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Transforming content knowledge:

A case study of an experienced science teacher
teaching in a typical South African secondary school

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Faculty of Engineering and the Built Environment

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Abstract

A successful education system is critically dependant on the quality of the teaching involved, and research into teacher education therefore remains an international priority. In the late 1980s Lee Shulman (1986, 1987) conceptualised a new type of knowledge, which fused content and pedagogy in the practice of teachers. This represented a major shift in research approach, away from an emphasis on teacher behaviour towards a greater emphasis on teacher knowledge. The unique knowledge that teachers possess Shulman called pedagogical content knowledge or PCK. In the following 25 years many scholars have conceptualised PCK, and only recently, with an international PCK Summit, have attempts been made to consolidate this field.

South Africa's primary and secondary public education system is continuously under scrutiny, as it continues to perform poorly in international benchmarking assessments. The need to understand what is happening in our classrooms, especially in science and mathematics, is now more important than ever.

In response to this need, this study investigated the classroom practice of a dedicated and experienced science teacher over a period of three years, as she taught the organic chemistry section of the Grade 12 Physical Sciences syllabus. PCK was used as a lens to focus on how teacher knowledge manifests in practice. Data collection included lesson observations, interviews and field notes. 97 lessons were video-recorded over the three-year period and 18 representative lessons were chosen for in-depth analyses. The components of PCK proposed by Park and Chen (2012) and Rollnick and co-workers (2008) were used as criteria for analysis. These include topic-specific instructional strategies, knowledge of the science curriculum, assessment, knowledge of students' understanding in science, explanations and content representations. An examination of how these aspects of PCK manifested in classroom practice gave insight into the teacher's PCK and other contributing knowledge domains.

Findings revealed that the teacher had well-developed pedagogical knowledge which manifested in a functional classroom where teaching took place every day. However, through the PCK lens, some gaps in her knowledge were identified, especially in the areas of students' understanding of science and her own in-depth understanding of the content of the subject. Her pedagogical content knowledge was therefore limited in some areas by her lack of subject matter knowledge.

However, it was also noted that she had more knowledge about content representations than what was observed in her practice. It was found that her orientation towards science teaching influenced what she chose to teach and how she chose to do so. The contextual factors, which include a highly prescribed syllabus accompanied by the pressure from the Education Department and the school to perform well in the Grade 12 matriculation examination, strongly influenced her actions.

Despite these constraints, positive changes in her practice were observed over the three year period of this study. Her planning became more detailed and her teaching approach shifted from being teacher-focused, to becoming more learner-focused in year 3. She introduced a new assessment strategy in the third year to enable more immediate feedback to her learners. Furthermore, she expanded her content knowledge in at least three areas, namely cyclic compounds, structure-physical property relationships, and combustion reactions.

As an in-depth case study, this study offers new insights that might be applicable to many other similar contexts in South Africa. Many South African learners learn science in a second language and many schools in South Africa are situated in low socio-economic areas. The strong focus on a high stakes examination influences all public schools in South Africa.

Shulman's (1986) original observation that there was less of a focus on content in teacher preparation programmes was evident in this study. The lack of subject matter knowledge plays a fundamental role in teaching as proposed by Shulman. If change is to be sought in science education in South Africa, teacher development programmes need to include more content preparation and a focus on the development of pedagogical content knowledge. All of this needs to be accompanied by longer term in-school support.

The value of this research study lies in its longitudinal nature. If the study had been shorter, the changes in the teacher's practice, which may have been partly influenced by the presence of the researcher, might not have been noticed. The longer involvement also provided time for a trust relationship to be established between the teacher and the researcher, which opened the opportunities for growth. Change is possible, despite contextual and other constraints, but it is a slow process that requires patience and support.

Declaration of originality

I know the meaning of plagiarism and declare that all the work in this document, except for that which is properly acknowledged, is my original work. This thesis has not been submitted for any degree or examination at any other university. This thesis does not contain other persons' writing, data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons. Where direct words have been used, their writing has been placed inside quotation marks, and referenced accordingly.

SIGNATURE:

Signed by candidate

René Toerien

DATE: 28 March 2013

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1 Introduction

'I begin with the assumption that competent practitioners usually know more than they can say. They exhibit a kind of knowing in practice, most of which is tacit...Indeed practitioners themselves often reveal a capacity for reflection on their intuitive knowing in the midst of action and sometimes use this capacity to cope with the unique, uncertain, and conflicted situations of practice.' (Schön, 1983, p.8)

Teaching is a complex human endeavour, and education is embedded in the socio-political setting of a country. When South Africa's first fully democratically elected government came to power almost 20 year ago, it was faced with a segregated and highly unequal education system. This issue was addressed, amongst other things, by introducing the first national curriculum in an attempt to unify education in South Africa. Facing numerous implementation challenges, the new curriculum has not yet delivered the desired outcomes, and South Africa continues to perform poorly in international benchmarking assessments like TIMSS¹ and PIRLS² (Martin, Mullis, Foy, & Stanco, 2012; Mullis, Martin, Foy, & Arora, 2012). The quality of matriculation results also remains a concern, especially in Mathematics and Physical Sciences (CDE, 2010), the so-called gateway subjects for access to tertiary education.

Central to the teaching endeavour is the quality of teaching as was highlighted in a report by the Centre for Development and Enterprise: *'The quality of an education system cannot exceed the quality of its teachers'* (CDE, 2007, p.16). This is of specific concern in science education since there is a shortage of science teachers in South Africa (CDE, 2011) and it has been claimed that many of the teachers who are currently teaching have low content knowledge (CDE, 2007).

Rollnick and Brodie (2011) identify seven guiding principles for teacher development in South Africa. One of the principles calls for actual school and classroom data to inform teacher learning and development programmes. As a contribution to this call, this study aims to describe what happens in a typical South African science classroom in order to provide insights into how teacher knowledge is transformed in practice.

¹ Trends in International Mathematics and Science Study

² Progress in International Reading Literacy Study

Research into teaching and teacher education over the past three decades has largely moved away from teacher behavioural research to focussing on teacher knowledge. This change was led by Lee Shulman (1986) when he introduced what he termed '*the missing paradigm*' (p.7) – pedagogical content knowledge or PCK – to the research community. This special mix of content and pedagogy captures how teachers transform the subject matter into a teachable form. PCK has since become an important focus in science education research since it places content knowledge and pedagogy central to the education endeavour.

This study uses PCK as a lens to look at the practice of an experienced science teacher at a typical South African township³ school over a period of three years. Like many senior science teachers in South Africa, she is the only senior science teacher at the school. For both her and her learners⁴, the language in which science teaching is supposed to take place (English) is their second language. The school is situated in a community where unemployment is high, single parent or child-headed households are common and crime is the order of the day.

The teacher was observed over a period of three years while teaching the organic chemistry section of the Grade 12⁵ Physical Sciences⁶ syllabus. Video recordings of her lessons, interviews and field notes were used to capture what happened in her classroom, and her reflections on the lessons. The data were analysed to reveal her pedagogical content knowledge and how this changed over time. The findings, analysis and discussion thereof are presented in this research report as outlined below:

Chapter 2 reviews the relevant literature in the domains of teacher knowledge and pedagogical content knowledge, and concludes with the most recent synthesis of the literature on PCK as summarised by the PCK Consensus Model. Manifestations of PCK from the literature review are proposed as an organising framework for the data analysis.

Chapter 3 motivates the choice of methodology and research design. It describes the research instruments and data collection procedures and elaborates on the data analysis procedures that were used in the study.

³ An urban settlement area characterised by high unemployment and low levels of infrastructure – both of course legacies of apartheid past where minimal provision was made for black South Africans to live in urban centres.

⁴ 'Learners' is the official term used for students in the South African curriculum documents.

⁵ Grade 12 is the 12th and final year of schooling in South Africa. Learners are generally 17-18 years of age, but could be older, especially in township schools.

⁶ Physical Sciences consist of both Chemistry and Physics in South Africa.

Chapter 4 presents the findings of the study and analysis of the data. Firstly the data set is analysed as a whole to obtain an overall picture, after which an in-depth analysis of a subset of the data is conducted using the manifestations of PCK. The chapter concludes by stepping back again to highlight the areas of development of PCK over the three years.

Chapter 5 gives an overview of the study and discusses the analysis to answer the four research questions.

Lastly, Chapter 6 draws conclusions and proposes recommendations for future research. Limitations of the study are also discussed.

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2 Literature review and theoretical framework

2.1 Introduction

If we consider education research over the decades, one of the golden threads that runs through the literature is the quest to deeply understand what good teaching is and how new teachers develop their expertise. A major contribution was made by Lee Shulman in the mid-80s when he proposed a new type of knowledge that he believed was *'the missing paradigm'* (Shulman, 1986, p. 7) in research on teaching.

Shulman was at the time examining teacher development programmes. He noted that content, or subject matter, had almost completely disappeared from teacher preparation programmes, and that pedagogy had come to be viewed as an essentially content-free skill (Shulman, 1986). In an attempt to highlight the importance of content, and to bring it back into teacher preparation programmes, he put forward a knowledge which is *'an amalgam of content and pedagogy that is uniquely the province of teachers'* (Shulman, 1987, p. 8). This new knowledge, which he called Pedagogical Content Knowledge (PCK), distinguishes the teacher from the subject matter specialist. In his definition PCK refers to the transformation of content into a form that makes learning possible. He further listed PCK as one of the seven fundamental knowledge domains in his professional knowledge base for teaching (Shulman, 1987) as shown in Table 2.1 below.

Table 2.1 Shulman's (1987, p.8) seven categories of the knowledge base for teaching

Shulman's knowledge base for teaching	
• Content knowledge • General pedagogical knowledge with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter • Curriculum knowledge with particular grasp of the materials and programmes that serve as 'tools of the trade' for teachers • Pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding • Knowledge of learners and their characteristics • Knowledge of educational contexts, ranging from the workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures • Knowledge of educational ends, purposes, and values, and their philosophical and historical grounds	

2.2 Conceptualising PCK

In the 25 years since Shulman's introduction of the concept, various conceptualisations of PCK have emerged. Most researchers have noted that PCK, rather than being simply one of seven distinct knowledge bases, is in fact closely interrelated to the other six. A number of models have suggested that PCK is an *integration* of some or all of the other knowledge areas outlined by Shulman. For example, Bishop and Denley (2007) conceptualise the relationship between PCK and the other categories as a 'spinning top' (Bishop & Denley, 2007, p. 9) where all the categories in Shulman's knowledge base merge into PCK as the teacher transforms the content being taught. This model is shown in Figure 2.1.

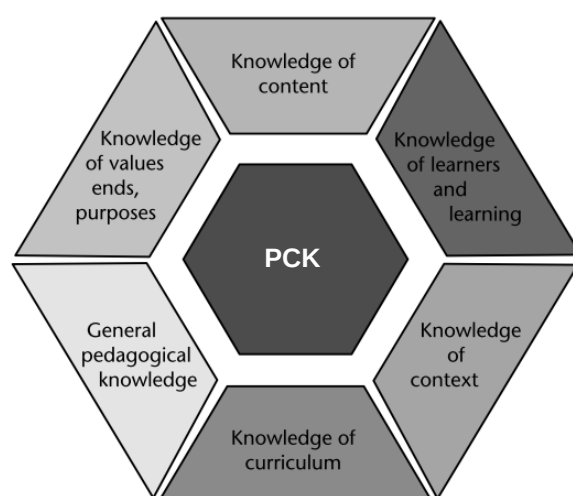


Figure 2.1 A 'spinning top' model for pedagogical content knowledge (Bishop & Denley, 2007, p. 9)

Another model which conceptualised PCK as an integration of other knowledge bases is that of Cochrane, De Ruiter, and King (1993), whose model emphasised the developmental nature of PCK. For them knowledge of pedagogy, subject matter, students and environmental context played the most important roles in the development of PCK. This is shown in Figure 2.2. It can be noted here that they use the term 'knowing' to emphasise the dynamic and active nature of PCK. They also proposed a synthesis and integration of the constituent components of PCK, as shown by the overlapping circles in the diagram. The arrows are included to emphasise the possibility of expansion and growth. A teacher can have varying levels of knowledge of the components, for example, limited knowledge of subject matter will restrict PCK and growth in this area will grow PCK.

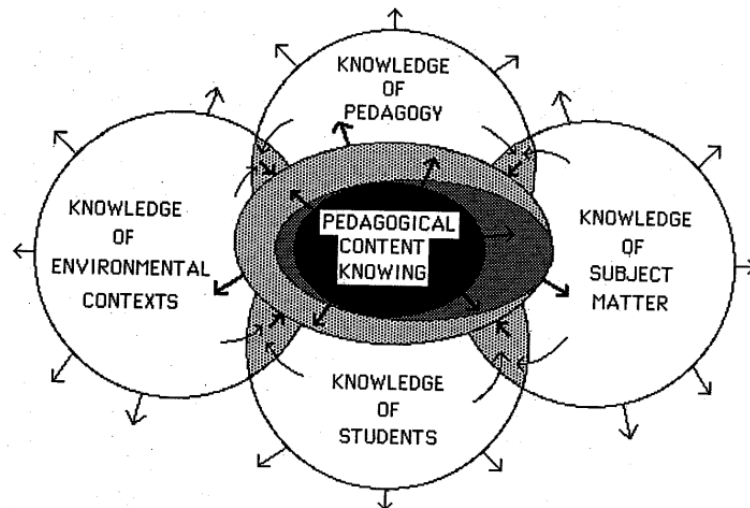


Figure 2.2 A developmental model of pedagogical content knowing (PCKg) (Cochrane et al., 1993)

Another view of PCK identified by Gess-Newsome (1999a) sees PCK as an *intersection* of subject matter knowledge, pedagogical knowledge and contextual knowledge as shown in Figure 2.3.

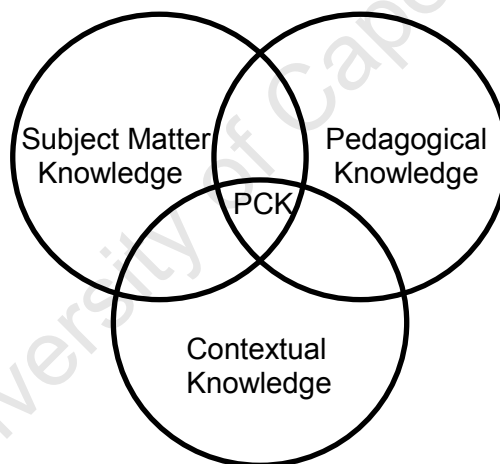


Figure 2.3 Gess-Newsome's model of PCK (Gess-Newsome, 1999a) (redrawn)

Several authors view PCK as a *transformation* of the contributing knowledge categories (Friedrichsen et al., 2009; Grossman, 1990; Magnusson, Krajcik, & Borko, 1999). Grossman (1990) conceptualises PCK as a transformation of the knowledge of pedagogy, content and context, as shown in Figure 2.4.

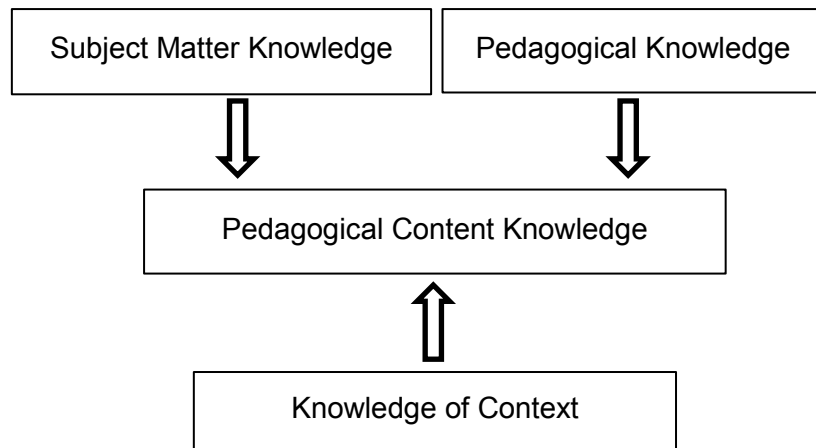


Figure 2.4 A transformative model of PCK (Grossman, 1990) (redrawn)

According to this model, content knowledge on its own, or pedagogy on its own, are not enough for quality teaching. Sound knowledge of these is necessary, but in addition, a transformation process is required in order for effective teaching to take place. The implication for research is that when studying PCK one cannot examine subject matter knowledge, pedagogical knowledge and contextual knowledge on their own, and then infer the PCK of the particular teacher. PCK itself also needs to be examined to obtain a more accurate reflection of the teacher's knowledge.

In the science education field, researchers looking to identify PCK in practice have developed further models of the key elements of PCK as manifested in actual teaching. For example, Magnusson et al. (1999) identified five distinct components of PCK, in addition to the knowledge categories that have been argued to contribute to PCK in Figure 2.4. These they identify as:

- Orientation to teaching science
- Knowledge of the science curricula
- Knowledge of students' understanding of science
- Knowledge of assessment of scientific literacy
- Knowledge of instructional strategies

These components are depicted in Figure 2.5.

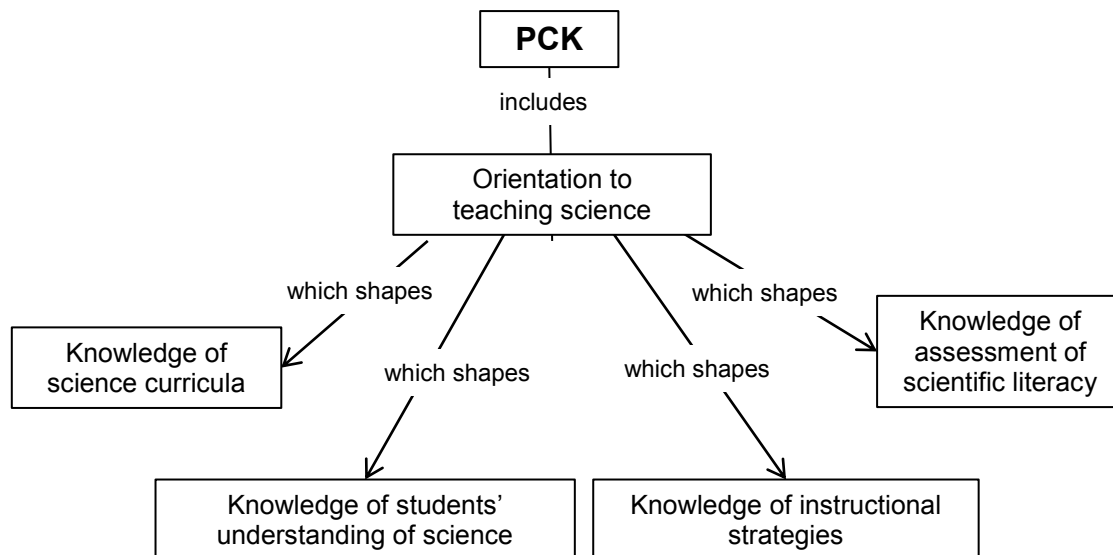


Figure 2.5 Components of PCK according to Magnusson et al (1999) (redrawn)

Park and co-workers (Park & Chen, 2012; Park & Oliver, 2008) further refined the Magnusson model by examining the influence each of the components have on the other components as shown in Figure 2.6. They suggest that all the components are closely integrated and that they influence each other when observed in practice. They also identified that PCK developed through the teacher's reflection on a lesson while teaching (reflection-in-action) and after a lesson (reflection-on-action) (Park & Chen, 2012; Park & Oliver, 2008; Schön, 1983, 1987).

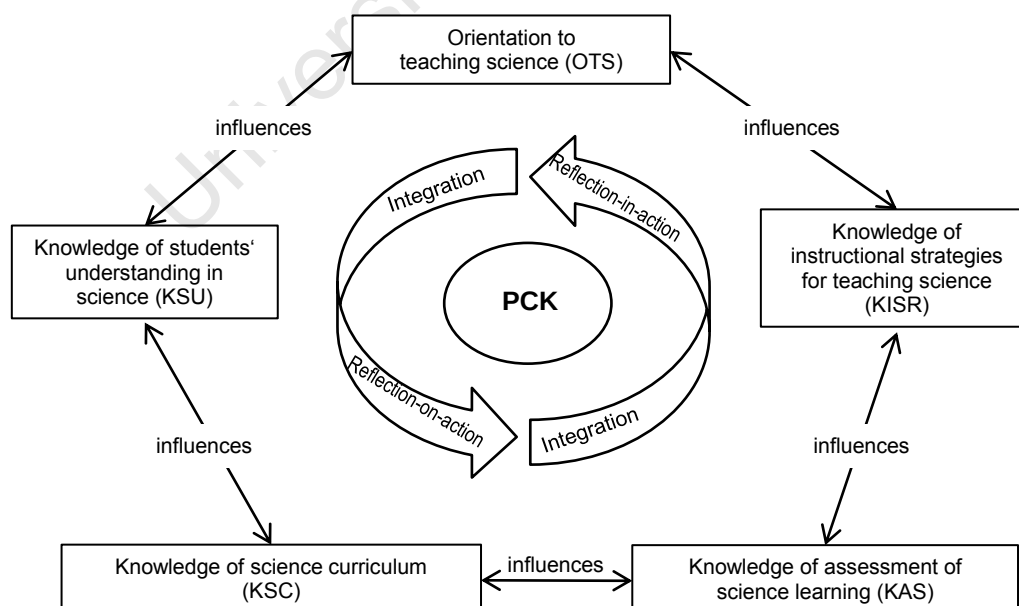


Figure 2.6 Park and co-workers' pentagon model of PCK (Park & Chen, 2012; Park & Oliver, 2008) (redrawn)

In South Africa, Rollnick and her team (Davidowitz & Rollnick, 2011; Rollnick et al., 2008) proposed a model which links what is observed in the classroom with PCK and the contributing fundamental knowledge bases. They identified ‘manifestations’ or observable evidence of the teachers’ PCK and showed how these are linked to the contributing knowledge bases of subject matter knowledge, knowledge of pedagogy, students and context. The manifestations of PCK which they identified were the following:

- Representations
- Curricular saliency
- Explanations
- Interactions with students
- Topic-specific instructional strategies

They propose that the manifestations of the PCK for a specific teacher are dependent on the topic and the context in which they are teaching and can vary from individual to individual. Their model is shown in Figure 2.7.

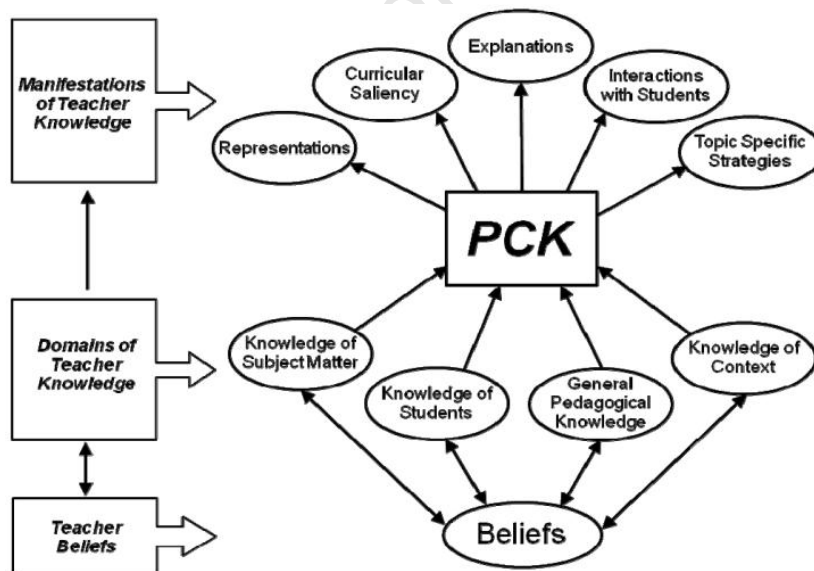


Figure 2.7 Rollnick et al.'s model of PCK (Davidowitz & Rollnick, 2011; Rollnick et al., 2008)

There are strong similarities between the manifestations in this model and the components identified by Magnusson and refined by Park and co-workers (Magnusson et al., 1999; Park

& Chen, 2012), offering theoretical elaboration of PCK that can be used to further direct research into PCK in action.

