by Maselise Ratlali of the University of Witwatersrand on *exploring PCK in the process of teaching radioactivity: the teaching strategies employed by Lesotho physics teachers*. I understand that no harm will result from my participation in this study, and that the study is being conducted for purposes of improving the teaching of physics in our schools. I understand that the material will be used for research purposes only.

I consent to being audio-taped during the interview. I understand that I have a right to listen to the audiotape before transcription so that I can delete or amend any of my remarks. I also understand that I have the right to review the transcripts made of our conversations before these are used for analysis if I so choose. I understand that everything I say will be kept confidential by the interviewer, and my real name will not be used in the transcripts. In addition, any persons I refer to in the interview will be kept confidential.

I understand that my actual words may be used in the research report as quotes, but they will be reported such that my identity is not known. I understand that the results of the study may be presented at a conference and/or published in an academic journal, but my name will remain unknown.

I have voluntarily given my consent to be interviewed and I understand that I can withdraw from the study at anytime.

Name: _____

Signature: _____

Date: _____

Appendix 16: Sample of audio tape transcripts

Interview transcript 2: Mr Victor (ITV)

I: Ok, ntate (*Mr*) Victor, eh! I have some questions in the interview schedule, now in the topic that you are doing I will be asking you some few questions for you to answer, now the first question reads: What do you think are the main ideas that you intend to teach form Es about radioactivity?

V: Thanks a lot for your question, Ah! The main ideas, I think when you are talking about radioactivity, there are different ideas which are coming together because you have like chemistry there, when you are talking about the atomic, even though is part of physics but we have to talk about the atom we have to talk about the, the radioactivity itself, it means a student should know what is radiation or what are radiations and that means the alpha, the beta the gamma. So they also have to know mainly about the uses of radioactivity which is very important, now I always say the ideas when you put them together, it is important for students to know them all because it is like a lady putting a full dress because if you are putting a skirt on top with something else, down with something else but with radioactivity is a full dress because one idea you start with connects to one idea you are going to teach later, you cannot talk about for instance, eh! For instance, radioactivity decay if a student does not know what is proton, what is mass number, so you see those ideas they complement each other, so I think all the ideas there are very important.

I: For example?

V: For instance, eh! Let me talk about, when you are talking about eh! How to write an atom which means having an element helium, where you are going to write the mass number and the proton number. Now when I am doing the radioactivity decay, the student should know how to place those two numbers so that he can balance the equation properly. That is what I can say.

I: Ok. Emh! Why do you think it is important for them to know these ideas?

V: Thanks a lot, I think maybe I was a bit in a hurry if I knew this question would come because as if I talked about it a little earlier so that's what I'm saying, all those ideas should be known to complement the whole lesson. If one of those ideas is out, a student might not know what is coming; let me say for instance, we can also say some knowledge even if it is not part of radioactivity even if a student does not know mathematics it is going to be difficult for that student to understand half-life because he is going to apply any situation to apply in mathematics there by calculation, so I see all the ideas important to complement the whole lesson together. So is a full dress.

Appendix 17: Video record consent letter

University of the Witwatersrand

Wits School of Education

Teacher's video-recording Consent Form for Conducting Research

Research Topic: Exploring PCK in the process of teaching radioactivity: strategies employed by Lesotho physics teachers.

I, _____ agree to participate in this study to be conducted by Maselise Ratlali of the University of Witwatersrand for the research on *exploring PCK in the process of teaching radioactivity: the teaching strategies involved by Lesotho physics teachers*. I understand that no harm will result from my participation in this study, and that the study is being conducted for purposes of improving the teaching of Science in our schools. I give permission for the material to be used for research purposes only.

I further agree to being observed and having videotaped in classroom. I also understand that I have a right to watch the video clips before transcription so that I can delete or amend any material or revise any of my remarks or my actions in the video clips. I understand I have the right to review the transcripts made of the video clips before these are used for analysis if I so choose. I understand that everything I say or do will be kept confidential by observer, and my real name will not be used in the transcripts. I understand that the video clips will be watched by me, the researcher and the supervisors only.

I understand that my actual words may be used in the research report as quotes, but they will be reported such that my identity is not known. I understand that the results of the study may be presented at a conference and/or published in an academic journal, but my name will remain unknown.

I have voluntarily given my consent to be video-taped and I understand that I can withdraw from the study at anytime.

Name: _____

Signature: _____

Date: _____

Appendix 18: Sample of video record transcripts

Video Record Transcript: Grace (VRTG)

G: We said of the three types of radiation re na le alpha, beta le gamma hakere (*we have alpha, beta and gamma, is it so*)?

S: Yes madam.

G: ra re radiation e etsahala (*we then said radiation happens*) inside the nucleus of an atom hakere?

S: Yes madam

Grace: Those which are unstable. If when radiation happens, radiation is emitted from the nucleus of the atom; do you think that the atom will remain as it was? Mpho.

S1: No.

G: Why not?

S1: Because there is too much radiation.

G: let's say we have carbon-14, no, not carbon-14, let's say we have radium (writing radium notation on the board). Suppose we have a radioactive emission from radium, will radium remain as it is like here (pointing at radium notation)?

S: (in chorus) no.