As seen above, in the 25 years since Shulman proposed this new type of knowledge, namely pedagogical content knowledge, many scholars have conceptualised it in many different ways. In an attempt to reach some degree of consensus, an international PCK Summit was held in Colorado Springs, USA in October 2012. One of the outcomes of the Summit was a consensus model for PCK. This is discussed below.

2.3 PCK Summit Consensus Model

The PCK Summit Consensus Model (Gess-Newsome & Carlson, 2013) as depicted in Figure 2.8 uses Shulman's professional knowledge base for teaching (Shulman, 1986, 1987) as a point of departure to show the relationship between what teachers as professionals know (or need to know), their classroom practice and student outcomes.

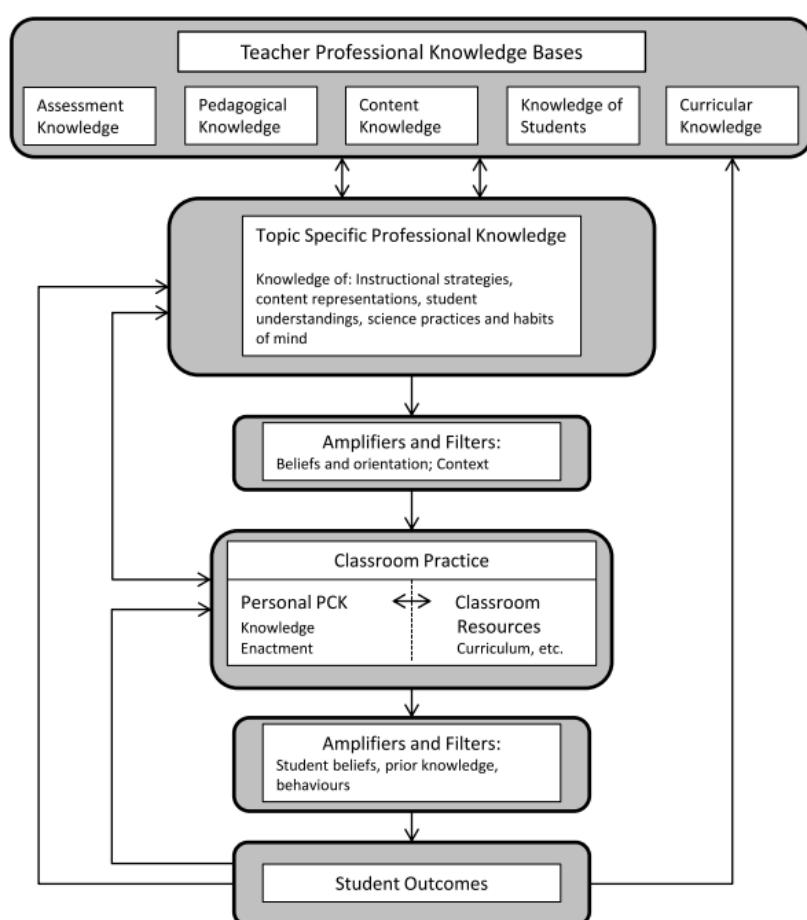


Figure 2.8 PCK Summit Consensus Model (Gess-Newsome & Carlson, 2013) (redrawn)

In the first level of their model they list the teacher professional knowledge bases, similar to what Shulman had, for example pedagogical knowledge, content knowledge, assessment knowledge, knowledge of students and curricular knowledge, but do not include pedagogical content knowledge at this level.

In the next level of their model they move to the topic specific level, proposing a modified knowledge base for each topic that is taught. This is called Topic Specific Professional Knowledge (TSPK).

TSPK is transformed as it is enacted in the classroom. This transformation process is influenced by factors which they call amplifiers and filters, for example, the teacher's beliefs and orientation to science teaching or the various contextual factors which play a role in teaching.

The model reserves the term PCK for classroom practice and uses the 'personal PCK' to highlight the individual nature of PCK. Personal PCK is defined as follows:

'Personal PCK is the knowledge of, reasoning behind, and planning for teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes. Personal PCK is the act of teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes.' (Gess-Newsome & Carlson, 2013, p.16)

As mentioned in the definition, student outcomes are included in the last part of the model. This aspect has been not been investigated in many PCK studies (Abell, 2008) and it is depicted here as the ultimate outcome of the teaching endeavour. The model proposes another set of amplifiers and filters between classroom practice and student learning, which could include student beliefs, prior knowledge and behaviours. Multiple interactions between the different levels are acknowledged and arrows are used to indicate these as per Figure 2.8.

The present study investigates the classroom practice of a teacher and thus focuses on the outcome of the transformation of topic specific professional knowledge as it is observed in practice. The term 'pedagogical content knowledge' will be used to refer to the teacher's unique knowledge of what to teach and how to do so, specifically observed by how this manifests in practice, and thus similar to what in the PCK Consensus Model is termed 'personal PCK'. Student outcomes fall outside the scope of the present study and will not be included here.

2.4 Manifestations of pedagogical content knowledge

Drawing together the findings across the literature, the following key components of PCK and its manifestations in practice (e.g. Magnusson et al., 1999; Park & Oliver, 2008; Rollnick et al., 2008) have been identified and form the focus for the present study:

- Use of topic-specific instructional strategies
- Knowledge of the science curriculum
- Use of assessment strategies
- Knowledge of students' understanding in science
- Use of explanations
- Use of content representations

2.4.1 Use of topic-specific instructional strategies

Estes, Mintz, and Gunter (2011) discuss a wide variety of instructional models, for example cooperative learning, concept development or problem-centred inquiry that teachers employ in their classrooms. They highlight the fact that teachers need to be knowledgeable about a variety of instructional models to be able to choose the most appropriate one for a specific class, or a specific topic. Friedrichsen et al. (2009) noted that direct instruction remains the predominant mode of teaching in many classrooms. They studied biology teachers in the US and observed a '*teaching-as-telling*' (p.370) approach in their classrooms, in line with the teachers' own experiences as learners and the teachers' views on science teaching.

2.4.2 Knowledge of the science curriculum

Experienced teachers know what to teach, when to teach it and how long to spend on it. This is what Geddis, Onslow, Beynon, and Oesch (1993) refers to as curricular saliency. This ability of teachers to work out the importance, extent and depth of a specific topic, and manage the tension between teaching for understanding and completing the curriculum, is a reflection of the teacher's PCK. Shulman (1986) included this component in his description of PCK when he explained that a teacher should have knowledge of the horizontal and vertical curricula. This includes knowing what topics are taught before and after the topic under discussion, and also what topics are taught in other subjects within the same grade.

2.4.3 Use of assessment strategies

Since teaching and learning are intimately connected, assessment of whether learning has taken place forms an important part of any educational event (Tamir, 1988). Novak (1993) highlighted the importance of assessment when he included evaluation as an important component of any educational event, alongside the learner, the teacher, the subject matter and a social environment. This component of topic specific professional knowledge could include knowledge of a variety of assessment methods, instruments, approaches and activities that would enhance effective learning of the topic.

2.4.4 Knowledge of students' understanding in science

Park and Oliver (2008) included this component under PCK. They identified knowledge of common misconceptions, students' learning difficulties and learning styles, as well as motivations, interests and needs under this heading. To teach a subject effectively the teacher needs to know which areas are difficult to understand and what pre-knowledge the students are likely to have about each topic.

Aspects of organic chemistry that have been identified as difficult to understand are polarity, the three-dimensional nature of molecules, structure-property relationships and functional group chemistry (Duis, 2011). Since organic chemistry builds on a number of fundamental concepts such as the atom, electronic structure, bonding and intermolecular forces, understanding of these concepts could also play a role in students' understanding of organic chemistry (Duis, 2011; Nakhleh, 1992).

2.4.5 Use of explanations

Bond-Robinson (2005) suggested that the teacher's role is to transform content, in line with the notion of PCK, so that learners are able to understand the subject matter. She proposed 'transforming explanations' (p. 94) as a tool to help learners form links between the different concepts being taught.

2.4.6 Use of content representations

Shulman (1986) defined PCK for a topic as *'the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject that make it comprehensible to others'* (p. 9) and states that the expert teacher should have *'a variety*

of alternative representations at hand' (p. 9) and be ready to be implement them when the situation calls for it. The ability to effectively represent content therefore plays an important role in making the content understandable for learners.

This present study has a specific focus on chemistry teaching. In this regard Johnstone (1991) introduced the 'Chemistry Triangle' in which he identified three distinct levels of representing chemistry: the macroscopic, or tangible, that which one can see and touch; the sub-microscopic which includes representations on atomic, molecular and ionic level; and the symbolic which includes symbols, formulae, equations or graphs. The expert teacher is able to move fluently between these three content representations, but the novice finds it difficult. Expert teachers are also aware of their learners' inability to cope with all three representations at the same time and therefore move carefully and slowly between them, giving guidance where needed.

Treagust, Chittleborough, and Mamiala (2004) identified a variety of representations, for example diagrams, illustrations and ball-and-stick or space-filling models that are needed to assist learners in constructing mental models for organic chemistry. Knowledge of how and where to use these representations was suggested as being an important component for the effective teaching of a topic such as this.

2.5 Orientation to teaching science

Many research studies into PCK include beliefs and orientation as a factor in teacher knowledge (e.g. Friedrichsen, Van Driel, & Abell, 2011; Luft & Roehrig, 2007; Rollnick et al., 2008), yet there is inconsistency in the use of the terms (Friedrichsen et al., 2009). A variety of other terminologies are also used (Pajares, 1992), for example 'conceptions of science teaching' (Hewson & Hewson, 1988), 'functional paradigms' (Lantz & Kass, 1987) or 'world images' (Wubbels, 1992).

Magnusson et al. (1999) used the term 'orientation' to specifically describe different approaches to science teaching. These authors identified nine orientations to science teaching, namely

- process (helping students develop the 'science process skills');
- academic rigor (representing a particular body of knowledge);
- didactic (transmitting the facts of science);

- conceptual change (facilitating the development of scientific knowledge by confronting students with contexts to explain that challenge their naïve conceptions);
- activity-driven (having students be active with materials; hands-on experiences);
- discovery (providing opportunities for students on their own to discover targeted science concepts);
- project-based science (involving students in investigating solutions to authentic problems)
- inquiry (representing science as inquiry);
- guided inquiry (constituting a community of learners whose members share responsibility for understanding the physical world, particularly with respect to using the tools of science). (p. 100)

Friedrichsen et al. (2011) found that, despite a world-wide push towards a more progressive view on teaching, many teachers still teach with a didactic orientation.

2.6 Contextual influences

The context in which teaching takes place is an important factor to consider when investigating teacher practice (Abell, 2008; Clark & Linder, 2006). South Africa has a particularly complex political and historical past. The effects of unequal opportunities to education many South Africans experienced over decades have been firmly ingrained in our current education system. To correct the inequalities of the past, the current government has education very high on its agenda and puts a high priority on academic success in schools.

Clark and Linder (2006) investigated science teaching in a township school in South Africa. They showed just how constraining the context of teaching in such an environment can be on the classroom actions of a teacher. The contextual influences that need to be considered could include the history of the country and the school, the socio-economic status of the community as well as the academic expectations that the school places on its teachers.

2.7 Summary

This chapter has shown that teachers possess a unique knowledge base that enables them to make content understandable to their learners. When teachers teach, the knowledge they have about the topic, and how to teach it, reveals itself in their classroom actions.

A number of PCK models (Davidowitz & Rollnick, 2011; Gess-Newsome & Carlson, 2013; Park & Chen, 2012; Rollnick et al., 2008) have been useful in identifying these manifestations of PCK and their relationships with the fundamental knowledge domains as described by Shulman (1986, 1987). The PCK models have also provided insight into the links between PCK, the teaching context and the teacher's orientation to science teaching. The manifestations, or observable evidence, of PCK in action, have been identified as how teachers use topic-specific instructional strategies, what knowledge they have about the science curriculum, how they use assessment strategies, how they explain and represent the content and what they know about the students' understanding of the topic they are teaching.

These aspects form the criteria for the analysis and will be discussed in Chapter 4. But first Chapter 3 will describe the research design and research methods used in this study.

3 Methods and methodology

Chapter 2 provided the theoretical framing for this research study and identified a number of manifestations of PCK in practice. What follows in this chapter will provide the rationale behind the choice of the research design and research instruments, describe the data collection procedures, and highlight issues of validity and ethical considerations.

3.1 Research questions

The act of teaching is a complex activity influenced by a number of knowledge domains. Teachers operate from this knowledge base when they make decisions about what to teach and how to do so. The first two research questions were formulated to focus on the teacher's general pedagogical knowledge (PK) and pedagogical content knowledge (PCK) and how these play out in the classroom.

How does the teacher's general pedagogical knowledge manifest during the teaching of organic chemistry?

How does the teacher's pedagogical content knowledge manifest during the teaching of organic chemistry?

Classroom actions are underpinned by what teachers believe good teaching is and how they see their role in a teaching-learning environment. In order to investigate what the teacher's orientation to science teaching is, and how this influences pedagogical decision-making, the second research question was formulated as follows:

How does the teacher's orientation to science teaching influence her pedagogical content knowledge?

The act of teaching is embedded in the context in which it takes place. To interrogate the influence that the context has, the third research question was:

How do the contextual influences affect the teacher's pedagogical content knowledge?

Since I had the opportunity to work with the teacher for three years, a final research question was formulated to track the development of knowledge and changes in her practice over the three years:

How does the teacher's pedagogical content knowledge develop over a period of three years?

3.2 Research design

This study formed part of a larger research study involving a whole school intervention. This study set out to observe and document the practice of an experienced physical science teacher over three years, teaching a specific part of the curriculum. The research design for the present study was guided by a qualitative case study methodology to enable a detailed description of the teacher's practice and the factors influencing and underpinning it.

The purpose of the study is to reach an in-depth understanding of a teacher's practice. To reach such an understanding, a research design which uses qualitative data and inductive analysis to generate a rich description of the events as it unfolds over an extended period of time, was chosen.

Cohen, Manion, and Morrison (2011) suggest that reality is multi-layered and complex and because of this an interpretive research design allows for interpreting such complexity. In addition, Cohen et al. (2011) suggest that events cannot be reduced to simplistic interpretations and thus 'thick' descriptions (Geertz, 1973) of contextualised behaviour constitutes an appropriate approach to qualitative research.

In an interpretive paradigm, the researcher operates from the assumption that a single objective truth cannot be obtained and therefore human interpretation is a useful channel to approach an understanding of some of the complexities of reality (Cohen et al., 2011). The researcher's analysis, synthesis and interpretations are central to such a study as these are able to capture the non-verbal aspects to which only a human instrument is sensitive (Merriam, 1998). Such interpretations are also open to alternative and additional interpretations by the reader, extending the value of the research.

A case study design was chosen for this research study. Opie (2004) defines a case study as an 'in-depth study of interactions in a single instance in an enclosed system' (p. 74). This study involves data collection with the same teacher at the same school teaching the same content over an extended period of time. The research questions probe the nature of PCK and how this translates in practice. To investigate how such knowledge is transformed in practice and the various factors influencing this process, a longer term involvement with the teacher affords a richer description and a more detailed picture of her practice. Data were therefore collected for three consecutive years.

When a case study design is adopted, data is collected in a particular context. Some scholars have critiqued case study methodology because it can't deliver generalizability in

the same sense that a traditional research design sampling for representivity across a population can (Yin, 2003). However, what the case study can offer is an in-depth understanding of how various aspects in the case interrelate. Case study is thus uniquely placed to deliver explanatory theory. The potential transferability of these findings to other similar contexts can only be partly suggested by the author, and ultimately is the responsibility of the reader – who can compare the case to another context. In this sense then, it has been argued that the case study is associated with its own particular forms of generalizability (Flyvbjerg, 2006).

3.3 Methods of data collection

The objective of the research study was to obtain detailed information about a teacher's practice and how the teacher's knowledge manifests in this setting. Research methods were chosen that would best capture this information. These included classroom observations (video recordings and field notes) and interviews.

3.3.1 Classroom observations

When observation is used in natural settings it enables data gathering on a number of different levels. Not only is the physical environment observed, but also the verbal and non-verbal interactions, planned and unplanned events, formal and informal interactions as well as the organization of resources (Morrison, 1993 cited in Cohen et al., 2011). These can potentially provide rich data to enable detailed descriptions of the events and give insight into the teacher's practice at different levels.

Adler and Adler (1994, p. 380) note that 'all research is some form of participant observation' and that one 'cannot study the world without being part of it'. I therefore took the role of a participant observer in a peripheral membership role (Adler & Adler, 1994). In order to understand the setting and obtain rich data I had to become an 'insider'. I was present in all the lessons, but did not participate by, for example, co-teaching or becoming part of the classroom discussions. I was however available if the teacher wanted to ask questions on the content that was taught or any other issue which came up. I remained seated at the back of the room while the teaching took place, in an attempt to let the interactions in the classroom carry on as if I had not been present.

The purpose of the observations was to gain insight into the teacher's practice and to capture the transformation of her knowledge of the teaching of organic chemistry. In the anticipation that actual footage of the events would reveal the most detailed representation

of what happened, I digitally video-recorded all the teacher's lessons. Since the study took place over an extended period of time, video footage also afforded me the opportunity to revisit lessons taught in previous years.

According to Cohen et al. (2011) field notes can be used as both descriptive and reflective tools. As descriptive tools they capture general descriptive events of the physical settings, the people involved, their behaviours and activities. As reflective tools they capture the researcher's comments on the activities as they take place, adding additional background information to the situation. They capture the observer's reactions to what has just been observed and can be used to identify possible lines of further enquiry. In this study I made field notes of all the lessons which I observed. The field notes were complementary to the video recordings and they were used mainly as a reflective tool to support the video recordings.

The limitations to using classroom observations are that they are time-consuming and prone to researcher bias (Cohen et al., 2011; Opie, 2004). It is acknowledged here that collecting and analysing a large number of lesson videos was time-consuming but allowed for a much more detailed description of the teacher's practice than other methods. Field notes were taken during or immediately after lessons and these captured my perceptions of or comments on the situation observed. To reduce researcher bias transcripts of actual lessons were made to provide a more accurate account of the actual event and these were revisited on numerous occasions during the data analysis phase of my research (Opie, 2004).

3.3.2 Interviews

Interviews provide flexible opportunities to probe for greater depth than what video recordings or field notes can provide. The focus of the research was not only to identify the manifestations of teacher knowledge but also to gain insights into the thinking and reasoning that took place in the process of knowledge transformation, and the teacher's reflection in and on action (Park & Chen, 2012; Schön, 1983, 1987).

Teacher interviews were used in the study to clarify, supplement and support what was observed in the classroom and provide information that could not be captured by observations alone.

Semi-structured interviews are pre-planned conversations guided by a set of initial questions, but which allow for deviation from the set questions (Opie, 2004). These provide opportunities to explore matters that naturally arise in the conversation, yet also to probe

matters pre-determined by the interviewer. Semi-structured teacher interviews were conducted at the beginning and end of the teaching of the organic chemistry section of the syllabus each year.

Unstructured interviews are informal conversations that follow the interviewer's prompts, but do not have a fixed structure. They do have a fixed focus however, mainly in response to events which happened on the day (Cohen et al., 2011). Unstructured interviews can be used to capture the teacher's reflections-on-action or gain information on a situation that is not obviously evident. During the course of my engagement with the teacher a number of unstructured interviews were recorded.

A possible weakness of using interviews is that of researcher bias (Cohen et al., 2011; Opie, 2004). In an attempt to address this, interviews were voice-recorded and transcribed to provide a more complete record of what was said.

3.4 Data collection procedures

3.4.1 Observation procedures

Morrison (1993) states that *'being immersed in a particular context over time not only will the salient features of the situation emerge and present themselves but a more holistic view will be gathered of the interrelationship factors'* (p. 88). I viewed it important to understand the learning environment in which the teacher was operating. Observations therefore took place over three consecutive years during April and May and followed the teacher as she taught the entire section on organic chemistry each year. I spent most of the day at the school during this time and had the opportunity to immerse myself in the setting to become familiar with the ebb and flow of schooling at the institution, thereby attempting to reduce the potential impact that my presence could have on the teacher and her learners.

The observations had a structured schedule which was pre-arranged with the teacher and the school. I attended all the lessons taught to the Grade 12s each year. On occasion Grade 11 organic chemistry lessons were taught at the same time and these were then also observed and recorded. However, only the Grade 12 data were used for this study. The teaching took place in the same designated science classroom each year, but in the third year occasional lessons were taught in the Grade 12 homerooms.

The lessons were recorded by the researcher using a digital video recorder. The recorder was placed at the back of the classroom. Files were downloaded and labelled each day and

backup copies were made. A total of 97 of the 115 Grade 12 lessons taught over the span of three years were video-recorded. Of the 97 recorded lessons, 18 were chosen for transcription and further analysis as summarised in Table 3.1. Ten of the 18 lessons were chosen because they were considered to be representative of her teaching and exhibited instances of explicit PCK. In addition, sets of lessons on the same topic were chosen to compare the teaching across the three years, for example, one set on cyclic compounds (3 lessons), physical properties (2 lessons) and reactions of organic molecules (3 lessons), respectively. As far as possible lessons from the same class were chosen, for example lessons from 12B in year 1; 12G in year 2 and 12P in year 3. A detailed observation schedule can be found in Appendix A and B.

Table 3.1 Summary of the recording and transcribing of lessons

	Year 1 (2 classes)	Year 2 (2 classes)	Year 3 (3 classes)	Total
Total lessons taught (Grade 12)	28	27	60	115
Total lessons recorded (Grade 12)	28	20	49	97
Total lessons taught (Grade 11)	14	---	40	54
Total lessons recorded (Grade 11)	5	---	19	24
Total lessons transcribed (Grade 12)	6	4	8	18

3.4.2 Field notes

Field notes were taken on computer during lesson observation and followed the guidelines provided by Bogdan and Biklen (2006). On occasion it was not possible to make notes during the lesson, usually when the lesson took place in one of the Grade 12 homerooms. In these instances field notes were done as soon as possible after observing the lesson. Where additional notes were added afterwards, these were described as such (see for example the field notes on lesson 12A4 in Appendix C).

3.4.3 Interview procedures

Semi-structured teacher interviews of 30 – 45 minutes each were conducted at the beginning and end of the teaching each year. Informal unstructured interviews took place during the teaching time. These generally varied in length from 15 – 30 minutes. Unstructured interviews were initiated by either the teacher or the researcher and were generally reflective in nature. The interviews took place in the science classroom or in the

deputy principal's office. Interviews were digitally recorded and transcribed. An extract from a transcribed interview can be found in Appendix E. The learners wrote an examination in June each year and an additional interview was arranged after the June examination scripts were marked to capture the teacher's reflection on the learners' performance in the organic chemistry sections of the examinations. A summary of when all the interviews took place can be found in Appendix D.

3.4.4 My positioning as a researcher

As mentioned earlier, I have been involved in this research as a participant observer with the focus on documenting the practice of the teacher. Although my role was not that of a change agent, some changes in the teacher's practice did occur. These changes were initiated by the teacher herself, and in response supported by myself. This could be a possible reason why the observed changes were slow and took place over a long time, as opposed to an focused intervention which usually has a much shorter time frame to improve classroom practice. This could also be the reason why the changes were only observed in year 3, once the teacher had established a trust relationship with me.

I have limited knowledge of isiXhosa, only 4 years of basic training at late primary school and early high school level, but due to the nature of the subject matter, and the degree to which English was spoken in the classroom, I could follow the lessons with ease. The nuanced conversations I could not follow and used the translations of the lessons to assist me in understanding the dialogue.

3.5 Preliminary analysis of lessons

This study generated a large amount of data. In order to condense the data, a first phase of a grounded analysis with the aim of capturing the overall trends in the lessons was used. In the analysis the activities of both the teachers and the learners were coded. At first, a number of lessons were watched to identify the different activities that were taking place to develop the coding scheme. These were refined and are summarised in Table 3.2. The 18 lessons were then watched a number of times and coded according to these categories, using MSEXcel™. A visual representation of the activities against time was drawn for each lesson. An example of such an overview graph is shown in Figure 3.1 below. The graphs were then compared to identify similar patterns and trends across the lessons.

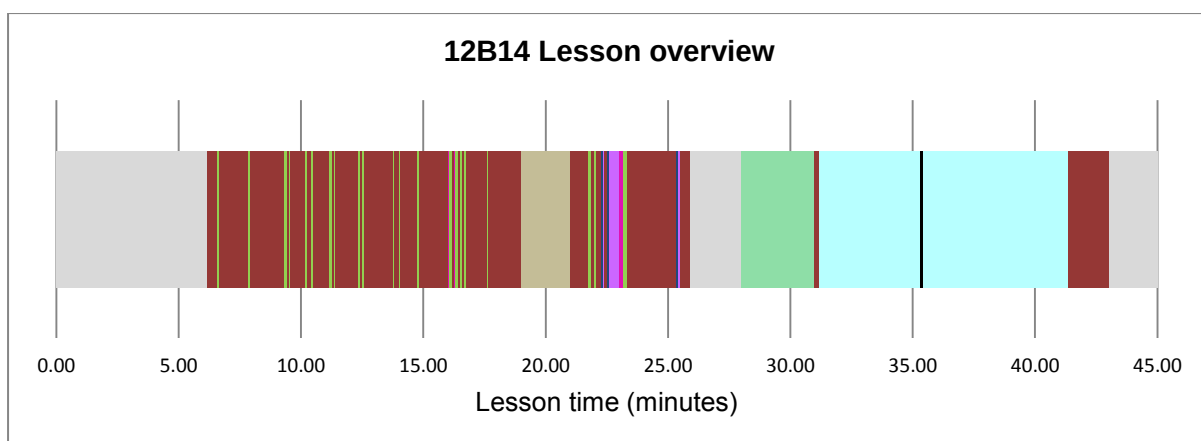


Figure 3.1 Overview graph for lesson 12B14

Table 3.2 Explanations of coding conventions

Teacher talking from the front of the room/at whiteboard	TT
Learners responding in unison as a class	LGR
Teacher asking a content question to the whole class	TQ
Teacher asking a question to an individual learner	TQI
Teacher answering a question from an individual learner	TAQ
Learners responding as a group but not in unison	LT
Individual learner responding to a question from the teacher	LAQ
Individual learner asking a question	LQ
Learners arrive/leave/'dead time'	X
Learners copy homework/boardwork	LCH
Learners work in small groups	LGW
Learners work in small groups with teacher circulating amongst the groups	LTGW
Bell rings	

3.5.1 Explanation of the codes

Teacher talking from the front of the room/at whiteboard (TT)

The teacher spent most of the class time in the front of the room, usually in front of the whiteboard, when she was teaching. All teacher actions where she was addressing the learners were classified under this heading.

Learners responding in unison as a class (LGR)

Most of the questions asked by the teacher in class were directed at the group, for example in the extract below. The learners then responded as a class and this was coded as LGR. On occasion the learners would say the words with the teachers, as can be seen in the last learner response below. This was also coded as LGR.

Teacher: ...If this was a long chain that has four carbons, and it's an alkane, what would you name it?

Learners: It's butane.

Teacher: What would you name it? It's butane, isn't it? But now, because it's a closed structure, we still keep the butane name right, but because it's closed, then the first part of the name becomes, what will it be?

Learners: Cyclo.

Teacher: So that we are able to differentiate when instructed to draw the structure; you are given butane, then again a closed chain, then you must differentiate between the two that when it's cyclo that means it is a ring OK? But it has the number of carbons – four, so the name of this compound we say it's ... cyclobutane.

Learners (with the teacher): Cyclobutane.

Teacher asking a content question to the whole class (TQ)

Two types of teacher questions were identified. The first was a rhetorical type question where the learners responded by answering 'yes' or 'no' – examples of this are provided in line 6 and 11 below. This was coded as TT as described above as it was considered part of her teaching style and not a specific question. The learners' answers in these cases were coded as LGR since they replied as a group. The second type of question was a content-based question for example 'how many products do we get?' in line 4. This was coded as TQ. Here the learners had to come up with a specific answer and not a general response.

- 1 Teacher: Dehydration OK? There is a hydrocarbon that means in order to identify that this is elimination, your reactants must have alcohol OK? If it is dehydration it will have alcohol. It's a saturated compound you want an unsaturated compound so there it is, one, two, three, four, so recall I said whenever we are speaking of elimination; how many products do we get?
- 5 Learners: There are two.
- 6 Teacher: Two OK?
- 7 Learners: Yes.
- 8 Teacher: There's a major and there's a minor. What is the major product of that compound? What will the major product of that compound be?
- 10 Learners: [inaudible]
- 11 Teacher: Yes. Can we all see how it is done?
- 12 Learners: Yes.

Teacher asking a question to an individual learner (TQI)

Whenever the teacher asked an individual learner, sometimes by name, a question it would be coded as TQI, for example:

Teacher: What were you saying Zuko my child, what were you saying?
Zuko: What effect will it have, the increase within the same functional group.
Teacher: What effect will increase have within the same functional group? And then what is the hypothesis? I need a sharp learner to follow through this question.
Learner 1: [inaudible]
Teacher: Anyone else? Lindiwe? What is the hypothesis there? The answer, the hypothesis?
Lindiwe: We increase the number of functional groups.

Teacher answering a question from an individual learner (TAQ)

This code was used whenever the teacher responded to a question from a learner.

Learners responding as a group but not in unison (LT)

This code was used when the learners responded all at the same time, but not in unison. Many learners would answer at the same time, but the answers were varied, and not necessarily correct. This was often in response to a content question to which the learners did not immediately know the correct answer.

Individual learner responding to a question from the teacher (LAQ)

This code was used when an individual learner answered a question from the teacher. The question could have been posed to the individual learner, or to the class as a whole.

Individual learner asking a question (LQ)

This code was used when an individual learner asked a question.

Learners arrive/leave/'dead time' (X)

This coding was used in the beginning of the lesson when the learners arrived, at the end of the lesson when they left, and on occasion during the lesson when there was 'dead time' where nothing happened, for example when the teacher was clearing the board to start a new section.

Learners copy homework/boardwork (LCH)

This happened very infrequently, but when learners were specifically given time to copy either the boardwork, or the homework from the whiteboard, this was coded as LCH.

Learners work in small groups (LGW)

This code was used when the learners worked amongst themselves, or in small groups of generally 2 – 5 learners, on homework exercises or worksheets.

Learners work in small groups with teacher circulating amongst the groups (LTGW)

This code was used when the learners worked amongst themselves, or in small groups of generally 2 – 5 learners, and with the teacher circulating between the groups.

3.5.2 Transcription and translation

IsiXhosa is the home language of the teacher and all the learners in her class. All the lessons were taught partly in English and partly in isiXhosa, as is common in many South African township classrooms (Mesthrie, 2002). The services of a transcriber/translator were used to firstly transcribe the lessons in isiXhosa, and then translate it from isiXhosa to English. A sample of the transcription and translation of a lesson is shown below and in Appendix F. The translated transcripts were used to code the lessons.

Teacher: And then umbuzo wesibini kuthiwa explain... explain the difference in boiling point. Kuyaboniswa pha intobangaba the boiling point, which is a physical property, is not the same. Now you need to explain, so your explanation, it must speak of the forces that are existing pha kweza nto ziyi-two. Mamela, indlela esiyionga ngayo lanto, because every time you are going to be given i-compound huneke uzi compar-ishe, this is how you should do it anhe? ... uzokwazi uphendula. Number one, everytime you are given i-compound, you must look at the factor, what is the factor that is affecting uba i-boiling point zakho zingafani, anhe? ... so that means the first thing, everytime when are looking you are given i-compounds, identify the factor.

Teacher: And then the second question says explain...explain the difference in boiling point. It is shown there that the boiling point, which is a physical property, is not the same. Now you need to explain, so your explanation, it must speak of the forces that are existing there in those two. Listen, the way we view that thing, because every time you are going to be given a compound and you have to compare, this is how you should do it OK? ... you will be able to answer. Number one, every time you are given a compound, you must look at the factor, what is the factor that is affecting such that your boiling points are not the same, OK?... so that means the first thing, every time when are looking you are given compounds, identify the factor.

The use of multiple languages in science classrooms is an area in which much contemporary research is being conducted (Adendorff, 1993; Mesthrie, 2002; Probyn, 2009;

Setati, Adler, Reed, & Bapoo, 2002). However, the scope of the present study did not extend to this aspect of the classroom and thus the extracts of classroom talk given in the thesis are only the translations.

3.5.3 Boardwork analysis

The classroom was equipped with a whiteboard as well as a data projector and interactive screen. Copies ('screenshots') of what the teacher wrote on the whiteboard were taken for complementary analysis. For reproduction purposes and to enhance the quality these were rewritten with NoteTakerND™ using a tablet, and the background removed using Adobe Illustrator™. An example of a screenshot and how it was enhanced is shown in Figure 3.2.

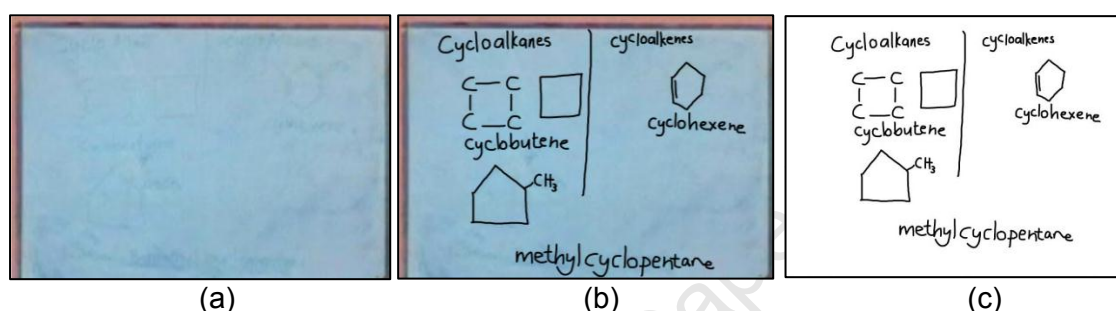


Figure 3.2 Analysis of boardwork a) screenshot from video footage (illegible in printed format); b) text overwrite; c) reprint without background

3.6 Validity

Robson (2002) identified two types of validity that need to be considered in the design of a case study, namely internal and external validity. The traditional notion of reliability is not applicable to a case study since there is no assumption that the same events would be captured if the observations were done at a different time (Lincoln & Guba, 1985).

3.6.1 Internal validity

Internal validity refers to the drawing of a relationship between the methods used and the claims made (Opie, 2004). To strive for a high degree of internal validity, data were collected over an extended period of time so that patterns of results could be observed and that interpretations and conclusions were not based on one-off events.

3.6.2 External validity

External validity refers to the generalizability of the study to other situations. Yin (2003) argues that case studies tend to seek analytical generalizability rather than statistical

generalizability. Analytical generalizability refers to the case's ability to contribute to the expansion and generalization of the theory. A single case can help the researcher understand cases or situations which are similar. It therefore provides the opportunity to test a theory in more than one empirical case rather than generalise the finding of the single case to others in general. In this study the teacher could represent many other teachers working in similar circumstances and the school could be representative of many other schools in South Africa.

3.7 Ethics

This study formed part of a larger whole school evaluation study conducted by the University of Cape Town. Permission from the Western Cape Education Department (WCED) to work in a WCED school was obtained as part of this larger study. In addition, ethics approval from the University of Cape Town had to be obtained. An ethics application was completed in the beginning of the study and was approved by the Faculty of Engineering and the Built Environment's Ethics Committee. This application is attached in Appendix M.

The teacher was known to the researcher through teacher workshops held at the Department of Chemical Engineering in previous years. The teacher was approached at the beginning of the study and the project was explained to her in person, and also in a letter, as per Appendix N. She had the freedom to not participate, or to withdraw at any stage, but gave consent for the study to take place. She was assured of her and her school's anonymity and that pseudonyms would be used in the reporting of the study.

3.8 Summary

In this chapter the choice of methodology and the research methods used in the study were discussed. A case study methodology operating in an interpretive paradigm was chosen to provide rich in-depth data on a teacher's practice over a period of three years. Classroom observations, interviews and field notes have provided insight into what happened in her classroom and the thinking and reasoning behind her actions. The findings of this study will be presented in the following chapters in a systematic and detailed way to make the process transparent and explicit. The analyses of the findings aim to shed light on the teacher's personal PCK and the factors influencing the transformation of knowledge.

4 Findings and analysis

4.1 Introducing the data

As you drive out of Cape Town and away from Table Mountain you soon notice the change of scenery. The leafy suburbs give way to settlements that are somewhat dusty, large houses give way to smaller dwellings, until you only see the shacks⁷ of the large informal settlements⁸ that have become landmarks in this area. From early on in the morning, schoolchildren are in transit catching buses, or taxis to attend 'better' schools closer to the city. Others are walking to a school in the local community. Themba High⁹ is one of these community schools. With 1100 learners from Grades 8-12, and 34 teachers, it is a large school. Today it is quite a highly regarded school in the community, the 'academic' school many learners want to attend. Despite its placement in a poverty-stricken neighbourhood it has managed to increase its pass rates over the years and was chosen as a Dinaledi¹⁰ science and mathematics focus school in 2006. This meant the school received a well-equipped science laboratory and additional teachers. Through initiatives of the Provincial Education Department the school has a computer classroom and a number of data projectors and interactive whiteboards.

Nomsa is one of the senior teachers at the school. As the Head of Physical, Life and Natural Sciences she manages a department of seven teachers. She is part of the management team at the school and is responsible for compiling all the learner reports at the end of each term. In addition she coordinates academic events like prize-giving and the afternoon teaching programme. She is often called to the principal's office and spends many free lessons and breaks doing administrative tasks for the school. She is a dedicated teacher who is always available to help learners even after hours or on weekends. Most of her school holidays are spent teaching additional lessons to Grade 12s. She has a few good friends on the staff, but does not spend a lot of time socializing in the staffroom. She says she would rather spend the time in her classroom preparing for the next lesson, helping learners or enjoying her lunch on her own. Her learners take first priority and she often says she '*does not want to disadvantage*' her learners. Themba High is the second school she is teaching at; the first one was a neighbouring school in the area. In the 5 years she has been

⁷ A single-room dwelling made from corrugated iron and other recycled materials.

⁸ Also called townships.

⁹ Pseudonyms are used throughout the study for the school, the teacher and learners involved.

¹⁰ Dinaledi is a national initiative which aims to increase the number and quality of mathematics and science Grade 12 passes. Schools are chosen as Dinaledi schools on the basis of previous pass rates and extra resources are provided to support the teaching and learning of these subjects.

at Themba High she has earned for herself the labels of 'good teacher', 'motivated', 'dedicated' and 'hard-working'.

It is Wednesday morning, week two of the second term. The Grade 12s started the new term with organic chemistry, one of the large sections in the Physical Sciences syllabus. The week-long April holiday was spent catching up on unfinished term one work.

The bell rings at 08:00 for the first lesson of the day, but as on most days the learners only start arriving around 08:15, with the lesson starting at 08:20. All the learners are present, except for four boys who arrive 10 minutes later. There are between 30 and 33 learners in each of the three Grade 12 classes Nomsa teaches, substantially smaller than the junior grades of up to 58 learners in a class. Nomsa generally teaches only Grade 11s and 12s, but one year she had three of these large Grade 8 classes together with the two regular Grade 12 classes. For a Head of Department she has an average teaching load with her teaching 26 or 27 out of the 36 lessons in the week. The Grade 12 attendance is relatively high with a maximum of 2 or 3 learners absent on any given day.

As the learners arrive, Nomsa is busy writing the examples she will be discussing on the whiteboard. The learners enter in an orderly manner, take their places, take out their workbooks and talk quietly amongst themselves as they wait for her to start the lesson.

Although the learners have textbooks, these are not brought to class and their teacher also seldom refers to the textbook in class. Instead she hands out summary notes which she has compiled from other sources, like textbooks or Education Department documents, workshop materials and exercises from past examination papers or study guides.

Nomsa introduces the topic: *'Today we are learning [about] hydrocarbons, today we are going to do cyclos'*. She reminds them of what was done in the previous lessons on the naming of hydrocarbons and tells them that this section is easy as it links with previous work, yet expands on it. *'It's very easy, nothing difficult at all... we are doing the same thing; it's just that now we are continuing forward.'*

She then spends the next 10 minutes in front of the whiteboard going through the examples of cyclic compounds she wrote on the board. Only the structures are drawn and the names are filled in as the lesson progresses. The examples are divided into the two categories 'cycloalkanes' and 'cycloalkenes' and examples are chosen so that they become progressively more difficult.

Nomsa teaches three Grade 12 classes and therefore repeats the lesson three times a day. This is the first one of the day. For the next Grade 12 lesson she clears the board and starts with new examples, most of them similar, but not identical to this first lesson's (see Figure 4.1 and Figure 4.2 for comparison).

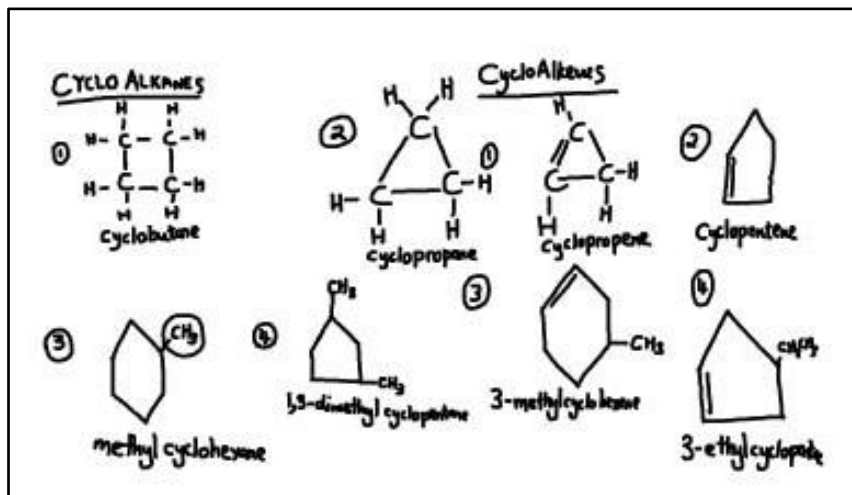


Figure 4.1 A sample of 12P6 boardwork

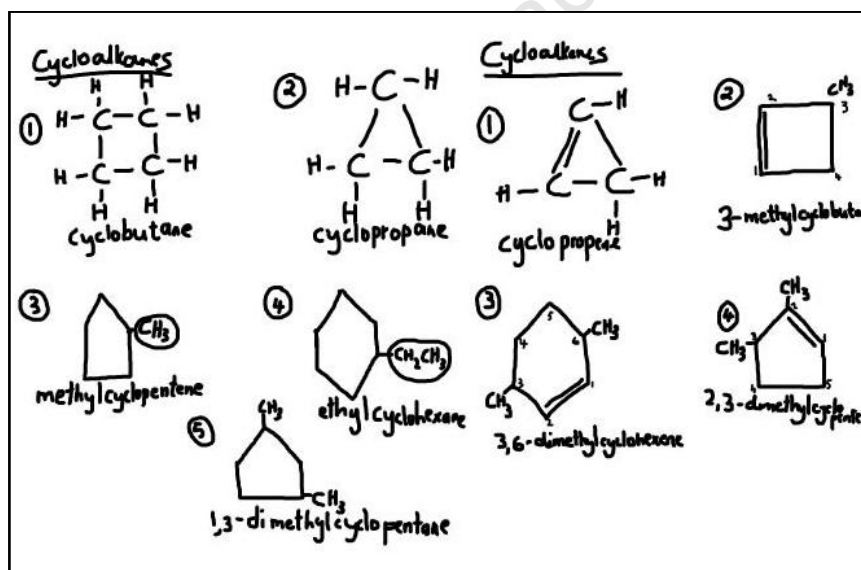


Figure 4.2 A sample of 12R6 boardwork

During this first part of her teaching, the class is quiet, no one asks a question, nor do they write in their note-books. Instead they answer as a group when prompted as can be seen in the following excerpt:

Teacher: Because the bonds between your carbons are single. The only difference is that while these bonds are single, they are closed OK? And every time when a hydrocarbon or a compound is closed the first part of the name is, we say cyclo, OK? Otherwise the

naming as you well know that if it was a straight chain. If this was a long chain that has four carbons, and it's an alkane, what would you name it?

Learners: It's butane.

Teacher: What would you name it? It's butane, isn't it? But now, because it's a closed structure we still keep the butane name right, but because it's closed, then the first part of the name becomes - what will it be?

Learners: Cyclo.

Teacher: So that we are able to differentiate when instructed to draw the structure; you are given butane, then again a closed chain, then you must differentiate between the two that when it's cyclo that means it is a ring OK? But it has the number of carbons – four, so the name of this compound we say it's ... cyclobutane.

Learners (with the teacher): Cyclobutane.

Teacher: Can you see how it happens? So there's no difficulty there, can you all hear class? (Lesson 12P6)

The explanation of the names for cyclic compounds progresses smoothly from the one example to the next. After the fourth cycloalkane example, about 30 minutes into the lesson, one of the learners asks for clarification regarding the use of di-methyl and not ethyl in example five, since there are two carbons. Nomsa explains that the side chains have only one carbon each, and these are therefore methyl groups. Because there are two groups 'di-' is used in front of the methyl to show this. She says:

'... There is only one carbon there and there. How many carbons? One. So they are methyls, we have two methyls so it will be 'di'. It's going to be 'di'.' (Lesson 12P6)

After this explanation she stops talking for a short while giving the learners a chance to copy the examples from the board, and when there are no further questions, she moves to the cycloalkenes. The first example is cyclopropene. She refers back to cyclopropane and points out the difference in structure (now there is a double bond) and then the accompanying change in naming convention – cyclopropene instead of cyclopropane. The learners seem to grasp this quite quickly and are able to answer the next example, cyclopentene, without hesitation. She consolidates the new content repeating the steps and accompanying convention as can be seen below:

'... cyclopentene because there's a double bond, five number of carbons. It's closed, it is cyclo. It has five carbons, therefore 'pent'. There's a double bond - it is 'e-n-e'. It is cyclopentene.' (Lesson 12P6)

For the next example she wants the learners to answer. She reminds them of the rules before giving them time to try it out.

'... Let us go to that last one. [she refers to number three on the board, see Figure 4.1]. Let us try naming here. The carbon, we don't forget our rules; by rule, we prefer first the functional group more than the side chain isn't it? So if our carbon has a double bond, it is number one, OK? Then the side chain will follow after because we depend on that functional group.' (Lesson 12P6)

After a few minutes she asks one of the boys in the back row to provide the name. At first he provides a partly incorrect name, but she does not correct him. She keeps quiet and eventually asks the rest of the class what they think. The first learner realises his mistake (he said hexene instead of cyclohexene) and provides the answer as '3-methyl cyclohexene'. There are a few minutes of silence as Nomsa ponders over his answer before writing it on the board. She does not notice the mistake (it should be 4-methyl cyclohexene) and concludes by saying *'Can we all see it? Can we all see how it is worked out OK, because that one is easy?'* (Lesson 12P6).

While she adds the final example on the board, the learners get time to copy the work so far. She goes through this last example with the class as well and the learners seem to grasp the naming of cyclic compounds fairly quickly. While they get time to copy the boardwork for the day, one learner gets up to draw a structure on the board (see Figure 4.3) and then asks the teacher about the naming of it.



Figure 4.3 Learner's example from lesson 12P6

She discusses the answer with the learner at the board and concludes the lesson by reminding the whole class about the numbering of a side chain at a double bond, in response to the example that the learner wrote on the board.

Noise is heard outside the classroom. The bell has rung, and the learners are dismissed.