G: Ok, listen; we have what we call radioactive decay. This is the disintegration of an unstable radioactive element forming a nucleus which is also unstable. It is disintegration, what does disintegration mean, it is a decay of an element which will form another unstable element. So we have an alpha decay. So what happens where we have alpha decay? When an atom decays by alpha radiation, what happens to the nucleon number? The nucleon number decreases by 4. When an atom decays by alpha, the nucleon number decreases by 4 and the proton number by 2 (writing on the board)

S2: Why 4?

G: re ile ra reng ka nature ea alpha particle (*What did we say about the nature of alpha particle*)? Kani, what did you say?

S3: We said the alpha particle is the helium nucleus.

Appendix 19: Sample of the field notes

Field Notes: Ms Grace

Lesson 6

The lesson began with Ms Grace narrating the story about the radiological accident that happened in Brazil in 1986. Ms Grace was characterised by noise every day, but today this class was so quiet when Ms Grace read the story from the paper. Questions that were asked orally and answered orally came in thereafter. After students gave different answers, Ms Grace went on to say which answer was correct.

She gave a scenario to be analysed by students about electricity generation through nuclear power stations where students were asked to give their opinion whether the nuclear power station should be built in Lesotho or not. In this discussion came out the misconceptions such as electricity cannot pass through water and current electricity generated from nuclear power stations is radioactive and it can cause harm to people using it since everything in the house will be radioactive. This lesson was done before students could deal with uses of radioactivity and the dangers of radioactivity. Students' reasoning was based on dangers, uses and safety precautions against radioactive radiation. At the end students were given an assignment on the uses of radioactivity, dangers and safety precautions against radioactive radiation to be presented in the following day.

Appendix 20: Sample of post observation transcripts

Mr Victor Post observation discussion Transcript: (POTV)

V: Like here, you see that we are trying to talk, just the word activity, now there is activity in science in radioactivity so I was trying to come out with something that a student can understand in radioactivity, this activity, what does it mean, does it have the same meaning as any other activity in other areas? So we are trying to bring it out. But I didn't want to be the one. Myself knowing the word activity in radioactivity I wanted them to find the word activity in English. That's why I allowed them to open the dictionary and find the meaning from there we will bring the discussion about that.

I was expecting to hear from the students, I don't know if they asked that question because maybe I am the one who explained that to students after telling them that half and another so I was expecting a student to ask me what is going to happen to that other half. I don't know if that question came or not. I was expecting them to ask that question.

You see now here, we have already defined what half-life is, where time taken is the key because once you say time taken; you say the time taken for a radioactive material to disintegrate. I gave them an example of bread and I told them that every 15 minutes maybe because we define half-life as the time taken, that is the key because what you see is the time taken for a radioactive element to disintegrate to its half so I think when I am trying to explain this to the students they are already aware of time taken that is why maybe it did not give them a tough time and when you put it in the diagram, the diagram of the half-life curve helped them more to understand it. The way you are going down with the starting activity, the way it comes down, you show it in the diagram, it is easy for the students to capture that mostly.

(Looking at the explanation that was offered by one student on how to find half-life from the decay curve) This requires knowledge of mathematics, so someone who is not good in mathematics, it is difficult for him to get this because he has to divide, to know what half is, so if you are not good in simple arithmetic you cannot do it. That is why I always say when somebody is doing science he should also have knowledge of mathematics.

But you see I was employing different words: activity, count rate, because I didn't want the student to come and ask me what is activity and what is count rate, I use different ways to explain the coordinates of the y-axis, I talked about count rate and activity. I don't know but they did not bring out such questions as what is the relationship between activity and count rate

because even some of the kids maybe they are limited, the fact that they don't know and it is the first time I do this topic they expect that whatever the teacher is saying is true so we don't have challenging questions.

I: What were your intentions as you used those different words, the y-axis as count rate and activity?

V: To help them understand that these words mean the same thing, I don't want them to say that this time they are talking about count rate, we didn't do count rate, next time if in the question paper they see count rate for activity they should have the same understanding, they should know that it means the same thing.

Appendix 21: Content in Physics section

COMBINED SCIENCES O LEVEL 2010

21. The Nuclear Atom

Content

- 21.1 Atomic model
- 21.2 Composition of a nucleus
- 21.3 Proton number and nucleon number
- 21.4 Nuclide notation

Learning Outcomes:

Candidates should be able to:

- (a) describe the structure of an atom in terms of a nucleus and electrons
- (b) describe the composition of the nucleus in terms of protons and neutrons
- (c) use the term *nucleon number*, A
- (d) use the term *proton number*, Z
- (e) use the term *nuclide* and use the nuclide notation A_ZX

22. Radioactivity

Content

- 22.1 Detection of radioactivity
- 22.2 Characteristics of the three types of emission
- 22.3 Nuclear reactions
- 22.4 Half-life
- 22.5 Safety precautions

Learning Outcomes:

Candidates should be able to:

- (a) describe the detection of alpha-particles, beta-particles and gamma-rays
- (b) show understanding that radioactive emissions occur randomly over space and time
- (c) state, for radioactive emissions,
 - (i) their nature
 - (ii) their relative ionising effects
 - (iii) their relative penetrating powers
- (d) show understanding of the meaning of *radioactive decay*, using equations (involving symbols) to represent changes in the composition of the nucleus when particles are emitted
- (e) use the term *half-life* in simple calculations which might involve information in tables or in decay curves
- (f) describe how radioactive materials are handled, used, stored and disposed of, in a safe way