4.2 Analysis of classroom practice

As elaborated upon in Chapter 2, the manifestations of PCK were identified from the literature (Davidowitz & Rollnick, 2011; Park & Chen, 2012; Park & Oliver, 2008; Rollnick et al., 2008). The following manifestations of PCK were chosen for the analysis of the data in this study:

- Use of instructional strategies
- Knowledge of the science curriculum
- Use of assessment strategies
- Knowledge of students' understanding in science
- Use of explanations
- Use of content representations

In the sections that follow these aspects of her classroom practice will be highlighted and the development over the three years will be shown. Chapter 5 will then discuss how some of these aspects can be used to describe her PCK and how some aspects reflect her pedagogical knowledge, and are therefore not necessarily a manifestation of her PCK.

4.2.1 Use of instructional strategies

To obtain an overall picture of Nomsa's instructional strategies the screenshots of her boardwork as well as the graphical representations of the lessons were used. Two representative lessons were chosen, both on nomenclature: lesson 12B3 from year 1 and lesson 12P6 from year 3. These provide the spectrum of instructional strategies and classroom patterns observed. The lesson overview graphs are shown in Figure 4.4 and Figure 4.5. The graphs were analysed and the following instructional strategies and characteristic features of her lessons were identified: monologue, dialogue, group work, the management of time, the language of instruction and lesson planning. These will now be discussed in turn, after which an overview of the changes over time will be done.

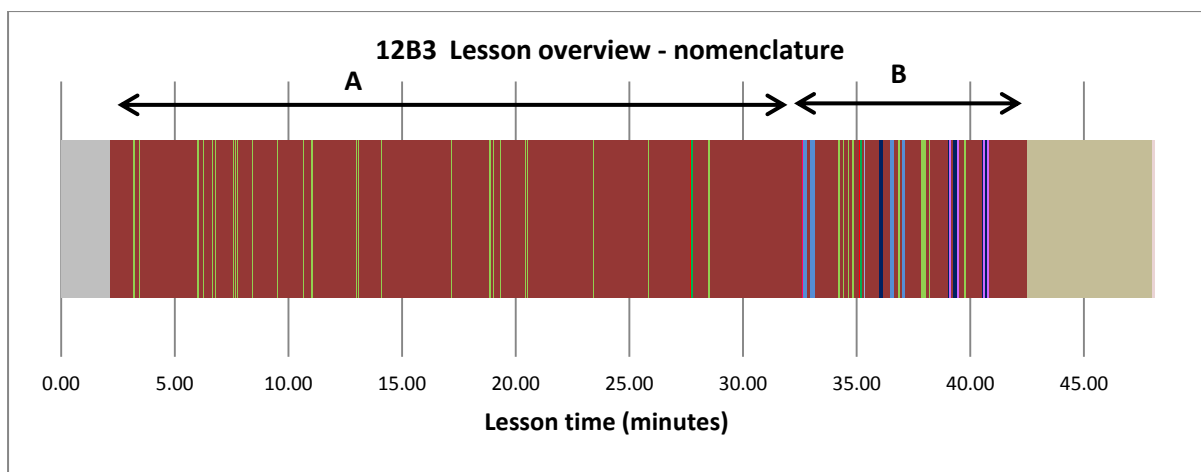


Figure 4.4 Overview graph of lesson 12B3

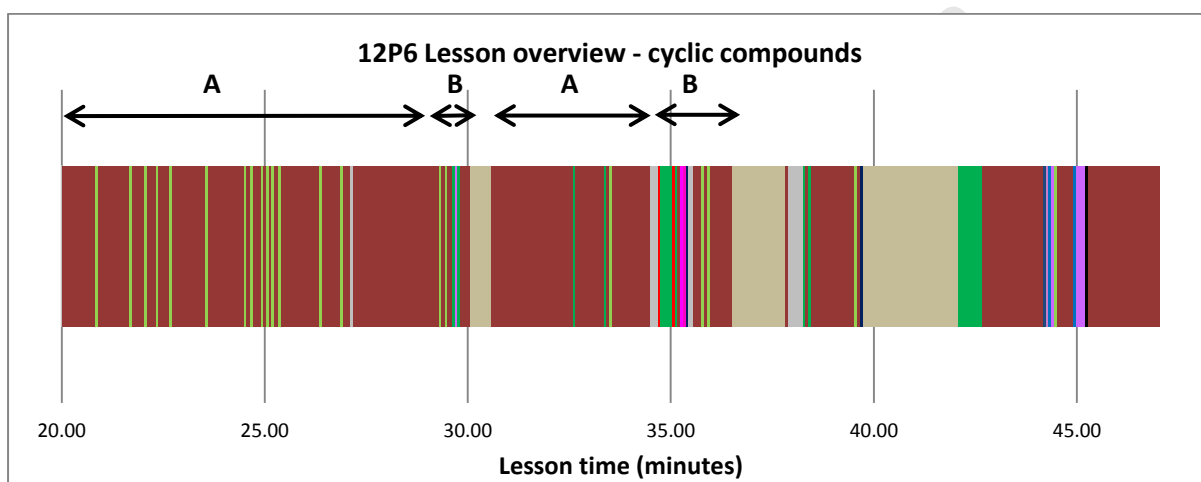


Figure 4.5 Overview graph of lesson 12P6

Key:

Teacher talking from the front of the room/at whiteboard	TT
Teacher asking a question to and individual learner	TQI
Teacher asking a focus question to the whole class	TQ
Teacher answering a question from an individual learner	TAQ
Learners responding in unison as a class	LGR
Learners responding as a group but not in unison	LT
Individual learner responding to a question from the teacher	LAQ
Individual learner asking a question	LQ
Learners arrive/leave/nothing happens	X
Learners copy homework/boardwork	LCH
Learners work in small groups	LGW
Learners work in small groups with teacher circulating amongst the groups	LTGW
Bell rings	
Monologue, teacher addressing the learners	A
Dialogue between teacher and learners	B

Monologue

Almost all Nomsa's lessons started off with an introduction of the topic for the day. She did this from the front of the classroom and remained teaching from there for the duration of the lesson, except on occasions where she walked around during group work sessions. The first section of her lessons was characterised by her talking, telling the learners the new 'facts' for the day. This is indicated by the brown areas (coded TT) in the figures and accounts for most of the lesson time. The learners were generally attentive, they did not talk amongst each other while she was talking and they responded in chorus when they were prompted to do so. The bright green vertical lines (coded as LGR) in the figures indicate group responses by the learners and are frequent through most of the lesson. Learners generally did not take their own notes, nor did they write in their books while Nomsa spoke. She said she preferred it this way as she believes that the learners cannot write things down and listen at the same time. She makes the following comment in an interview: *'I don't want them to write, you know, in other classes they just write, write, but here, here they must listen'* (Interview 7). She gives them time during or at the end of the lesson to copy the boardwork. This can be seen in Figure 4.4 at 45 minutes and in Figure 4.5 at 31, 37 and 41 minutes.

The main characteristic of this section of each lesson is what I consider a monologue and indicated by 'A' on the figures. Her teaching approach is teacher-centred where she is the one talking and the learners are listening. The new information for the day is being transferred. This teaching approach was characteristic of all Nomsa's lessons across the three years.

Dialogue

In almost all of her lessons the monologue was followed by a dialogue, indicated by 'B' on the figure, between her and her learners. Once she had told them the new 'facts' they had the opportunity to ask questions. The changeover is sometimes indicated quite clearly by her body language, for example by her putting the whiteboard markers down, or stepping away from the board, or keeping quiet for a while and taking a sip of water from her water bottle. Through these cues the learners knew that they could ask questions which Nomsa would answer. The dialogue was often led by the same learners, but generally not dominated by any one or two individuals. The learners usually put up their hands to indicate that they wanted to ask a question. They would then wait until they were called upon, and then they would ask. Questions were always answered and despite the answer being addressed to an individual learner, it was audible and meant for the whole class.

The number of learner questions varied between 0 and 15 per lesson with an average of about 4 - 5 questions per lesson. The dark blue lines in the figures (coded as LQ) indicate a question asked by an individual learner, for example just before 40 minutes in Figure 4.4 and around 45 minutes in Figure 4.5. The questions were generally asked to clarify what was just explained for example:

Teacher: What is the question my child?

Learner: Pardon me miss, where did the dimethyl come from? (Lesson 12P6)

On occasion learners would ask about examples that they made up themselves, like the learner described in the beginning of this chapter (Figure 4.3), but generally the questions dealt with what was covered in that lesson. I did not observe any questioning based on content or experiences outside of the syllabus.

Group work

The monologue-dialogue pattern would often repeat, especially when a new subtopic was done. For example in lesson 12P6 in year 3 there is a repeat when cycloalkenes are taught (31-37 minutes in Figure 4.5). After the monologue-dialogue phases the learners then had the opportunity to copy the work from the board for example at the end of the lesson in Figure 4.4. If there was time, and if this was part of the plan for the lesson, they would then go into a group work session where the learners were expected to work on worksheets in class. The learners usually organised themselves into groups of two to five learners, without any specific direction from the teacher. It was clear that they knew what to do and what was expected. The classroom was fitted with long tables and bar-type stools for the learners. This allowed learners to easily form groups with those next to, behind or in front of them. Nomsa valued the group work sessions as can be seen by the following comments during an interview:

‘So if they are sitting together here, you know, while I am busy teaching and then after that, when I give them time for questions, or whatever, then the one is able to explain to the other, ‘Okay, you know, the teacher means this, the teacher means that’, you know, or if I am doing a calculation on the board and then, you will find that there are learners who do not understand. You know, so by grouping them together, like you make sure that, at least, at the end of the lesson, at least, your outcome is reached somewhere, somehow at the end of the day.’ (Interview 16)

The general pattern was therefore monologue, then dialogue followed by either a repeat of this sequence, a group work session, or the end of a lesson. On occasion the group work session was replaced with a session where individual learners were asked to write the

worksheet answers on the board. The rest of the class would then mark their work. This would give the teacher an indication of which sections were not well understood.

Managing time

As noted earlier, very few lessons started on time. The first lesson of the day usually ran late because the learners arrived late for school. During the day the learners moved between the venues and as a result lessons invariably started 5-10 minutes late. Despite this, Nomsa managed to engage with the learners for the allocated 40-45 minutes per day. She did this by teaching until after the bell had rung at the end of the lesson. The school has a 10-day timetable with fixed lesson times and a siren to indicate the beginning and end of a lesson. The school secretary operates the siren. A copy of Nomsa's timetable can be found in Appendix G. The general routine at the school was so that the siren indicated the start and end of a lesson, but the actual teaching ran slightly out of synchronisation with the bell times. Despite this, the day ran smoothly and all the lessons took place.

Language of instruction

The official language of instruction at the school is English and the learners write all their tests and examinations in English. However, Nomsa taught only about 60% of the lesson in English with the remainder being taught in the learners' home language, isiXhosa, in a typical code-mixing style (Mesthrie, 2002; Setati et al., 2002). The learners also asked all their questions in isiXhosa. When prompted about teaching in isiXhosa, she said she '*had always taught like this*', in her previous school and this one and the reason she has for doing so is to help the learners understand better because '*the learners are not good with English, they struggle*' (Interview 11). An example of the language used is included in Appendix F.

Planning

Nomsa did limited written planning. In the first two years none of her own planning documents were available, but despite the lack of written evidence of her planning, she knew what she wanted to teach. She was able to tell me at any point on a macro-level what she would be teaching in the coming weeks as can be seen from the following excerpt from an interview:

'...and the next week we will do combustion, and then substitution, addition and elimination, you know, the reactions.' (Interview 5)

The same was observed in other sections, for example in the lesson described earlier she writes the examples she wanted to discuss on the board before the lesson starts. No notes were used and new examples were added when needed while she was teaching. It seemed like she knew the content and had a clear idea of what she wanted to cover in that lesson.

Her planning practices shifted in year 3 when she started to also plan on a micro-level. Figure 4.6 shows a sample of her planning in this year. An outline of what she wanted to do each day was written down and the exercise for the first lesson was included in quite a lot of detail. She was going to use this as a class exercise, but changed her mind and converted it into the first short test. She asked me to help her typeset the test and while we were working on the document, she made some additions to the questions. A copy of this test can be seen in Figure 4.7.

THURS - Alkanes, Alkenes, Alkynes, Halo alkane			
FRI - Alcohols, Aldehydes, Ketones			
SAT - Carboxylic acids, Esters			
~~Exercise with the class~~ The molecular formula of 3 hydrocarbons are given below: A: CH_4 , B: C_2H_4 , C: C_3H_4			
① Draw the structural formula of each molecule			
② Write down the IUPAC name of each molecule			
③ ~~Write~~ To which homologous series do each molecule belong to			
④ ~~Write down the~~ ~~What is the~~ functional group of C			
STRAIGHT CHAINS			
① Simple chain STRUCTURE	ALKANE butane C_4H_{10}	ALKENE but-2-ene C_4H_8	ALKE ALKYNE but-1-yne C_4H_6
② with side chain (1 or 2)	2-methyl pentane	3-methyl pent-2-ene	2-methyl pent-1-yne
③ RINGS • simple • side chain or bonds •	cyclohexane 1,3 dimethyl cyclo pentane		

Figure 4.6 Sample of Nomsa's planning

Organic chemistry short test 1		
NAME:	Class:	
<u>Question 1:</u>		
The molecular formulae for 3 hydrocarbons are given below:		
A: CH_4	B: C_2H_6	C: C_3H_4
1.1 Draw the structural formula of A. (1) 1.2 Draw the structural formula of B. (1) 1.3 Write down the general formula for C. (1) 1.4 To which homologous series does B belong? (1) 1.5 Write down the functional group of C. (1)		
TOTAL: /5		

Figure 4.7 Short test 1

Topic-specific instructional strategies

As discussed above, most of the strategies that were identified in Nomsa's practice were general instructional strategies. However, she did make use of a topic-specific instructional strategy that is often used in the nomenclature section. She started off with a specific example, to show the learners how the new rule is applied. This would then be followed by a series of further examples to reinforce the correct application of the rule. The examples used were explained by the teacher while drawing on the board, with the learners following what she was doing, and copying the correct name next to the structure in their workbooks.

Change over time

Over the three years, although her instructional strategies remained very similar, some changes were noted in her practice. Her planning shifted from macro-planning to micro-planning as shown above. In addition, her boardwork suggested that her thinking became much more structured, deciding ahead of the lesson what needed to be covered and in which order. This was particularly evident in her teaching in year 3, for example the section on different types of reactions was completed in two lessons in year 1, with very few examples provided during the teaching. The learners were given all the new information in one sitting, with all the exercises at the end. The same section in year 3 was spread out over four lessons. Each day she would discuss the new reaction type and then give the learners some exercises to do in class. This would then allow for practice and question time in between each new piece of information. In year 3 she diversified further by using one example to explain the new reaction type and then for subsequent examples the learners had to try it out first before the answers were given. A sample of her boardwork from year 3 is provided in Figure 4.8 to show the reaction at the top and the examples further down. Here the dehydrohalogenation reaction was used to explain an elimination reaction. The learners then had to apply what they had learned in the first example to the following two before these were discussed. This signals a departure from the teaching strategy used in year 1 where all the examples were discussed with very little participation from the learners.

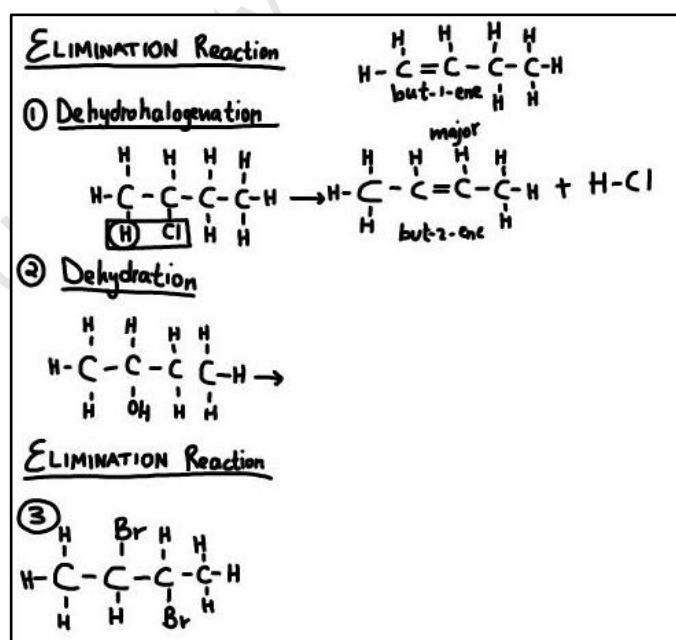


Figure 4.8 A sample of her boardwork from lesson 12Q19

4.2.2 Knowledge of the science curriculum

Curricular saliency

The Physical Sciences curriculum for South African teachers (Department of Education, 2003) is quite closely specified in the National Curriculum Statement (NCS) including specific content that needs to be covered in each grade (Department of Education, 2006). Appendix H shows the organic chemistry section from the NCS Content Document (Department of Education, 2006). In addition to the curriculum document, examination guidelines are also provided annually. These give further specifications, as can be seen in Appendix I. Not all the sections from the NCS are examinable, for example in year 3 dienes, amines, amides, arenes and macromolecules were not examinable.

When Nomsa was asked how she knows 'what to teach and what not to teach' she seemed almost a bit puzzled by the question and simply stated '*The WCED [Western Cape Education Department] is the one who decides what to teach ...*' (Interview 16)

When she was then asked to elaborate on how she uses the curriculum documents, she said the following:

'I've got exam guidelines, which tell me exactly where to focus when I'm teaching that particular, you know, topic. ... and the work schedule that has been provided, you know, by the WCED. ... I'm guided by the weeks that we are given to do that certain topic. Then I try to fit everything in there and then, you know and then like to, for me to know that the learners have grasped, knew the things, then I try to give them as many activities as I can. You know, like that is what I do in Saturday classes to expose them to different kinds of questions. Then I know that, at least, what we have done, even though I had to follow the pacesetter, because at the end, we are writing common exam, you know, so if I don't finish, then it will decide, so I rush according to the weeks that we have, but I try to expose them in the afternoon classes.' (Interview 16)

At the end of the data collection period, Nomsa had been teaching for more than 10 years. Her experience in a school such as Themba High showed through in the above interview extract. Despite the pressure from the Education Department and her school principal to complete the syllabus, she did not just move to the next topic, but did her best to ensure that all the learners were on board before moving on. She said: '*I just cannot move if they really don't understand. Then you know, we have to kind of stay there up until at least you feel that, okay, you can move on to something else*' (Interview 16). Her dedication to her learners ensured that she completed the syllabus even if it meant that additional classes needed to take place in the holidays or on the weekends.

From her comments in the interview, the tension between completing the syllabus and making sure that all the learners understand was clear. Managing this tension is what Geddis et al. (1993) included as part of curriculum saliency. In addition to managing this tension, the teacher needs to know where the topic fits into the bigger picture and what the core content is. Nomsa, being aware of the pressures of the final Grade 12 examination, used her knowledge of what is required in Grade 10-12 to shape what was taught in earlier grades. In the following excerpt she explained how the Grade 8 and 9 syllabus was adapted; cutting out what was not required in Grade 10 and only teaching the core content:

‘Then I look at Grade 10 now, what is being done in Grade 10 and what is important for Physical Sciences in Grade 10, you know, then I bring it into Grade 8 in their level. So I know, okay, here, just if you are talking about matter and material, just do the Periodic Table. You know, do the balancing of the chemical reactions, like writing the wording and even writing the chemical formula, you know, then because I have to break so that I know when they are in Grade 9, then they add and then when they are in Grade 10, there is no problem. So that is what I do. I look at what is being done in Grade 10.’ (Interview 16)

In examining her teaching schedule for organic chemistry there was much less flexibility in what she did compared to what she explained in this interview. Table 4.2 summarises the order in which Nomsa taught the organic chemistry sub-topics over the three year period. If this is compared to the sub-topics specified by the syllabus in Table 4.1, it will be noted that no change to the prescribed order was made. The syllabus prescribed terminology, then nomenclature, then physical properties and then reactions and she taught it in exactly the same order for all three years.

Nomsa did not go into a lot of depth and did not cover any content that was outside the syllabus, for example when the section on the reactions of organic molecules was done, only two to six carbon structures were ever used in examples like in Figure 4.8. No ring or branched structures were discussed. When Nomsa was probed about the teaching of additional content outside of the syllabus, her response was: *‘I don’t have time for that, nè¹¹?’* The constraining influence of a prescribed syllabus and a high stakes examination at the end of Grade 12 can be seen in the decisions Nomsa made around what to include and what not to include.

¹¹ ‘nè’ means ‘not so’.

Table 4.1 Content for organic chemistry from the NCS Content Document (Department of Basic Education, 2006)

Organic molecules (2 weeks):

- Organic molecular structures: functional groups, saturated and unsaturated structures, isomers;
- Systematic naming [nomenclature] and formulae,
- Structure-physical property relationships;
- Substitution, addition and elimination reactions.

Table 4.2 Summary of lessons taught on organic chemistry

Year 1	Year 2	Year 3
12B1: Terminology; Nomenclature (alkanes, alkenes, alkynes)	12G1: Introduction; Terminology	12P1: Terminology & Functional groups; Nomenclature (alkanes, alkenes, alkynes)
12B2: Nomenclature (branched hydrocarbons)	12G2: Nomenclature (alkanes, alkenes, alkynes)	12P2: Nomenclature (branched hydrocarbons)
12B3: Nomenclature (branched hydrocarbons)	12G3: Nomenclature (halogens, alcohols)	12P3: Nomenclature (branched hydrocarbons)
12B4: Nomenclature (cyclic hydrocarbons & halogens)	12G4: Worksheet (Nomenclature)	12P4: Short test 1 (Nomenclature); Worksheet (Nomenclature)
12B5: Nomenclature (alcohols)	12G5: Nomenclature (carboxylic acids, esters)	12P5: Going through test and homework answers
12B6: Terminology (functional groups & isomers); Nomenclature	12G6: Informal test: Nomenclature	12P6: Nomenclature (cyclic compounds)
12B7: Worksheet (Nomenclature)	12G7: Physical properties (2 hour lesson)	12P7: Nomenclature (halogens and alcohols)
12B8: Checking of answers to the worksheet	12G8: Physical properties	12P8: Short test 2 (Nomenclature); check answers
12B9: Reactions: Combustion & Substitution	12G9: Reactions: Combustion	12P9: Nomenclature (Carboxylic acids & Esters)
12B10: Reactions: Substitution & Addition	12G10: Reactions: Substitution, elimination & addition	12P10: Worksheet (Nomenclature)
12B11 Reactions: Addition	12G11: Test: Organic Chemistry	12P11: Nomenclature (Aldehydes & Ketones)
12B12: Worksheet (Reactions)	12G12: Worksheet (Organic chemistry)	12P12: Worksheet (Nomenclature)
12B13: Worksheet (Organic Chemistry)	12G13: Worksheet (Organic chemistry)	12P13: Structure-physical property relationships
12B14: Reactions: Elimination; Worksheet (Organic Chemistry)	12G14: Nomenclature (Aldehydes and Ketones)	12P14: Structure-physical property relationships
12B15: Test: Organic Chemistry		12P15: Worksheet (structure-physical property relationships)
		12P16: Reactions: Combustion
		12P17: Reactions: Substitution
		12P18: Reactions: Addition
		12P19: Reactions: Elimination
		12P20: Test (Organic Chemistry)

Knowledge of curriculum materials

Themba High, like many schools in the area, does not have a library, nor does the science department have a collection of curriculum resources or university textbooks. Nomsa, however, keeps a collection of school textbooks in her classroom which she mainly used as a source for exercises. Each year she made use of a different set of notes or PowerPoint™ slides. Early in year 1 she attended a training workshop on organic chemistry which was organised by the Provincial Education Department. The notes and exercises from this workshop were used in her teaching in year 1. In year 2 the Education District office arranged for a talk on the teaching of organic chemistry and also supplied all their schools with a set of PowerPoint™ slides. Nomsa used these notes, worksheets and slides in her teaching in year 2. In year 3, one of the universities arranged an organic chemistry short course. Nomsa signed up, but was unable to attend because she had to do the term 1 reports at her school. She got hold of the slides that were used at the course and used some of these in her teaching in year 3.

It can be noted that different curriculum materials were used each year, and that the nature of these depended on what was provided by outside sources shortly before teaching the section. She did not show evidence of making her own choices around the resources that she most liked using or that which she thought were most suitable for her learners. She also did not combine pieces from different resources. Organic chemistry in the NCS curriculum is a much larger section than what it used to be in the previous syllabus (before 2008). The National and Provincial Education Departments have put substantial emphasis on teacher training in this topic and provided additional learning support materials as can be seen by the description above.

The content she taught was strongly guided by the curriculum materials to which she had access. This can be illustrated by examining an introductory lesson from each year - 12B1, 12G1 and 12P1. In lesson 12B1 (year 1), no slides were used and a general context for learning about organic chemistry was not given. The section was introduced by classifying compounds into either organic or inorganic and then proceeding straight to the naming of organic compounds. In lesson 12G1 (year 2) a set of PowerPoint™ slides were used to guide her to talk about why organic chemistry is important and why we need to know about it, before going into the terminology and nomenclature. In 12P1 (year 3) a different set of slides were used. These guided her into discussing the element carbon and its properties as an introduction and did not include any contextual information like in year 2.

The importance of the topic relative to the curriculum

Organic chemistry accounts for a third (50 out of 150 marks) of the Grade 12 final chemistry examination as per Appendix J. This is the largest chemistry section and the most time is allocated for teaching it. It is also an important section as it is examined in a high stakes Grade 12 national examination where learner, teacher and school performance is assessed.

Conceptually it is not the most challenging section in Grade 12 since the content at school level does not include conceptually demanding topics such as reaction mechanisms or stereochemistry. It does however require a good understanding of prior concepts, like chemical bonding and intermolecular forces, and an application of this knowledge to new situations.

4.2.3 Use of assessment strategies

Two broad assessment categories, formal assessment and informal assessment, were identified in Nomsa's classroom practice. A formal examination took place in June every year, as per the requirement of the Provincial Education Department. A formal test was also required per term. One formal organic chemistry test was written each year which counted as the formal test for the term (see lessons 12B15, 12G11 and 12P20 in Appendix A). The formal tests were set by Nomsa, who generally used questions from the previous Grade 12 national examinations. The June examination was set by the District Office and written by the schools in the area, all on the same day. An example from the year 1 district examination is shown in Appendix L. Organic chemistry content made up a third of this examination. Both formal assessments were marked by Nomsa soon after they were written, but the answers were not discussed in class. The learners received their test and examination scripts back for filing, but these were not used to inform further teaching. For example, in year 3 the learners received the May test on organic chemistry back in July together with their June examination scripts (Field notes 26 July).

Informal assessment practices consisted of informal questioning in class, worksheets and short tests.

Questioning practices

Two types of questioning were identified in Nomsa's classroom, one type was used to provide her with feedback on the progress of her learners, whether they grasped what had been discussed, and the other was more a rhetorical type question which I have considered

to be part of her teaching style. In this latter case, learners generally answered 'yes' or 'no', or said the words with the teacher. For example, in the excerpt below, the learners answer 'yes miss':

Teacher: Can we all see it? Can we all see how it is worked out OK, because that one is easy? Can you see how easy that one is, we just name right away ...OK?
Learners: Yes miss.
Teacher: Your carbon...the carbon with the double bond is always number one isn't it?
Learners: Yes. (Lesson 12P6)

These learner responses are done in chorus and, as discussed under instructional strategies, are characteristic of her teaching. These were coded as LGR in Figure 4.4 and Figure 4.5. Generally the whole class would speak together, but on occasion where the learners did not know what to say, far fewer learners responded. For me as an observer it gave the impression that the learners were not sure about what was discussed. In response to specific situations like this Nomsa informally commented to me that she did not think that the learners were grasping the content. She used the first part of the next lesson to repeat the explanations to the class. Here she used the learner responses to gauge whether they understood the work and to guide her decisions on what to teach in the next lesson.

Other examples of informal questioning included more content-focused questions where she wanted to know if the learner knew the answer to a specific question. These were coded as TQ in Figure 4.4 and Figure 4.5. Here learners couldn't answer 'yes' or 'no', but needed to supply correct information. The level of questioning was basic recall and she used it to confirm whether the learners knew the basic answers. An example of this type of questioning can be seen below:

Teacher: ... If this was a long chain that has four carbons, and it's an alkane, what would you name it?
Learners: It's butane.
Teacher: What would you name it? It's butane, isn't it? But now; because it's a closed structure; we still keep the butane name right, but because it's closed, then the first part of the name becomes, what will it be?
Learners: Cyclo. (Lesson 12P6)

Where the learners also asked questions, these were generally for clarification of something that was explained. Learner questions were always answered, and generally the answers repeated the facts that were stated earlier. On a number of occasions the learners' questions highlighted something that they didn't understand, or did not grasp the first time. Nomsa would then explain the content again to the whole class. The learners very seldom, if at all,

asked questions that challenged what was said, or which were beyond the scope of the topic under discussion, nor did Nomsa push the boundaries of their thinking around the content that they are covering in class. They also very seldom corrected mistakes made on the board. This lack of error checking from the side of the learners is quite common in township schools in South Africa (Clark & Linder, 2006)

Nomsa encouraged her learners to ask questions, for example: *'You have to ask questions because out of those questions that is how you understand better'* (Lesson 12Q18). She used the questions to give her a general sense of whether the learners were following her, but the cognitive level of questioning limited their use to probe for deep understanding.

Homework and classwork practices

Another assessment strategy that was used was that of giving the learners exercises or worksheets to do, either at home or in class. As elaborated upon earlier, working on these exercises in small groups in class is an activity that was done often, and Nomsa used this to determine whether the learners were coping with the work. Nomsa chose the exercises herself, and these were generally obtained from previous examination question papers and study guides as she explained in an interview in year 3:

'I use past exam question papers and like, you know, other study guides that I have, like Answer Series where I, you know, I just extract what is important for that certain topic. You know, then that is how, that is how I do it.' (Interview 16)

An example of such an exercise is given in Figure 4.9. This one, obtained from the notes which the Education Department supplied in 2011, is on aldehydes and was given for homework after the topic was discussed in class. It contains basic recall questions to test whether the learners have grasped the basic ideas.

Activity 4.2.12

1. Write down the general formula for an aldehyde.
2. Write down the structural formula for the functional group of the aldehydes.
3. Write down the condensed structural formula for the functional group of the aldehydes.
4. Explain why the -CHO group in an aldehyde can only occur at the ends of the aldehyde molecule.
5. Consider the following organic compounds represented by the letters A and B:
A: butanal B: 2-bromo-4,4-dimethyloctanal
6. Write down the molecular formula for A and B respectively.
7. Write down all the isomers of A using structural formulae.
8. Give the IUPAC name of each isomer in 7.

Figure 4.9 An example of an exercise given for homework in year 3

Homework was not given out daily, nor was it checked regularly, but there was the expectation that whatever exercises were handed out should be done. On one occasion, Nomsa decided unannounced to check if the learners' work was done, and she was very upset with the learners who did not do their homework. They were sent outside to finish it first before they were allowed into the classroom for that lesson. She said in an informal interview later (Interview 9) that the learners generally did their homework, but she saw that some learners did not do their work on that particular day.

Nomsa often dedicated parts of a lesson, or whole lessons, to working on exercises as was discussed under topic-specific instructional strategies on page 41. The learners worked together on the given problems in small groups while the teacher walked around in the classroom to answer any questions. These group work sessions were used as an informal assessment strategy to find out whether the learners had grasped the concepts and to inform her of which areas she needed to spend more time on.

Change over time: short tests

In the third year Nomsa's assessment practices changed slightly. In this year there were 20 organic chemistry lessons compared to the 14 or 15 in the previous two years. This can be ascribed to the change in assessment practices when she taught nomenclature. In year 2 in an interview after the June examination (Interview 10), Nomsa expressed concern about a number of learners performing far below average in the examination. She wanted to know what could be done to help them. We discussed approaches to get quicker feedback cycles to identify learners falling behind. In response to this she introduced short informal class tests every few days in year 3. She asked me to help her do the tests on the computer as her skill of drawing organic molecules on computer was limited. She would give me the handwritten test, and I would type and draw it for her. On occasion I would just give her the structures and she would type the test herself. An example of the planned test was discussed in the section on planning on page 39. Samples of the typed tests are shown in Figure 4.10. The purpose of the tests was to assess whether the learners understood the content that was taught in the preceding lessons. The tests were meant to take 5 – 10 minutes and feedback would be given immediately.

Upon reflecting on the use of these tests, Nomsa said that she did the tests to make sure that everyone in the class grasped the new concepts. She was aware that learners could answer the worksheets correctly by copying from a friend and still not know the content as can be seen from her comments during Interview 16:

'You give them tests ... like short tests, you know, because you know what you want, okay. You know that you want you want to know if they understand that certain concept. So you just give them just a short test to test that concept, because sometimes they work in groups, 'nè', sometimes there are learners there in that group who don't know anything.'

Allowing for this, Nomsa believed that the short tests she instituted at the beginning of the lessons had greater value and continued to use them in other sections of the syllabus:

Nomsa: Like I'm doing, I was doing machines, so I've used them. So I know, at least.

René: And is it working?

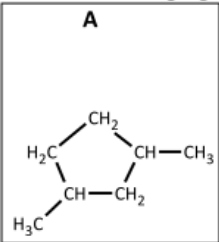
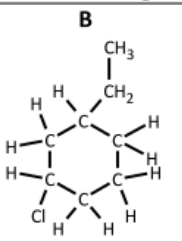
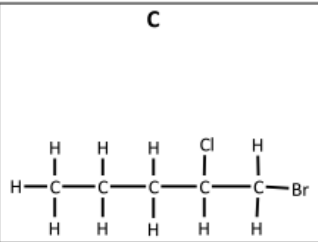
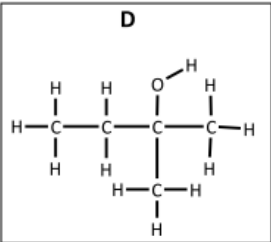
Nomsa: It's working, it really is working.

René: What do the learners say?

Nomsa: They like it ... they are very much serious now ... because I tell them that I am just testing that concept that we did yesterday ... they mark it themselves, now I don't mark it myself anymore. (Interview 16)

The tests were done for the nomenclature section, but later in the year for other topics as well, as she explained in the above interview.

Introducing the tests was not without problems. The learners were not familiar with this practice and initially took very long, a whole lesson, to complete the five minute test. This improved as they got used to the tests. Marking the tests was also very time-consuming, resulting in Nomsa changing the practice so that the learners marked it themselves. The tests were usually written in the beginning of the lesson and the answers discussed immediately thereafter. The response from the class would then determine whether more time was needed on the previous day's work, or whether she could move on. On occasion, usually at the end of a couple of subtopics, she would do a slightly longer test as shown in Figure 4.10 on the next page.

ORGANIC CHEMISTRY SHORT TEST 4	
NAME:	CLASS:
1. The following organic molecules are given:	
A 	B 
C 	
D 	
Answer the following questions.	
a. To which homologous series does compound A, B and C belong?	
A:	
B:	
C:	(3)
b. Write down the IUPAC name for each of the following compounds:	
B:	
C:	
D:	(2x3=6)
c. Write down the structural formula for the functional group of compound D.	

(1)	
d. Which type of alcohol is compound D?	

(1)	
2. Write down the structural formula for each of the following compounds:	
a. 1,3-dimethylcyclobutane (2)	c. 2,2-dimethylpentan-3-ol (2)
b. 3-ethyl-5-methylcyclohexene (2)	d. 2-bromo-4-chloro-3,3-dimethylhexane (3)
TOTAL: /20	

Figure 4.10 An examples of a short test used in year 3

4.2.4 Knowledge of students' understanding in science

Learning difficulties

Nomsa was aware that there were certain sections within organic chemistry where her learners would struggle more. She would typically spend more time on such sections. For example, in the area of combustion reactions, each year Nomsa spent one whole lesson on teaching the balancing of equations.

When Nomsa was asked when she thought her learners learn best, she acknowledged that learners learn in different ways. She identified visual, audio and verbal learners and expressed the need to engage with these learners in different ways to make learning more meaningful (Interview 16). In the interview excerpt below she mentioned that she could use pictures, videos and PowerPoint™ slides in addition to the usual talking as a learning aid for her learners.

'Like, you know, when I am teaching, 'nè', if I expose them, like in the practical work side, you know, put the videos there, they see the reactions, they see what is happening there, I think and even if like I'm presenting my lessons, if I use PowerPoint™, you know, where they see the sketches, they see the diagrams, you know, like whenever they are seeing something that I'm talking about, then I think that is when, you know, they learn best. Other than me, you know, talking, you know, trying to draw something on the board maybe, or talking to them. So sometimes you find that they don't, they really don't understand up until I put a picture, you know, then if I put a picture now in front of them, then whatever that I have said, you know, they try to match it with the picture. Then that is where the understanding comes in.' (Interview 16)

Despite what she believed *should be done*, in the teaching of organic chemistry she did not use any pictures or videos. She made use of PowerPoint™ slides, but very few of the slides included visuals. They were mostly filled with key words to guide her teaching. It therefore appeared that they were used as a teaching aid for the teacher rather than a learning aid for the learners.

Prior knowledge

Organic chemistry is mainly taught in Grade 12, with a small section done in Grade 11. It builds on a number of foundational concepts, for example the electronic properties of carbon, chemical bonding and intermolecular forces done in Grades 10 and 11. Nomsa very seldom explicitly linked what she taught at the time with what was taught in previous years, nor did she expect the learners to be able to make these links. For example, none of the

worksheets or exercises specifically prompted the learners to use concepts done in previous years. The questions posed in class also did not probe for these links.

On occasion she asked the learners whether they had heard of something that should have been covered in a previous year, for example Van der Waals forces. Where prior knowledge was mentioned, it was often with the examination in mind, and not because it was needed for understanding. In the extract from lesson 12P13 below she mentioned the need to know certain terms because the test would require it:

‘We haven’t left those homologous and other things behind. Always it needs to be something we carry with in our minds, ok? When you are given physical properties you have to go back, we will go back again, we will go name, we will go write the structural isomer, the question will say so, ok?’ (Lesson 12P13)

Motivation and interest

The very first lesson of term 2 in year 1 started with a motivational talk (Field notes 12 April). The learners had just completed their first test series and Nomsa was handing out their test answers. She was not happy with their results. She reminded them that they are in their last school year, and motivated them to work harder to achieve good results at the end of the year.

When Nomsa was asked how she saw her role as a science teacher two years later (Interview 16), she was a bit unsure about what to answer, but after thinking for a while the first thing she said was that a teacher should be a motivator:

‘... a teacher is like, is a motivator, ... a facilitator, ... you become everything, man, to these learners, you know, like you motivate, you show them the importance of whatever the teacher is doing in class, you know.’ (Interview 16)

She felt responsible for the learners in her class and believed that one must ‘*lead by example*’. She wanted to show the learners that she was prepared, she was at school every day and that she worked hard.

‘... you know, the learners look at what the teacher is doing. You can talk, talk, talk, but if you are not practising what you are saying ... so you lead by example. So if you say to them, ‘Be responsible’ and you are not responsible, then whatever you say, it will just, it will fade away somewhere, somehow ...’ (Interview 16)

As Head of Department Nomsa has the bigger picture of Physical Sciences as a subject at the school in mind. She wants more learners to choose Physical Sciences, in line with the

national focus on Mathematics and Physical Sciences as gateway subjects to tertiary education. She also wants the learners to obtain good results, as evidenced by the following quote from an interview with her:

‘... it's one of my desires that if there can be more learners who are doing Physical Sciences, not just only doing science, but who are more determined to pass and who are passing, you know, with good symbols - that is what I really want.’ (Interview 16)

It seems like Nomsa has a good understanding of what motivates her learners. She has been quite successful in motivating learners to choose Physical Sciences. The Physical Sciences Department at Themba High has grown over the years. In year 1 there were only two Grade 12 Physical Sciences classes and three Grade 10 Physical Sciences classes. This increased to five Grade 10 and three Grade 12 classes in year 3.

4.2.5 Use of explanations

Nomsa's explanations follow a largely procedural approach. The extract below is from one of the lessons dealing with structure-physical property relationships, in which she explained systematically and clearly what the learners needed to do to earn marks:

‘... every time when you are looking you are given compounds, identify the factor, identify the factor and then ... what is the physical property that is given there? Then after identifying the factor, then you give an explanation. So you have identified your factor, then because of this factor, that is why the boiling point is not the same OK? ... then you explain that, then that is when you are going to explain: ... are the intermolecular forces strong or are they weak? Then you will speak of intermolecular forces, then you are going to speak of the energy, after that, that is why the boiling point is high or the boiling point is low. The way you answer must be consistent so that you clearly look like you are going to get those marks; you cannot just say something that will not earn you marks.’ (Lesson 12Q15)

Nomsa's teaching approach is guided by the importance of getting the right answer, and the way she explained the content was consistent with this objective. Her approach is supported by the notes supplied by the Education Department during the talk in year 2. The notes (see Figure 4.11) summarise the section on physical properties in terms of key phrases that would ensure that learners obtain the relevant marks in the Grade 12 examination.

There is a remarkable similarity in the order of the key words Nomsa highlighted in her explanation above and that which was supplied by the notes handed out during the workshop (see point 1 in Figure 4.11 on the next page).

Relationships	Explanation
<i>Relationships between (melting point, boiling point, vapour pressure and viscosity) and chain length</i>	
1. The longer the chain length the higher the boiling point and the melting point	1. The longer the length of the chain the larger the surface area the stronger the intermolecular (Van der Waals) forces, the greater the energy required to separate the substance into its individual molecules, the higher the boiling point and melting point.
*2. The longer the chain length the lower the vapour pressure	2. The longer the length of the chain, the larger the surface area the stronger the intermolecular (Van der Waals) forces, the fewer the individual molecules above the surface of the substance, the lower the vapour pressure.
3. The longer the chain length the higher the viscosity	3. The longer the length of the chain, the larger the surface area the stronger the intermolecular (Van der Waals) forces, the thicker the fluid or the greater is its resistance to flow, the higher its viscosity.

Figure 4.11 Section from the notes supplied in year 2

The similar approach was found in other sections as well, where a procedural approach was used to ensure that learners arrive at the right answer. As mentioned on page 41 Nomsa explained the naming of hydrocarbons by giving the learners one example and then applying the same method to other similar examples. This is a typical topic specific strategy that is employed in the teaching of nomenclature with the explanations focused on applying the same rules to different situations.

In a further section on reactions the requirement at school level is to only be able to write down and name the reaction products, and to state the reaction conditions under which the reaction takes place. Neither the syllabus nor the final examination requires any explanation of reaction mechanisms or an understanding of why a specific reaction condition is required. The quote below was taken from a lesson on addition reactions. The reaction conditions were written down as shown in Figure 4.12. No explanation was provided and, although the learners were given sufficient time to copy the reactions, none of them asked any questions. In effect they were following their teacher's instruction to '*just write it down, end of story*'.

'Recall I said yesterday; in all the reactions we do there are reaction conditions OK? I am not going to talk about conditions because I need us to, need you to know that, know this one today, I will give you each condition OK? Of each substance and then you just write it down, end of story. So listen then, may we please look on the board, OK?' (lesson 12Q18)

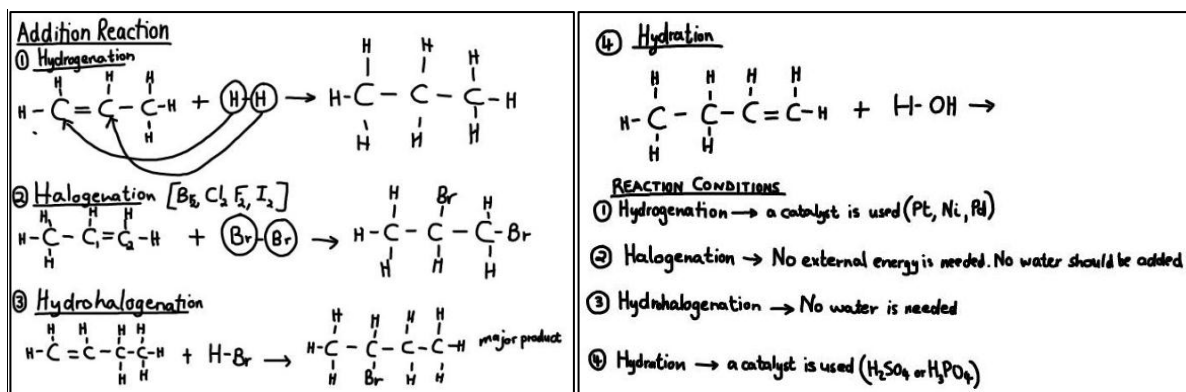


Figure 4.12 Boardwork from lesson 12Q18

The following excerpt is also from this lesson. Here Nomsa explains how to derive the products for an organic reaction. The dialogue refers to the third reaction on hydrohalogenation in Figure 4.12 where there are two different products possible.

'Listen then, because to get this product, you have used the rule, so every time you use Markovnikoff's rule, you must know that the product that you get, it is called the major product. Major. So every time you use Markovnikoff's rule, your product, you call it a major product. ... That means here in this, in this reaction, there are two products that you can get. You get the major one. How do you get the major? You get, you get it when you have used the rule. Then you get the minor, how do you get the minor? You get it when you haven't used the rule.' (Lesson 12Q18)

An alkene addition reaction like the one explained above, involves the interaction of the electrons in the double bond of the alkene. In the case of a hydrohalogenation, two products are formed at the same time, but with one of them more likely to form (the major product) due to the stability of the carbocations involved. In Nomsa's explanation Markovnikoff's rule is used as a tool to get to the right answer: '*Use the rule for the major product and don't use the rule for the minor product*'. The learners do not get a real sense of what organic reactions are about, nor do they have the correct understanding of how such rules are derived. I would contend that this again supports the notion of a procedural and not a conceptual approach, which is driven by an exam-centred curriculum.

Nomsa's explanations are generally procedural in nature and focused on *what* to do next, and not *why* it is done. In her approach science is treated as a collection of 'facts' that needs to be explained in a systematic and clear way so that the learner can remember it. The reasons why things are the way they are and how these 'facts' have been discovered through the processes of science are not discussed. Again I would argue that this approach

is strongly supported by the prescriptive syllabus and the nature of the high stakes examination she is preparing her learners to write at the end of their Grade 12 year.

4.2.6 Use of content representations

A wide variety of representations of organic molecules are known in the literature, as was mentioned in Chapter 2. In her teaching Nomsa made use of two of these representations, namely structural formulae and line drawings. Figure 4.13 shows an example of these two representations.

Her choice of representations was the same as that which is generally used in textbooks, curriculum materials and examinations, for example, Figure 4.14 shows a question from a national Grade 12 Physical Sciences examination (Department of Basic Education, 2011) . Here the structural formulae were given and the IUPAC names had to be supplied. In the last question the learners were required to draw the structural formula from the supplied name.

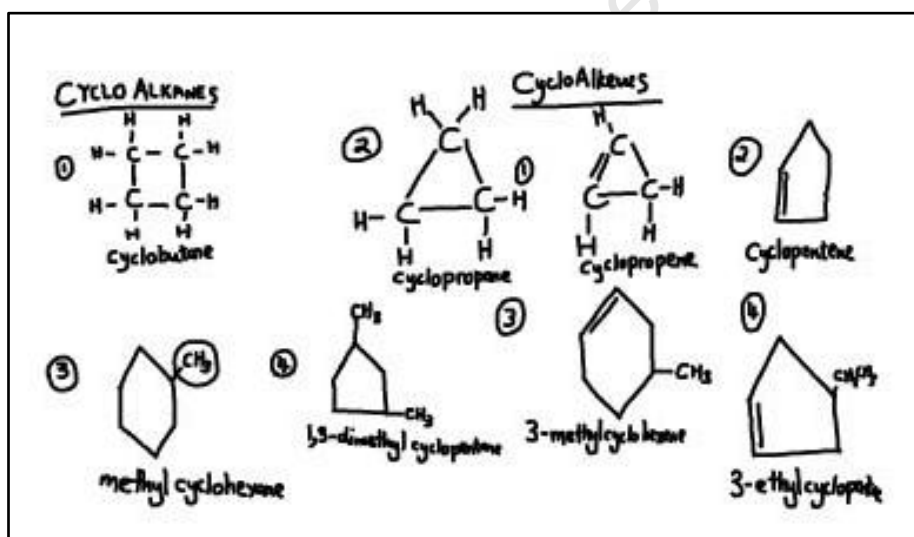
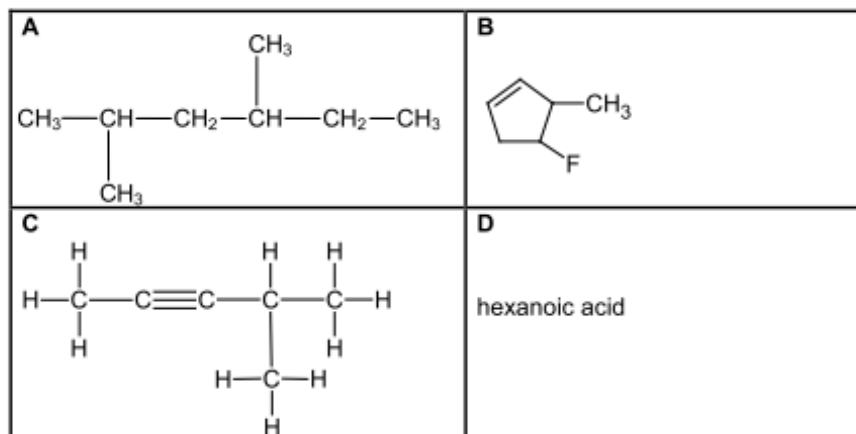


Figure 4.13 Boardwork from lesson 12P6

QUESTION 3 (Start on a new page.)

Four compounds, labelled **A**, **B**, **C** and **D**, are shown below.



Write down the:

- | | | |
|-----|--|-----|
| 3.1 | Homologous series to which compound A belongs | (1) |
| 3.2 | IUPAC name of compound A | (2) |
| 3.3 | IUPAC name of compound B | (2) |
| 3.4 | IUPAC name of compound C | (2) |
| 3.5 | Structural formula of compound D | (2) |

[9]

Figure 4.14 Sample question from a Grade 12 final examination

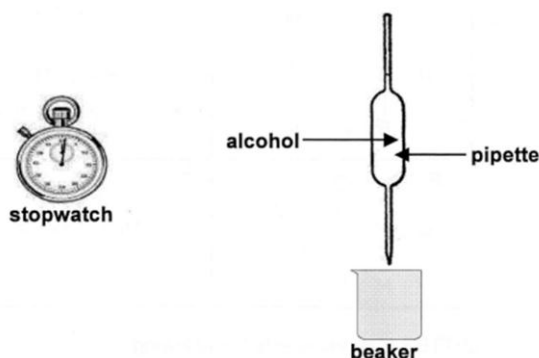
Alternative representations, like ball-and-stick models, computer-modelling programs and space-filling models, were not used in Nomsa's teaching nor in her worksheets or test papers, although she did have access to molecular modelling kits and the internet.

Johnstone (2000) further identified macroscopic, sub-microscopic and symbolic representations as discussed on page 14 in Chapter 2. Macroscopic representations include the use of actual chemicals, for example in a practical demonstration. The laboratory in which Nomsa taught had sufficient glassware and chemicals available. However, she did not do any practical work or demonstrations because she said '*there is no time*' for it (Interview 8). Practical experiments are suggested, but not prescribed by the syllabus. However, examination questions are often based on practical scenarios as illustrated in the extract from a Grade 12 examination in Figure 4.15 (Department of Basic Education, 2010).

4.3 Viscosity is a measure of a fluid's resistance to flow. Learners conduct an investigation to compare the viscosities of the first three alcohols (A - C) in the table below.

A	Methanol	B	Ethanol
C	Propan-1-ol	D	Butan-2-ol
E	2-methylpropan-2-ol		

They use the apparatus shown below.



The learners use the stopwatch to measure the time it takes a FIXED VOLUME of each of the alcohols to flow from the pipette. They record this flow time, which is an indication of the viscosity of each alcohol, as given in the table below.

	Alcohol	Flow time (s)
A	Methanol	4,0
B	Ethanol	7,9
C	Propan-1-ol	14,3

4.3.1 Formulate an investigative question for this investigation. (2)

4.3.2 Which ONE of the alcohols has the highest viscosity? Use the data in the table to give a reason for the answer. (2)

4.3.3 Refer to the intermolecular forces of the three alcohols to explain the trend in viscosities as shown in the table. (2)

4.3.4 Lubricants reduce friction. Which one of the alcohols, A, B or C, will be the best lubricant? (1)

Figure 4.15 Sample of an examination question based on a practical scenario

To prepare her learners for this type of examination question, Nomsa discussed a similar one from a previous examination. She says: *'we haven't done an experiment here, that question seven helps us to know this alkene experiment'* (lesson 12P19). Despite having the laboratory resources and someone who could set up and assist her with practical work, Nomsa did not demonstrate the experiment, nor did she show pictures, videos or equations.

Instead she described it verbally: *'in beaker A, where there is ethene, which is a double bond, it reacts with bromine, a liquid which is brown in colour, ethene will decolourise bromine, then make it colourless, which means your products now will be a haloalkane'* (lesson 12P19).

4.2.7 Content knowledge

Nomsa grew up in similar circumstances to the learners she is teaching, and attended a similar school. After school she was able to study to become a teacher. She completed her teaching diploma at a technical college. The first two years of the four year diploma course were spent on consolidating the school curriculum and the remainder on content and pedagogy training.

New content

A new Physical Sciences syllabus was introduced in 2006, resulting in the first Grade 12s writing the examination based on the new syllabus in 2008. The organic chemistry section was expanded greatly from the previous syllabus to the new one. The structure-physical property relationship section was one of the new topics. This section requires the learner to explain the observed phenomena of boiling points, melting points, vapour pressure or viscosity, using the structure and spatial orientations of the molecules.

Nomsa did not teach the physical properties section in the first year. Instead she gave the learners the exercises to do and moved on to the next section. As noted on page 46, in year 2 she attended a talk that was organised by her education district, and she asked me to explain the content to her before she had to teach it. Year 2 was therefore the first time she actually taught the section. Although she had access to school textbooks and the internet to find information on this new section, she only started teaching it after the training sessions. In year 3 she taught this for the second time and an improvement in her ability to explain the relationships was observed.

Cyclic compounds were also a new section for Nomsa, but she taught this in all three years. In year 1 however, she made some errors in naming the compounds, and at times was not 100% confident about the IUPAC name of the compound. On one occasion a learner asked her about the names of the two compounds shown in Figure 4.16. Her uncertainty related to the changed orientation of the structure for methyl cyclopentane. She was unsure as to whether the two representations depicted the same compound, and if not, how the naming of

the compound would be affected. She was unable to answer the learner and came to me after the lesson to find out what the answer was.

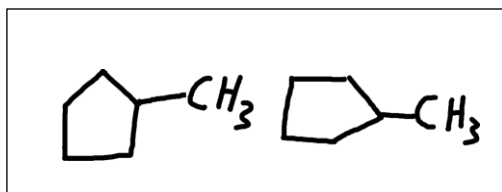


Figure 4.16 Two structures for methyl cyclopentane

From our conversation at the time (Field notes 14 April, year 1) it was clear that she had not mastered the different representations or the numbering conventions, and apart from the pentagonal structure that was not drawn accurately, she was not fully aware of the representational nature of these structural formulae. (The two structures are in fact representing the same compound.)

Change over time

Nomsa's confidence in teaching cyclic compounds increased over the three years. Figure 4.17 shows the boardwork of the same section of work in the first and the third year.

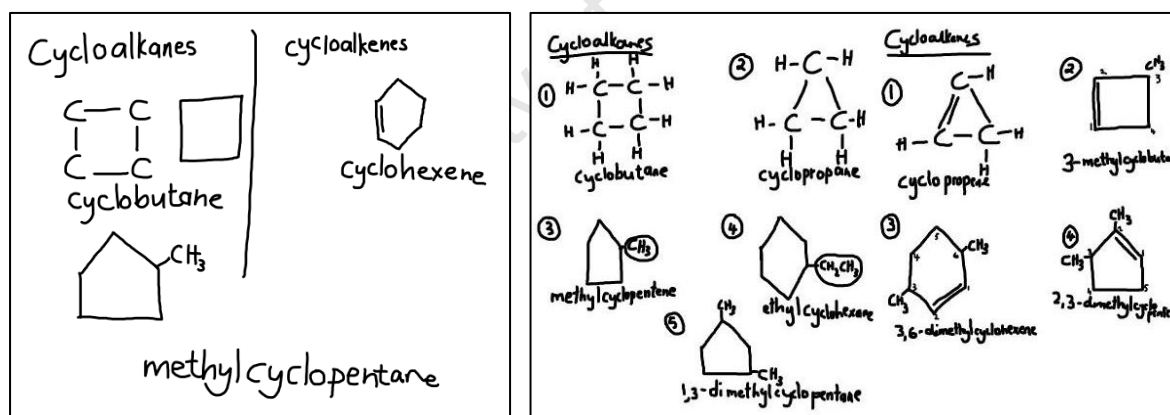


Figure 4.17 Comparison of boardwork of cyclic compounds in year 1 and 3

When the boardwork is compared, it can be noticed that many more examples were used to explain the same section of work. Furthermore, the choice of her examples was more advanced in year 3. In both years she started off with the same example (cyclobutane), but whereas she used one additional example in the first year, she used four additional progressively more advanced examples in year 3.

In year 1 Nomsa confided to me that she was not always sure of all the names in this section: *'I know that I am not comfortable with this'* (Interview 5). In year 1 she made extensive use of notes, from which she copied the structures as she taught. In year 3 she did not use any notes and was able to make up new examples 'off the cuff'. This increased comfort in handling the content is evidence of her increase in content knowledge in this section of the work. It should however be noted that she still made mistakes in naming some of the compounds, but these occurrences were far less than in year 1. One such incident was described at the beginning of Chapter 4 on page 34. A learner named 4-methyl cyclopentane incorrectly and neither Nomsa nor the learners noticed anything, or if they did notice, they did not speak up. Again, as mentioned on page 49, the lack of error checking by learners is often found in classrooms such as Nomsa's.

Although by year 3 her content knowledge had expanded, some aspects remained unchanged. Organic molecules were still seen as flat structures (for example, the pentagon shape for cyclopentane was still drawn in the shape of a 'house'). It is also notable that the extent of the content did not change, and that Nomsa in year 3 was still only teaching the content prescribed by the syllabus.

One area where significant growth was observed was during the section on combustion reactions, specifically the section on the balancing of chemical equations. When I asked Nomsa in year 1 which sections in organic chemistry she found the hardest to teach, this topic was mentioned (Interview 1). She attended a workshop shortly before having to teach combustion reactions in year 1 and made extensive use of the notes that were supplied during the workshop. Figure 4.18 shows the section on combustion reactions from the notes and Figure 4.19 shows her boardwork of this section in year 1. There are strong similarities between these - the same examples and order are used as in the notes. Before she taught the section again in year 2, she asked me to help her once more with the balancing of equations. This happened again in year 3 before she had to teach the section. The boardwork from year 3 is shown in Figure 4.20. This year she explained the balancing steps with ease, showing more than one example on the board. She was even able to point out where the learners usually go wrong and then gave them three reactions to try out in class while she walked around helping them.

C.1 COMBUSTION OF ALKANES

General: When alkanes burn in sufficient or excess O_2 , CO_2 and H_2O are always formed.

Complete combustion:

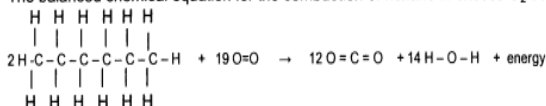
This occurs when alkanes burn in sufficient or excess O_2 .

Example:

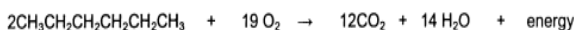
The balanced chemical equation for the combustion of hexane in excess (or sufficient) O_2 using molecular formulae is:



The balanced chemical equation for the combustion of hexane in excess O_2 using structural formulae is:

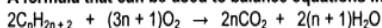


The balanced chemical equation for the combustion of hexane in excess O_2 using condensed structural formulae is:



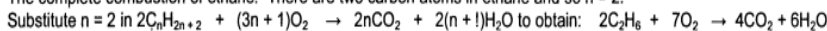
NOTES: Excess $O_2(g)$ is required and a flame e.g. from a burning splinter. Combustion is an oxidation reaction because the oxidation number of oxygen increases. The combustion reaction is exothermic i.e. energy is released or $\Delta H < 0$. The products are always CO_2 and H_2O . The reaction as a whole is a redox reaction.

A formula that can be used to balance equations involving the complete combustion of alkanes is:



Example showing how to use this formula:

The complete combustion of ethane: There are two carbon atoms in ethane and so $n = 2$.

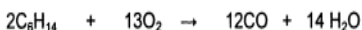


Incomplete combustion:

This occurs when alkanes burn in insufficient O_2 .

Example:

The balanced chemical equation for the combustion of hexane in insufficient O_2 using molecular formulae is:



NOTES: When $O_2(g)$ is insufficient, CO is formed instead of CO_2 . (Carbon solid can also form). CO is a poisonous gas that can damage the brain. CO combines with haemoglobin in the blood, reducing its capacity to carry oxygen and this can lead to death.

A formula that can be used to balance equations involving the incomplete combustion of alkanes is:

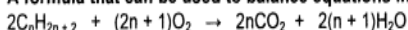


Figure 4.18 Section from the workshop notes in year 1

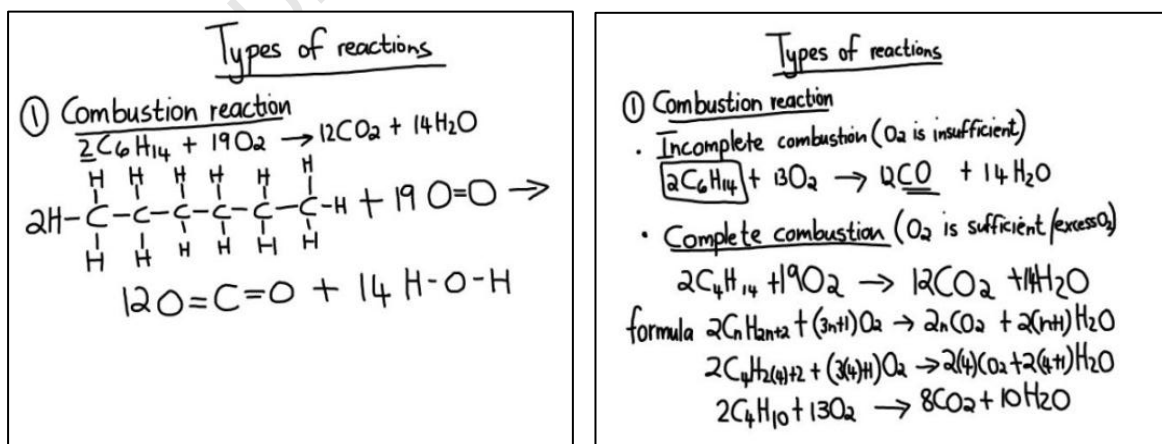


Figure 4.19 Boardwork from lesson 12B9 in year 1 on combustion reactions

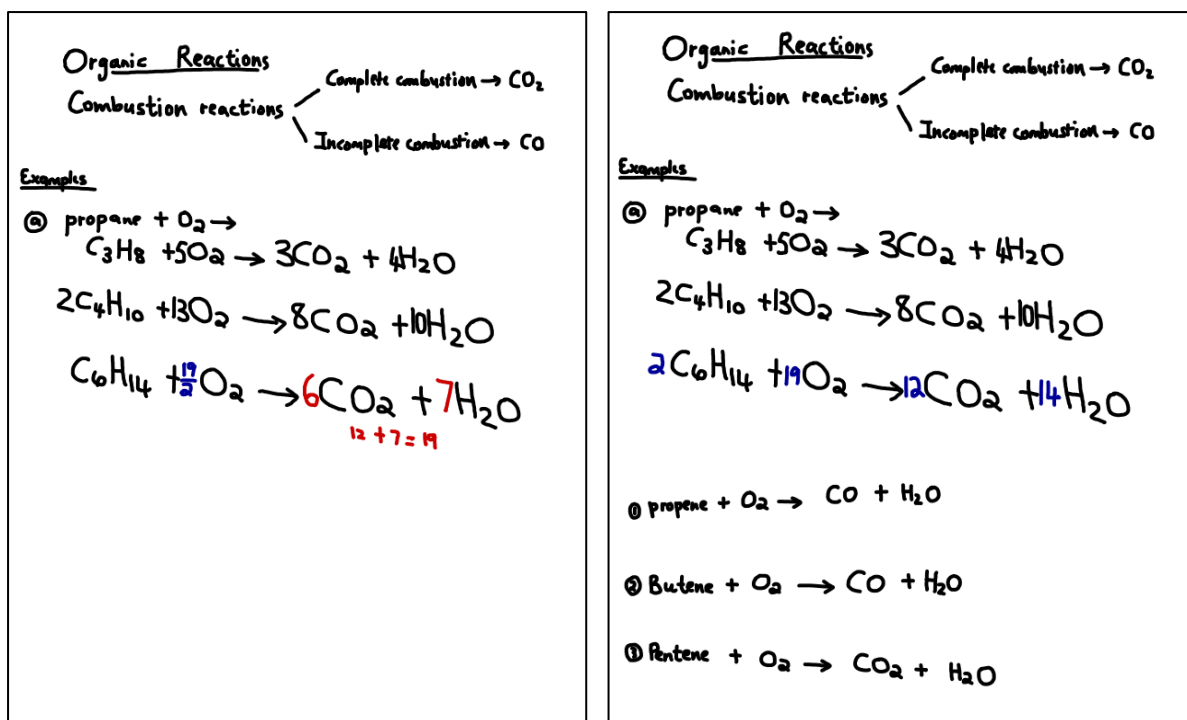


Figure 4.20 Boardwork from lesson 12Q16 in year 3 on combustion reactions

Of further interest is the choice of representations – the condensed and expanded structural formulae – which is strongly guided by the textbooks and examination requirements as discussed in the section on representations on page 58. The peculiar way of drawing carbon dioxide (O=C=O) and water (H-O-H) is evidence of the influence of the examination guidelines. Her experience as a Grade 12 examiner helped her coach the learners to write the ‘correct’ answer to earn them the marks in the final examination. She reported to me in interview 10 that learners who wrote CO₂ and H₂O in the previous Grade 12 examination did not get the marks for a balanced equation which asked for structural formulae.

4.3 Summary

This chapter described the findings from the analysis of Nomsa’s teaching over a period of three years using the manifestations of PCK as identified in Chapter 2. Nomsa’s teaching style can be described as predominantly monologue interspersed by sessions where the learners could ask questions. These questions were generally used to clarify what was discussed in class. During some lessons she made use of small group sessions where she could interact with the learners on an individual basis. Nomsa taught in English and isiXhosa because she felt this would assist her learners in understanding the content. Her lesson planning improved and her thinking became more structured over time. Nomsa was very

knowledgeable about the science curriculum and what was required for examination purposes. She has access to curriculum materials and made use of these in her teaching.

Nomsa used a limited variety of assessment strategies, but broadened her repertoire by successfully introducing short tests in year 3. Her practice did not reveal much evidence of her knowledge of learner difficulties, nor did she explicitly include learner's prior knowledge in her teaching. Her explanations follow a largely procedural approach. Although she was aware of additional content representations which could enhance the learning of organic chemistry, she chose to limit her representations to those used in school textbooks and the examination. Nomsa's content knowledge was found to be limited in some areas, especially in the first year of the study, but she had shown substantial growth in her content understanding over the three years.

The next chapter will draw from the analysis done in this chapter to answer the research questions posed in Chapter 3.

5 Discussion

This present study is centrally focused on pedagogical content knowledge and how this manifests in a typical South African Physical Sciences classroom. Chapter 4 presented the analysis of the data collected over the three year period. This chapter will now integrate what was discussed in Chapter 4 to answer each of the research questions as posed in Chapter 3:

1. How does the teacher's general pedagogical knowledge manifest during the teaching of organic chemistry?
2. How does the teacher's pedagogical content knowledge manifest during the teaching of organic chemistry?
3. How does the teacher's orientation to science teaching influence her pedagogical content knowledge?
4. How do the contextual influences affect the teacher's pedagogical content knowledge?
5. How does the teacher's pedagogical content knowledge develop over a period of three years?

5.1 Research questions 1 and 2: Manifestations of PK and PCK

Nomsa's teaching presented evidence of a rich store of pedagogical knowledge. She operated in a functional classroom where teaching took place every day. She understood the logic of the school where she was teaching and was able to operate in it. She knew what was required by the curriculum and had access to, and used, a number of resource materials in her teaching. Although her repertoire of instructional strategies was limited, she 'covered' all the necessary topics in good time. She made use of a few assessment strategies and even tried a new strategy in the hope that her learners would get better results. Furthermore, she had a good relationship with her learners and they had the freedom to ask her about the work, even outside of the normal lesson times.

Looking across the analysis presented in the previous chapter, two key findings regarding the manifestation of PK and PCK emerge from this study. The first is that not everything that is observed in the classroom is a manifestation of PCK and the second is that expert content knowledge is essential for well-developed PCK.

Not everything is PCK

Most of what was observed in the classroom were manifestations of Nomsa's general pedagogical knowledge and not necessarily her PCK. Notwithstanding their importance in practice, they are all general strategies that she would have employed in any topic and in any classroom. Looking through the lens of PCK (Gess-Newsome & Carlson, 2013; Shulman, 1986) these aspects fall under the general knowledge base for teaching which supports, as was shown in this study, an effective classroom.

PCK, however, involves the transformation of content and this study also aimed to identify aspects of her practice that reflected this transformation. Looking at her lessons from this perspective, her practice did not reveal many aspects of expert PCK. The content representations she used had limited variety and did not offer learners multiple ways of thinking about and visualising organic molecules. Questioning in class did not probe for deeper understanding and she seldom elicited learners' own opinions or prior knowledge. Her explanations generally followed a procedural approach and did not encourage learners to think deeply about the content.

Why is there such a discrepancy between her pedagogical knowledge and her PCK? Nomsa's PCK was limited in these areas by her lack of knowledge in two main areas – knowledge of students' understanding of organic chemistry, the areas where they might struggle and the reasons for their struggle; and gaps in her own understanding of the content. Her lack of subject matter knowledge played a crucial role in this regard and will be discussed in the next section.

The role of content knowledge

The importance of content knowledge has been affirmed in this study. In the areas of cyclic compounds, reactions and the physical properties, where Nomsa had limited content knowledge, she either did not teach the section at all, or had limited capacity to provide in-depth explanations. Shulman's (1986) definition of PCK as the 'amalgam of content and pedagogy' has emerged as one of the central themes in this study. The study has shown that pedagogy can ensure a functional classroom, but a deep understanding of the content is essential for truly effective teaching of science. This affirms what was found by a number of studies into the crucial role that content knowledge plays in PCK (Bishop & Denley, 1997; Hashweh, 1987; Lee, 1995; Rollnick et al., 2008). Of particular note is the study of Rollnick et al. (2008) which was conducted in South Africa. They claim that the role of subject matter

knowledge is even more important in a country where many teachers have a low content base (CDE, 2011).

Nomsa's lack of content knowledge made her rely more heavily on her knowledge of pedagogy to ensure a well-organised classroom environment. This finding corresponds to that of Lee (1995) where she found that teachers with limited subject matter knowledge often relied on strict classroom order and generally tended to avoid discussion activities in class.

The next section will now discuss possible reasons why Nomsa's PCK is shaped the way it is, and manifested in the way it did.

5.2 Research question 3: Orientation to science teaching

The second research question probes the influence of a teacher's orientation to science teaching on PCK. As seen across the analysis, Nomsa's practice was largely characterised by a didactic approach to teaching (Magnusson et al., 1999) where the focus was on the transmission of information in a clear and logical way. Her explanations, worksheets and representations presented the learners with the information that was required for the examination and provided rules to help them remember the 'facts'. Friedrichsen et al. (2009) found that, despite a push for teachers to teach in a more progressive style, many teachers in their study were still teaching from a strong didactic viewpoint.

This approach influenced how her PCK manifested in the classroom, for example she knew that there were a number of alternative representations available to teach organic chemistry, but only those that lined up with her approach to teaching were chosen. The worksheets she chose were also those which tested the learner's basic knowledge. In other words, only representations or worksheets which supported the transmission of information were used.

Nomsa sees herself as a coach and a motivator and aligned her lessons according to this view. She often encouraged learners to work harder and keep the final examination in mind. The PCK Consensus Model (Gess-Newsome & Carlson, 2013) characterises orientation to science teaching as an 'amplifier' or 'filter' between what the teacher knows about teaching and what is enacted in classroom practice. In Nomsa's case, some aspects of her view on teaching acted as filter between her 'intended' PCK and her 'enacted' PCK, preventing her from showing the full extent of her pedagogical content knowledge, yet other aspects motivated her to be at school, to be prepared for lessons and to try new practices.

In summary, it was shown here - in alignment with many other PCK studies in this area (for example, Friedrichsen et al., 2011; Gess-Newsome, 1999b; Meis-Friedrichsen & Dana,

2005) - that a teacher's orientation to teaching has an influence on what happens in the classroom. Although her orientation to science teaching has certainly influenced her teaching, the analysis suggests that the context in which she was operating had a much more significant influence on what she did in class. The next section will explore this influence of the context on the manifestation of her PCK.

5.3 Research question 4: Contextual influences on classroom practice

The third research question probes the impact of teaching in a township school in South Africa on Nomsa's PCK. The analysis suggests that the contextual influences shaped her practice in a dramatic way. The contextual influences that were identified include the background of her learners – not having grown up with books and facing the challenge of learning in a second language, the pressure that the principal and the Education Department put on her to produce good results in the final matriculation examination, and most importantly, the prescriptive nature of the syllabus coupled with a high stakes examination at the end of Grade 12. This, and the increased pressure for learners to gain access to tertiary institutions, played the biggest role.

Nomsa only taught the content that was in the examination, only used representations that would be found in the examination and did not do practical work, as the examination did not include a hands-on practical component. From the additional resource materials she picked the sections that would prepare the learners for the examination and her explanations described the steps to ensure that learners derive the right answer in the test. The enormous pressure that was placed on her as the only Physical Sciences teacher in the school restricted her to doing only that which was required for the examination.

The PCK Consensus Model (Gess-Newsome & Carlson, 2013) classifies contextual constraints, just like orientations to science teaching, as 'amplifiers' or 'filters' of PCK. In Nomsa's case the most important influence was the high stakes examination that influenced her PCK. The use of curriculum materials had the potential to enhance her PCK, but due to the overarching examination pressure, she chose to use only the sections that were exam-orientated, and not the content which broadened the scope of the syllabus.

Nomsa's classroom practice shows the actions of a focused teacher preparing her learners for the final Grade 12 examinations, as expected of her by the education authorities, the community and her principal, and in line with how she sees her role as their teacher. She has only ever operated in this type of system, and has learned to negotiate the constraints of such a system to ensure that her learners are prepared for the task that lies ahead.

Amidst all the constraints Nomsa has a willingness to learn and reflect on her practice and has shown some areas of growth. These will be discussed in the next section.

5.4 Research question 5: Development of PCK over time

One of the unique features of this study was the length of time that I was able to work with Nomsa. The project was linked to another university-based research project, which afforded me three years of access to the school. The teaching of the same section of work was observed as Nomsa taught it to multiple classes over the three years. The last research question probes the changes that took place over the three years.

Four main growth areas have been identified, namely improved planning, changes in her assessment strategies, a shift in her instructional strategies, and expansion of her content knowledge.

Planning

Nomsa is a lead teacher, not only in her school environment where she fulfils a number of management roles, but also in her district where she has a leadership role as an experienced teacher. With experience a teacher is expected to rely less on the minor details of how the content will be taught, as these have already been established in prior years. Planning therefore takes place on a macro-level and the micro-level details fall into place as they do every year.

During the first two years Nomsa planned on a macro-level, as can be expected from an experienced teacher. However, in the third year she started planning on a micro-scale again. This is evidence of her willingness to rethink what she had been doing for many years to try something new. Her attitude towards change and openness to new ideas set the scene for the changes that are described further on in this section.

Assessment strategies

During the third year of data collection Nomsa introduced short informal assessments in class. The aim of the tests was to give immediate feedback to the learners on whether they were coping with the new content or not. However, change often has unintended consequences: the short test took much longer than initially anticipated and Nomsa took longer to finish the syllabus. Marking all the tests herself was not practical either, but she was able to adapt the assessment strategy to make it work. This showed her flexibility and

determination in trying new practices. The outcome was that the learners liked the tests and requested her to do similar ones in other topics.

Instructional strategies

Nomsa also adapted her instructional strategy over the three years, for example when she was teaching the chemical reactions section. She moved from teaching all the new content in one sitting, to spreading it out over a few days. This allowed for more learner interaction and gave her more time to answer questions on smaller sections of the work.

Although this change in practice was only found in a small section of the work, and right at the end of the data collection period, it is an indicator of a deeper change that is starting to take place. This is a change from viewing teaching as monologue to seeing it as dialogue, and a change from being teacher-centred to becoming more learner-centred. This is a fundamental mindset shift for any teacher and was shown to be one of the starting points in growing PCK (Veal, Tippins, & Bell, 1999).

The role of content knowledge

Over the three years evidence of an improvement in Nomsa's content knowledge was observed. At first she needed notes to teach cyclic compounds, but later she was able to not only teach without notes, but could also make up new examples while in front of the board. During the first year she did not teach the structure-physical property relationship section, but after attending a workshop and asking for help, she attempted this in the second year and improved on teaching it the following year. A further expansion of her content knowledge was in the area of the balancing of combustion reaction equations. In the first year she copied the equations from the notes onto the board and talked through the content, but in the third year she was able to explain the section without hesitation, to add her own examples and even to identify where learners usually make mistakes.

Nomsa is the only senior science teacher at her school. There is no one at school to help her if she struggles with any section of the work. This research study provided her with daily access to someone who could help her with content related questions. She often made use of this opportunity to ask questions which contributed to the growth in her content knowledge in this topic.

The growth in Nomsa's content knowledge took place over a long period of time and changes were only detected when year 3 data were compared to that of year 1. Although most of the development was not in PCK but rather in general pedagogical knowledge

(planning, short tests and instructional strategies) and content knowledge, all of these influence PCK. Hashweh (1987) identified content knowledge as an underpinning knowledge domain for PCK, in line with Shulman's (1986) definition of PCK. The fact that Nomsa had better content knowledge meant that she was able to teach certain sections which were not taught previously. The shift to micro-planning identified the need for more effective assessment strategies, which has the potential to inform and improve practice.

Many scholars (for example Baird, Fensham, Gunstone, & White, 1991; De Jong & Van Driel, 2004; Loughran, 2012; Nilsson, 2008) have identified that reflection on practice plays an important role in the development of PCK. Nomsa had shown a willingness to rethink her practice and try out new ideas, which initiated growth in her PCK.

As Michael Fullan (2001, p. 49) points out: 'Change is a process, not an event'. This study shows that changes in a teacher's practice are slow and take place in small steps over an extended period of time. If this study had been shorter, some of these changes might not have been detected. Nomsa had someone working with her for three years, someone whom she could ask if she was not sure about what to do next. In addition, making changes to practice has unintended consequences that can easily deter teachers from trying new things. In Nomsa's case she was able to handle the problems of implementing new practices which showed her determination to improve her practice.

5.5 Summary

Not everything that happens in the classroom is in the realm of PCK. As was seen in this study, aspects like classroom management or general assessment points to the teacher's knowledge of pedagogy rather than PCK. Although these general aspects of a teacher's practice were highlighted in this study, this study also attempted to analyse for aspects which reflect personal PCK. What the analysis has shown is an absence of practices that might be expected for expert PCK, for example, conceptual teaching strategies, using a variety of content representations or addressing areas where learners experience difficulty in understanding the content.

This study shows that context exerts a very powerful influence on what is possible, and logical, in a South African classroom. Yet teachers like Nomsa understand the logic of the institution and are able to negotiate the circumstances so that they can do their job. Nomsa showed a willingness to change her practice and was able to include new strategies in her teaching. The teacher's orientation to teaching plays a role, but this is overarched by the contextual influences.

General pedagogy was found to be very functional in this classroom but pedagogical content knowledge was limited. As shown in this study, many factors play a role in influencing this state of affairs. A likely key aspect is the traditional focus of teacher training which has been more on pedagogy than on content – Shulman’s original issue when he conceptualised PCK more than two decades ago.

University of Cape Town

6 Conclusion and Recommendations

In this study the classroom practice of Nomsa, an experienced science teacher teaching in a typical South African school, was observed and analysed. This revealed the various ways in which she transformed subject content to make it understandable to her learners, while negotiating the demands of the curriculum and the pressures from the Education Department and her school for her learners to perform well in the final matriculation examination. The analyses indicated that her pedagogical knowledge manifested quite strongly in her practice, but her PCK was limited. She understood her learners and their expectations of Grade 12 schooling and responded by preparing them for the high stakes examination at the end of the year. Her teaching was framed by what she believed good teaching to be. She showed a willingness to reflect on her practice, a trait which enabled her to change and improve her teaching. Although this change took place slowly, in small steps and with support, it does bring hope that growth can take place amidst constraining circumstances.

The significance of the case study

Nomsa is representative of many other dedicated science teachers in South Africa, and Themba High is just one of many schools like it. Although this case study cannot be generalised to all classrooms, there are commonalities between this case and many similar classrooms in South Africa: the teacher training that she received is similar to that of many teachers in South Africa; the contextual constraints that she experienced are not unique to Themba High, and the pressure of the final matriculation examination is the same in all public schools in this country.

Although the highly prescriptive syllabus did support classroom practice by providing a firm framework for what to teach, it also acted as a limitation as it prevented the inclusion of any additional material to broaden the horizons of the learners and to relate the concepts to real-life applications.

South Africa's first fully democratically elected government, after almost 20 years in power, is still dealing with the effects of a historically unequal education system. The ongoing attempts to address the educational legacy of apartheid have to date mainly been in the area of implementing curriculum change. Recently there has also been a further intensification of focus on the matriculation examination in the light particularly of the gatekeeping role this plays in determining access to tertiary education. This focus was very evident in the case study and strongly shaped the teaching that took place. This type of scenario, however, is

not conducive to really improving the quality of teaching. The focus will have to move away from being solely on the results of a matriculation examination towards effective science teaching and learning.

Implications for practice

If change is to be sought at the chalk face, then teacher pre-service preparation programmes and more critically, ongoing professional development programmes for in-service teachers in South Africa, would have to focus more on the development of content knowledge, specifically conceptual knowledge. A deep understanding of the content and how to teach it was shown to be essential in the teaching endeavour.

This study further showed that curriculum materials have the potential to impact classroom practice. However, these need to be accompanied by training sessions which address the development of pedagogical content knowledge rather than purely providing examination support. South Africa already has a number of such initiatives to support teachers, for example the various Provincial Education Departments' professional development programmes, PSP¹², SAASTA¹³ or ProGro¹⁴, but these need to be expanded. Furthermore, these programmes need to provide ongoing support over an extended period of time.

In addition to curriculum resources, the value of human resources, like expert colleagues or mentors cannot be underestimated and these should form part of professional development programmes. The research on Lesson Studies (Lewis, Perry, & Hurd, 2004) is one example where such programmes, which incorporate planning, doing and reflection with colleagues, have led to successful teacher development.

Pedagogical content knowledge

There is still an ongoing debate about the nature and components of PCK, making research in the field challenging. This study was focussed on the interplay between teacher knowledge and teacher practice and specifically looked at classroom practice and the manifestations of PCK in the classroom. A list of manifestations of PCK was constructed, largely from the studies of two influential research groups, namely that of Rollnick (Davidowitz & Rollnick, 2011; Rollnick et al., 2008) and Park (Park & Chen, 2012; Park &

¹² Primary Science Project

¹³ South African Agency for Science and Technology Advancement

¹⁴ National and Professional Teacher's Organisation of South Africa (NAPTOSA)'s Professional Growth Seminar series

Oliver, 2008). The PCK Consensus Model's notion of 'amplifiers' and 'filters' was useful to frame the influence of orientation to teaching and context on practice. The present study draws together the three models mentioned above to examine teacher practice in South Africa, and contributes to the refining of the Consensus Model, especially in countries where contextual constraints play a crucial role in teaching.

The study has re-affirmed the value of research into PCK to identify how teachers teach and to understand why they teach the way they do. It has also provided pointers for the development of PCK in science classrooms.

Methodological implications

Longitudinal studies of longer than one year are rare in science education. However, change was not observed in the first year of this study. It was the longitudinal nature of this study, conducted over a much longer time frame than is usually the case, which enabled the observation of changes in teaching practice. More studies of this nature are needed to deepen our understanding of schooling in South Africa, and what is needed to catalyse change in our classrooms.

Gaining access to classrooms, especially for such a long period of time, is difficult. Many research studies opt for surveys, or only interviews, due to this restriction. The findings from the present study would not have been possible with survey or interview methods alone, highlighting the importance of actual classroom observations as an effective tool to document and understand classroom practice. The findings described in this document also demonstrate the importance of larger long-term projects in education research, and the valuable contribution that they can make to our understanding of continuous teacher development.

I conclude with Hargreaves (1992) who wrote:

'Attempts at teacher development and educational change will meet with little success unless they engage with the purposes of the teacher, unless they acknowledge the person that the teacher is, and unless they adjust to the slow pace of human growth that takes place in the individual and collective lives of teachers.' (p. 236)

7 References

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Appendices

Appendix A: Summary of Grade 12 organic chemistry lessons taught and observed

Year 1		
Date	Class (12A)	Class (12B)
12 April	12A1	12B1
13 April	12A2	12B2
14 April	12A3	12B3
15 April	12A4	12B4
16 April	12A5	12B5
19 April	12A6	12B6
20 April	12A7	12B7
21 April	12A8	12B8
22 April	12A9	12B9
23 April	12A10	12B10
26 April	12A11	12B11
27 April	Public holiday	
28 April	12A12	12B12
29 April	12A13	12B13
30 April	12A14	12B14
3 May	Test	Test

Year 2		
Date	Class (12B)	Class (12C)
11 April	Teacher absent	
12 April	12F1	12G1
13 April	12F2	12G2
14 April	12F3	12G3
15 April	Prize-giving	
18 April	12F4	12G4
19 April	12F5	12G5
20 April	12F6	12G6
21 April	12F7	12G7
22 April	Public holiday	
25 April	Public holiday	
26 April	12FG8 comb	
27 April	Public holiday	
28 April	School holiday	
29 April	School holiday	
2 May	Public holiday	
3 May	12F9	12G9
4 May	12F10	12G10
5 May	12F11	12G11
6 May	Test	Test
9 May	12F13	12G13
10 May	12F14	12G14

Year 3			
Date	Class (12C)	Class (12D)	Class (12E)
9 April	Easter (Public holiday)		
10 April	Teacher absent		
11 April	12P1	12Q1	12R1
12 April	12P2	12Q2	12R2
13 April	12P3	12Q3	12R3
16 April	12P4	12Q4	12R4
17 April	12P5	12Q5	12R5
18 April	12P6	12Q6	12R6
19 April	12P7	12Q7	12R7
20 April	12P8	12Q8	12R8
23 April	12P9	12Q9	12R9
24 April	12P10	12Q10	12R10
25 April	12P11	12Q11	12R11
26 April	12P12	12Q12	12R12
27 April	Public holiday		
30 April	School holiday		
1 May	Public holiday		
2 May	12P13	12Q13	12R13
3 May	12P14	12Q14	12R14
4 May	12P15	12Q15	12R15
7 May	12P16	12Q16	12R16
8 May	12P17	12Q17	12R17
9 May	12P18	12Q18	12R18
10 May	12P19	12Q19	12R19
11 May	12P20	12Q20	12R20
18 May	Test	Test	Test

Grey shaded blocks indicate lessons that were observed.

Lessons codes in **bold** indicate the lessons which were transcribed.

Total organic chemistry lessons taught to Grade 12's = 115

Total Grade 12 lessons recorded = 97

Appendix B: Summary of Grade 11 organic chemistry lessons taught and observed

Year 1		
Date	Class (11A)	Class (11B)
12 April	11A1	11B1
13 April	11A2	11B2
14 April	11A3	11B3
15 April	11A4	11B4
16 April	11A5	11B5
19 April	11A6	11B6
20 April	11A7	11B7

Year 3		
Date	Class (11A)	Class (11B)
9 April	Public holiday	
10 April	Teacher absent	
11 April	11P1	11Q1
12 April	11P2	11Q2
13 April	11P3	11Q3
16 April	11P4	11Q4
17 April	11P5	11Q5
18 April	11P6	11Q6
19 April	11P7	11Q7
20 April	11P8	11Q8
23 April	11P9	11Q9
24 April	11P10	11Q10
25 April	11P11	11Q11
26 April	11P12	11Q12
27 April	Public holiday	
30 April	School holiday	
1 May	Public holiday	
2 May	11P13	11Q13
3 May	11P14	11Q14
4 May	11P15	11Q15
7 May	11P16	11Q16
8 May	11P17	11Q17
9 May	11P18	11Q18
10 May	11P19	11Q19
11 May	11P20	11Q20
18 May	Test	Test

Note: In year 2 Nomsa did not teach Grade 11

Grey shaded blocks indicate lessons that were observed.

Total organic chemistry lessons taught to Grade 11's = 54

Total Grade 11 lessons recorded = 24

Appendix C: Examples of field notes

Thursday 15 April Year 3

Code 12A4, Grade 12A, Period 6 12:00 – 12:45

Bell rings at 12:04, recording started at 12:09

31 learners present

Nomsa is teaching cycloalkanes and cycloalkenes in this lesson. Nomsa draws the hexagon shape on the board for cyclohexane. I wonder what the learners 'see' as the real structure of this compound. One learner had a good question about why not including the side chain when you count the longest chain when a cyclic compound is present.

Now they are discussing double bonds in cyclic compounds. Interesting that she chooses cyclobutene as an example, probably to test for 4 carbons, but in reality this compound is highly unlikely to exist. She wouldn't know this. One girl asks about two double bonds on one carbon and how it's numbered. Nomsa explains.

No hydrogens drawn in the cyclic structure. No attempt is made to show them 'real' structures or visualise any of it, like with models, pictures from the internet, etc. Nomsa has a laptop and email address (yahoo) so must have access to the internet. She also has an interactive whiteboard. Must ask if this is working and if so, whether she uses it. [added later, she has internet access at home, the whiteboard is working, she used it once this year to show pictures for chemical equilibrium, but the interactivity is not working. She said they had training on using this but it was very short and she does not really know how to use it.] [added later, the CD with the computer program to run the interactivity is missing so none of the interactive whiteboards in the school is working]

The learners get the answers for new compounds very quickly – unless they are the brightest kids shouting out – they must have grabbed the concept well...

They then move on to halo-alkanes. Just started when bell goes at 12:46.

She carries on teaching, learners don't move either. The next class has arrived outside and are waiting. She finishes naming 2-chloro butane. Dismisses learners at 12:50.

Monday 7 May Year 3

Code 12Q16, Grade 12D, Period 3 09:34 – 10:19

Topic: Combustion reactions

This lesson was taught in the learners' home room (in the hall, upstairs, same level as her classroom) Nomsa said it's better there because their whiteboard is bigger.

When we arrived the learners were still writing a Geography test. It seems like all the learners do science and geography in this class. Some learners carried on writing the test well into the science lesson. They were not stopped, although Nomsa did say that they have five minutes left. This was ignored by some and they wrote until they were done. Most learners handed in around 09:45. So the lesson started very late, but since it was not a long lesson, she managed to get done what she intended.

She used the stuff I explained to her earlier today; see voice recording (Interview 14).

I stood at the back of the room, class is full, very little room to move, and could only record, not take any notes as I did not have a chair or my computer.

The lesson introduction gave no context or real life examples, just started with the facts.

There were lots on 'singing along' yet I got the impression that they did know how to do the balancing of the combustion reactions. How many hydrogen on this side... 8, how many on this side, 2, how many do you need, 4 (they don't say 6, which means that they do know she means number of molecules)

A fraction is not allowed, therefore you multiply by 2. This is the procedural explanation, and not conceptual. No pictures of molecules, no models, no analogies.

Also quite a bit of questions from the learners and learner interaction. Good lesson to use to describe this. Nomsa gave some background/context with the Grade 11s in the next lesson (11Q16), but not in this one.

Appendix D: Summary of teacher interviews

Interview number	Date	Type of interview
Year 1		
Interview 1	12 April	Semi-structured
Interview 2	14 April	Unstructured
Interview 3	16 April	Unstructured
Interview 4	20 April	Unstructured
Interview 5	6 May	Unstructured
Interview 6	9 June	Semi-structured

Year 2		
Interview 7	13 April	Semi-structured
Interview 8	21 April	Unstructured
Interview 9	3 May	Unstructured
Interview 10	23 June	Semi-structured

Year 3		
Interview 11	13 April	Semi-structured
Interview 12	25 April	Unstructured
Interview 13	3 May	Unstructured
Interview 14	7 May	Unstructured
Interview 15	18 June	Unstructured
Interview 16	26 July	Semi-structured

Appendix E: Extract from an interview transcript

Date: [Interview 16]

Interviewer (I): René

Interviewee (TEACHER): Nomsa

I: How do you maximise student learning in your classroom?

Teacher: Okay, like I, by grouping the learners, you know, and to find out what they know. [Okay] You group them, you find out what they know and then after that, you do the actual teaching. You know, and then, you know, what I normally do is, that to give them as much information as they need, so that whenever I am doing something, then at least, they don't depend on what I'm giving them. When I am teaching in class, they have other resources to look at and then they come with questions, then we attend to those questions.

I: Okay. What do you mean, when you give them extra information, like, for example, what?

TEACHER: Like, you know, my learners have their own textbooks, okay, that they are using and then like, when I am preparing my lessons, I don't use one thing, you know, I use variety. Like I watch videos like the one that you gave me, of Angela, you know, so I watch that and then I see how, you know, how she teaches and then I take points there and then, you know, I bring everything in. Then when I find that, okay, the information that Angela has there, is relevant to my learners, you know, then I just make copies. [Okay] You know, make copies and then, so that I can distribute to the learners and then to look at other textbooks, what do they say and what am I about to teach, you know and if I find, 'Okay, this is not in their textbook, it's good, it will help them.' Then you know, I get that information. Then I make a copy of little notes, notes that then, you know, that I give them.

I: Okay, so they have got their own textbook, you hand out additional notes from your resources. Do you give them any other documents, or information?

TEACHER: (Mm-mm)

I: Not really?

TEACHER: Not really.

I: And worksheets, or exercises?

TEACHER: 'Ja'¹⁵, I do, no, 'ja', I do, no, we do worksheets, we do exercises.

I: (Mm, mm?) Do you set them yourself?

TEACHER: Sometimes not, sometimes yes.

I: And if you don't set them, where do you get them from?

TEACHER: From the - okay, let me think - no, the exercises, I set them myself, or I use past exam question papers and like, you know, other Study Guides that I have, like Answer Series where I, you know, I just extract what is important for that certain topic. You know, then that is how [Okay], that is how I do it.

I: Okay, so you said, to maximise student learning, you group the learners. What do you mean with that?

¹⁵ 'Ja' means 'yes'.

TEACHER: I mean, like, you know, like at school, I mean, when you go to class, Learners are already sitting in their groups. [Ja] You know, so I'm like, when, when you are busy teaching a certain topic - you know, other learners, they grasp so quickly. You know, others, then it takes time. So if they are sitting together here, you know, while I am busy teaching and then after that, when I give them time for questions, or whatever, then the other is able to explain to the other, 'Okay, you know, the teacher means this, the teacher means that', you know, or if I am doing a calculation on the board and then, you will find that there are learners who do not understand. You know, so by grouping them together, like you make sure that, at least, at the end of the lesson, at least, your outcome is reached somewhere, somehow at the end of the day.

I: Okay, so with 'grouping', you mean, they sit in, they work, or sit in little groups?

TEACHER: 'Ja'.

I: And you let them choose the groups?

TEACHER: Yes, I don't really, I let them choose, because they are so comfortable with their friends, you know.

I: And do you find them mostly sitting with friends?

TEACHER: Friends.

I: Friends groups?

TEACHER: 'Ja'.

I: And do the groups ever mix boys and girls, or

TEACHER: 'Ja'.

I: are they mixed groups?

TEACHER: Mixed groups, they are boys and girls.

I: Okay, do you ever find learners who don't join a group like that, who sit on their own?

TEACHER: There are, but I try, you know, I try, not learners to sit alone - you will find - I had that instant of like three learners who were sitting, you know, the other one is sitting there and the other one in that corner and, right at the back, you know and you find out, even though you are there in class and you are teaching, they are not party of that, because they are behind, you know, so they are afraid to ask. [Okay] You know, so I try to minimise that, because I will go to them, I went to them. I said: 'No, no, no, you're not supposed to sit alone. Just find somewhere, or just come in front' and I know they don't want to come in front. 'Just come and sit in front in this group', and then I'll tell them that, 'I will monitor you, you don't sit alone.' [Okay] You know. So, there are cases like that.

Appendix F: Example of a transcription and translation of a lesson

Lesson 12Q15 isiXhosa transcription

Teacher: And then umbuzo wesibini kuthiwa explain... explain the difference in boiling point. Kuyaboniswa pha intobangaba the boiling point, which is a physical property, is not the same. Now you need to explain, so your explanation, it must speak of the forces that are existing pha kweza nto ziyi-two. Mamela indlela esiyionga ngayo lanto, because everytime you are going to be given i-compound huneke uzi compar-ishe, this is how you should do it anhe? ... uzokwazi uphendula. Number one, everytime you are given i-compound, you must look at the factor, what is the factor that is affecting uba i-boiling point zakho zingafani, anhe? ... so that means the first thing, everytime when are looking you are given i-compounds, identify the factor. Identify the factor and then id... what is the physical property that is given there. Then after identifying the factor, then you give i-explanation, so i-factor yakho uyi-identify-yile, then because of this factor, that is why i-boiling point is not the same anhe? ...then uyachaza intobangaba, then that is when you are going to explain. You speak intobangaba apha, anhe? ... because of i-factor leyo, ingaba i-intermolecular forces zapha zi-strong okanye zi-weak na? ... then uzawuthetha nge intermolecular forces, then you are going to speak of the energy, emveni koko that is why i-boiling point is high or i-boiling point is low. So, uba indlela yakho yokuphendula funeke ibeyindlela eyi-one, so that ucape intobangaba you are going to get those marks, awuzuveske uthethe into ezabangela uba ungafumani niks pha. So mamela ke ngoku, that means when you look at this, okokuqala neh? apha yeyiphi i-factor, makakhe..., umntu makaphendule, yeyiphi i-factor oyibonileyo pha?

Learners: Branching.

Teacher: Branching anhe? ...the one i-branched and the other one is not branched anhe?

Learners: Yes.

Teacher: Mamela ke ngoku, awunothi xa uthetha i-reason yakho uthi i-chain length increases. The chain length is another factor and when we look here, akho chain length that is increases...that is increasing, because we have the same number of carbons, ...andithi? ...ukuze sijonge i-chain length we will look at the number of carbons anhe? ...asijongi kwi-halogen, we look at the number of carbon intobangaba from the first one, how many carbons do we have, the second one how many carbons do we have then we can say intoba as we are going along, is the chain increases nhe? ...increasing or the chain is remaining the same, so in this case; the chain, asinakude sithethe nge-chain mos, siyavana class? So funeka siyazi intoba; when to speak of the factor ye-chain length, when to speak of branch ungathethi into ezimbini entweni eyi-one. So it's good apha xa si-identify sithi ok apha yi-branching, so this one, uyabona uba this one is more branched? ...because ine-side chain ezininzi, and this one, usenothi zi-less branched okanye not branched anhe? So, xa the one that is not... le ingekho branched, which is this one, siyabona intoba ine-boiling point engakanani? E-high siyavana class? Then we say this one that is less branched anhe? Less branched results into stronger intermolecular forces. So, the intermolecular forces there, they are stronger noba ungathi brackets ubhale, noba ungabhala van de Waals, sobe ungazifumani i-marks anhe? ...so the intermolecular forces are stronger, then that means more energy is needed, uyabona? To... to break the compound, so that is why the boiling point is high and then le yesibini, this one is more branched, so when the, when... when the organic compound is more branched, that means weaker intermolecular forces. Uyabona uba siqala nge intermolecular forces anhe?

Learners: Yes.

Teacher: And then sijong' i-factor then sithi, OK, because of that factor ... because everytime yi-factor that is causing the physical property not being the same, eny'ibenkulu enye ibe-low. So, this one more branched, weaker intermolecular forces, xa sithi int'e-weaker intermolecular forces that means less energy will be needed to break the compound, that is why the boiling point is low ...not high but low. Uyabona nhe? ...So, this is how you should answer; you start with i-intermolecular forces, then uthethe nge-energy, emveni koko umfumene u-three marks wakho. So, mamela ke, ndicela siye pha kula maphepha ndigqiba kuninika wona, because bekufaneluba ndithi zididizeleni, imbangi yoba ndini-

photo kopele wona lamaphepha they are very much important, yindlela ekubuzwa ngayo xa kuthethwa nge-physical property. Ubungajonga i-questions kwi-previous questions papers, you will see intoba OK, nyani, everytime kwi-physical property you are given i-questions that are similar, then you need to answer. You look, you have to find the differences ...and then ... ulantuke. So, mamela ke ubangaba u-answer ngoluhlobo, oluhlobo ndithetha ngalo lithi, if you are given i-co... i-organic compounds, different organic compounds, the first, there are two things that you must identify kwezo organic compounds that you are given. The first one, you must always identify intoba what is the factor that is affecting ezi-compounds uzinikiweyo. That is number one everytime everytime noba unganikwa i-question ethini, because i-questions will always be like that. You are given i-question, you are given i-compound, wena into yokuqala ekufuneka uyazi, identify the factor, number one, then number two, identify the physical property; what is the physical property ekuthethwa ngayo pha, because ayisoloko i-physical property iyi-boiling point. Zinga ... sisazikhumbula i-physical property zethu?

Learners: Yes.

Teacher: We got i-melting point also, we've got i-viscosity, and then we got i-vapour pressure, anhe?

Learners: Yes.

Teacher: And then ndithe yesterday, xa when the boiling point is high, melting point injani?

Learners: i-high.

Teacher: I-vapour pressure injani?

Learners: i-low.

Teacher: And then i-viscosity injani?

Learners: i-high.

Teacher: Asiyilibali i-vapour pressure yiyo, ubangaba zoyi-three zi-high, then i-vapour pressure izabanjani?

Learners: izaba-low.

Teacher: If you are given, masijonge pha, uyabona pha kulamzekelo uwunikwe pha? ... you've got the other one has i-high boiling point and the other one has i-low boiling point anhe? ... and then i-question say, from those compounds, which one will have the higher vapour pressure?

Learners: Uzaba ngu-number two.

Teacher: uzabangu-number two anhe? ... because as long as the boiling point is low, i-vapour pressure injani?

Learners: i-high.

Teacher: Uyabona? and then when the boiling point is high, i-vapour pressure injani?

Learners: i-low.

Teacher: So, pha ku-number 51 degrees, if i-boiling point is low, that means i-melting point izabanjani nayo?

Learners: izaba-low.

Teacher: ...and the i-viscosity izaba njani?

Learners: izaba-low.

Teacher: Izaba-low so, funeka siyazi ngoluhlobo intoba ezi ziyi-three, zihamba zonke and then eyi-one isecaleni, uyabona uba eny'inyukile, izabasezantsi, because i-question izabuza ukuba what is the vapour press... it can ask any lantuka, any physical property. So, everytime xa unikwe i-compound, identify the factor, and then okwesibini, what is the physical property? Because zezozinto zimbini qha that are very much important, now njenguba ndikunike eliphepha ndiyacela intobangaba ngexesha lakho onalo, just go and read through this because apha, yilendlela ndithetha ngayo, this is how you should write... uyabona ndiyayithetha ngomlomo anhe? Ndiyaphinda ndikunika ibhaliwe, so wena, into oyenzayo ilula anhe? ...uba mawuthathe amehlo akho nengqondo yakho in your own time, you go and re-read this so that uzoyazi intobangaba uzayifumana soze ungayazi uba ibhalwa nje, because le ndlela ndiyi thetha ngayo, yilendlela funeka uyibhale ngayo so that, nam ndibesure xa ku-mark-ishwa soze ungazifumani ezi marks, so ke please asigcwalisi ncwadi sibhala i-English pha, we want facts uba yintoni oyibonileyo pha, uyayazi how to identify intoba whenever you are given i-probl...uba uyayazi uba ujonga ntoni, so that is the most important thing, anhe? So, apha into esiyithethayo we are looking, we are talking about of is skill intobangaba how to get u-five out of five when you speaking of i-physical properties.

Lesson 12Q15 English translation

Teacher: And then the second question says explain...explain the difference in boiling point. It is shown there that the boiling point, which is a physical property, is not the same. Now you need to explain, so your explanation, it must speak of the forces that are existing there in those two. Listen, the way we view that thing, because every time you are going to be given a compound and you have to compare, this is how you should do it OK? ... you will be able to answer. Number one, every time you are given a compound, you must look at the factor, what is the factor that is affecting such that your boiling points are not the same, OK?... so that means the first thing, every time when are looking you are given compounds, identify the factor. Identify the factor and then id...what is the physical property that is given there. Then after identifying the factor, then you give an explanation. So you have identified your factor, then because of this factor, that is why the boiling point is not the same OK? ... then you explain that, then that is when you are going to explain. You speak that, here, OK, because of that factor, are the intermolecular forces strong or are they weak? Then you will speak of intermolecular forces, then you are going to speak of the energy, after that, that is why the boiling point is high or the boiling point is low. So if, the way you answer must be consistent so that you clearly look like you are going to get those marks, you cannot just say something that will not earn you marks. so listen then now, that means when you look at this, firstly OK? ... what is the factor here? Can a.. a person must answer, what factor have you spotted there?

Learners: Branching.

Teacher: Branching OK? ... the one is branched and the other one is not branched OK?

Learners: Yes.

Teacher: Listen then now, you cannot, when explaining, say your reason is that the chain length increases. The chain length is another factor and when we look here, there is no chain length that is increases...that is increasing, because we have the same number of carbons, isn't it? In order to look at the chain length we will look at the number of carbons OK? ... we don't look at the halogen, we look at the number of carbon that from the first one, how many carbons do we have, the second one how many carbons do we have then we can say that as we are going along, is the chain increases OK?... increasing or the chain is remaining the same, so in this case; the chain, we cannot even talk about the chain length here, are we all together class? ... so we have to know when to speak of the factor of chain length, when to speak of branch, so that you don't speak of two things in one. So it's good here when we identify we say ok here this is branching, so this one, can you see that this one is more branched? ... because it has many side chains. and this one, you can say it is less branched or not branched OK? so when, the one that is not...the one that is not branched, which is this one, can we see what its boiling point is? it has a high. do we hear each other class? then we say this one that is less branched OK? less branched results into stronger intermolecular forces. so the intermolecular forces there, they are stronger. you may use brackets and write, or you can write Van der Waals, there's no way you won't score marks OK? so the intermolecular forces are stronger, then that means more energy is needed, can you see? to..to break the compound, so that is why the boiling point is high. and then the second one, this one is more branched, so when the, when...when the organic compound is more branched, that means weaker intermolecular forces. can we see we start with the intermolecular forces OK?

Learners: Yes.

Teacher: And then we look at the factor and say, OK, because of that factor... because every time it is the factor that is causing the physical property not being the same, where one is high and the other is low. So this one, more branched, weaker intermolecular forces, when we say int..weaker intermolecular forces that means less energy will be needed to break the compound, that is why the boiling point is low ... not high but low. Can you see, OK? ... so this is how you should answer; you start with the intermolecular forces, then talk about the energy, thereafter you have your three marks. so listen then, can we please turn to the page I have just handed you guys, because I should say that you must do it on your own, the reason why I photocopied for you those papers are very much important, that is the way the questions are asked when we speak of physical property. if you may look at questions from previous questions papers, you will see that, OK, really, every time in physical property you

are given questions that are similar to this, then you need to answer. You look, you have to find the differences...and then you ... thingy, so listen then, if you answer this way, this way I am talking about that says if you are given a co... organic compounds, different organic compounds, the first, there are two things that you must identify in those organic compounds that you are given. The first one, you must always identify the question of what is the factor that is affecting these given compounds. That is number one every time. Every time no matter what question you may be given, because the questions will always be like that. You are given a question, you are given a compound, the first thing you have to know, identify the factor, number one, then number two, identify the physical property; what is the physical property being spoken of there, because the boiling point is not always the featured physical property. There are... do we still remember our physical property?

Learners: Yes.

Teacher: We got the melting point also, we've got viscosity, and then we got the vapour pressure, OK?

Learners: Yes.

Teacher: And then I said yesterday, when, when the boiling point is high, how is the melting point?

Learners: It is high.

Teacher: How is the vapour pressure?

Learners: It is low.

Teacher: And then how is the viscosity?

Learners: It is high.

Teacher: We don't forget the vapour pressure, it is the one, if all three are high, then how will the vapour pressure be?

Learners: It will be low.

Teacher: If you are given, let us look there, can you see there you are given an example? ... you've got the other one has a high boiling point and the other one has a low boiling point OK? ... and then the question says, from those compounds, which one will have the higher vapour pressure?

Learners: It will be number two.

Teacher: It will be number two OK? ... because as long as the boiling point is low, how is the vapour pressure?

Learners: It is high.

Teacher: Can you see? ... and then when the boiling point is high, how is the vapour pressure?

Learners: It is low.

Teacher: So there in number 51 degrees, if the boiling point is low, that means, how will the melting point be as well?

Learners: It will be low.

Teacher: And how will the viscosity be?

Learners: It will be low.

Teacher: It will be low so we have to know it this way that these three, go together and then the other one is on the side, can you see if one goes up, then it will be low, because the question will ask, what is the vapour press...it can ask anything, any physical property, so every time when you are given a compound, identify the factor, and then secondly, what is the physical property, because those are the two things that are very much important, now the paper I have given you, I need to ask that in your own time, just go and read through this because here, this is the way of answering I was talking about, this is how you should write...can you see I am saying verbally, OK? ... and then again I give it you in writing?... so now you, all you do is easy OK? ... you take your eyes and your brains, in your own time you go and read this so that you know how to get it, you'll never not know that it is right this way, because this way I am talking about, is the way you need to write so that, even I am sure that when papers are marked, you will get marks, so please then we are not filling books, writing English there, we want facts about what you see there, you know how to identify that whenever you are given a probl... if you know what to look for, so that is the most important thing, OK? ... so here, what we are saying is we are looking, we are talking about of is skill of how to get five out of five when you are speaking of physical properties.

Appendix G: Nomsa's timetable for year 1 - 3

Year 1 (69% teaching load)

Period	Monday	Tuesday	Wednesday	Thursday
1 (08:20 - 09:05)	12B		12A	11C
2 (09:05 - 09:50)	11A		11B	
3 (09:50 - 10:35)	12A	11C	11C	
4 (10:35 - 11:20)			12B	11B
5 (11:20 - 12:00)	Lunch	Lunch	Lunch	Lunch
6 (12:00 - 12:45)	11B	12A		12A
7 (12:45 - 13:30)		11B		11A
8 (13:30 - 14:15)	11C	11A	11A	12B
9 (14:15 - 15:00)		12B		

Period	Friday
1 (08:20 - 09:05)	11C
2 (09:05 - 09:50)	11A
3 (09:50 - 10:35)	11B
4 (10:35 - 11:20)	12A
5 (11:20 - 12:00)	Lunch
6 (12:00 - 12:45)	
7 (12:45 - 13:30)	12B

Year 2 (72% teaching load)

Period	Monday	Tuesday	Wednesday	Thursday
1 (08:20 - 09:05)	8D		8C	8B
2 (09:05 - 09:50)		8D		8C
3 (09:50 - 10:35)	12B	8B	8B	12B
4 (10:35 - 11:20)		12C		12C
5 (11:20 - 12:00)	Lunch	Lunch	Lunch	Lunch
6 (12:00 - 12:45)	8B	12B	12B	8A
7 (12:45 - 13:30)		8C	12C	8D
8 (13:30 - 14:15)	8C		8A	
9 (14:15 - 15:00)	12C	8A	Register	Register
10 (15:00 - 15:10)	Register	Register		

Period	Friday
1 (08:10 - 08:50)	Assembly
2 (08:50 - 09:30)	
3 (09:30 - 10:10)	8A
4 (10:10 - 10:50)	
5 (10:50 - 11:30)	8D
6 (11:30 - 12:10)	Lunch
7 (12:10 - 12:50)	12B
8 (12:50 - 13:30)	12C
9 (13:30 - 13:40)	Register

Year 3 (69% teaching load)

Period	Monday	Tuesday	Wednesday	Thursday
1 (08:00 - 08:45)		12D	12C	
2 (08:47 - 09:32)			11B	12E
3 (09:34 - 10:19)	12D	12C		
4 (10:19 - 10:50)	Lunch	Lunch	Lunch	Lunch
5 (10:52 - 11:37)	11B	12E	12D	11A
6 (11:39 - 12:24)				12D
7 (12:26 - 13:10)	12C		12E	12C
8 (13:10 - 13:25)	Lunch	Lunch	Lunch	Lunch
9 (13:27 - 14:12)	11A	11A	11A	11B
10 (14:14 - 15:00)	12E	11B		

Period	Friday
1 (08:00 - 08:40)	Assembly
2 (08:42 - 09:22)	12C
3 (09:24 - 10:05)	12D
4 (10:05 - 10:35)	Lunch
5 (10:37 - 11:17)	11A
6 (11:19 - 12:01)	11B
7 (12:03 - 12:43)	12E
8 (12:43 - 12:58)	Lunch
9 (13:00 - 13:40)	

Appendix H: NCS content document

Organic molecules:	Learners must be able to	
Organic molecular structures – functional groups, saturated and unsaturated structures, isomers;	- give condensed structural, structural and shorthand formulae for alkanes and compounds containing the following functional groups: double carbon-carbon bonds (including conjugated double bonds), triple carbon-carbon bonds, alkyl halides, alcohols, carboxylic acids, esters, amines, amides, ketone, arene (benzene ring) - explain the terms saturated, unsaturated and isomer - identify compounds that are saturated, unsaturated and are isomers (up to 8 carbon atoms)	Links to Gr 11 multiple bonds (matter and materials) Gr 12 polymers biological macromolecules (matter and materials) and chemical systems To <u>recognise structures</u> of polymers and biological macromolecules learners will need to work with compounds containing an unlimited number of carbon atoms. The functional groups listed are required for the <u>recognition</u> of common polymers and biological macromolecules
Systematic naming and formulae, structure physical property relationships;	Give the systematic name given the formula, and vice versa, for compounds with the functional groups listed under Gr 12 Organic Molecules above, up to a maximum of 8 carbon atoms Recognise and apply to particular examples the relationship between melting points, boiling points, vapour pressure, viscosity and intermolecular forces (hydrogen bonding, Van der Waals forces including dispersion or London forces number and type of functional group, chain length, branched chains)	Link to Grade 10 matter and materials intermolecular forces.
Substitution, addition and elimination reactions.	Unsaturated compounds undergo addition reactions to form saturated compounds e.g. $\text{CH}_2=\text{CH}_2 + \text{Cl}_2 \rightarrow \text{CH}_2\text{Cl}-\text{CH}_2\text{Cl}$ Saturated compounds undergo elimination reactions to form unsaturated compounds e.g. $\text{CH}_2\text{Cl}-\text{CH}_2\text{Cl} \rightarrow \text{CH}_2=\text{CHCl} + \text{HCl}$ Two types of saturated structure can be inter-converted by substitution e.g. $(\text{CH}_3)_3\text{OH} + \text{HBr} \rightarrow (\text{CH}_3)_3\text{Br} + \text{H}_2\text{O}$ $(\text{CH}_3)_3\text{Br} + \text{KOH} \rightarrow (\text{CH}_3)_3\text{OH} + \text{KBr}$	Link to Grade 11 Chemical Change: Types of reaction addition and elimination reactions Grade 12 Chemical Systems: SASOL fuels (cracking) - elimination Grade 12 Chemical systems: polymerization addition

Appendix I: Physical Sciences examination guidelines

MATTER AND MATERIALS	
Organic molecules	Learners must be able to:
Organic molecular structures – functional groups, saturated and unsaturated structures, isomers; *systematic naming and formulae	• Give condensed structural, structural and molecular formulae given the IUPAC name, or give the IUPAC name when given the formula for: ○ *Alkanes – maximum eight carbon atoms in the longest chain; branched alkanes with maximum three alkyl substituents; maximum two carbon atoms per alkyl substituent; number longest chain beginning at end nearest to first substituent; arrange substituents alphabetically by name; know that alkanes are our most important fuels (fossil fuels); combustion of alkanes (oxidation) is highly exothermic and carbon dioxide and water are produced: $\text{alkane} + \text{O}_2 \rightarrow \text{H}_2\text{O} + \text{CO}_2 \quad \Delta H < 0 \text{ (revision from Grade 11)}$ ○ *Cycloalkanes – maximum of six carbon atoms per ring; maximum three alkyl substituents; maximum two carbon atoms per alkyl substituent ○ *Alkenes – maximum of eight carbon atoms in the longest chain; branched alkenes with maximum three alkyl substituents; maximum two carbon atoms per alkyl substituent ○ *Cycloalkenes – maximum of six carbon atoms per ring, maximum three alkyl substituents; maximum two carbon atoms per alkyl substituent ○ *Dienes – conjugated dienes (two double bonds separated by a single bond), isolated dienes (one or more saturated carbon atoms between two double bonds) or cumulated dienes (two double bonds formed to one carbon atom); maximum eight carbon atoms in the longest chain; branched dienes with maximum three alkyl substituents; maximum two carbon atoms per alkyl substituent ○ *Alkynes – maximum eight carbon atoms in the longest chain; branched alkynes with maximum three alkyl substituents; maximum two carbon atoms per alkyl substituent ○ *Haloalkanes – maximum eight carbon atoms in the longest chain; branched haloalkanes – maximum two carbon atoms per alkyl group; haloalkanes can have one or more X-groups (X = F, Cl, Br or I) attached; number longest chain beginning at end nearest to first substituent, regardless of whether it is alkyl or halo; give alphabetical preference to substituents when longest chain can be numbered from either side; include cyclic haloalkanes for rings up to six carbon atoms, e.g. 1,2-dibromocyclohexane ○ *Alcohols – maximum eight carbon atoms in the longest chain; primary, secondary and tertiary alcohols; branched alcohols with maximum three alkyl substituents; maximum two carbon atoms per alkyl substituent; number longest chain beginning at end nearest to hydroxyl group ○ *Carboxylic acids – maximum eight carbon atoms in the longest chain; branched carboxylic acids with maximum three alkyl substituents; maximum two carbon atoms per alkyl substituent; number longest chain beginning at end nearest to carboxyl group ○ *Esters – maximum eight carbon atoms in alkyl group (unbranched) attached to oxygen i.e. alcohol side of ester, and maximum of eight carbon atoms in carboxylic acid side (unbranched) of ester; know that an ester is the product of an acid catalysed condensation between an alcohol and a carboxylic acid; identify the alcohol and carboxylic acid used to prepare a given ester and vice versa, and write an equation to represent this preparation ○ *Amines – primary, secondary and tertiary alkyl-substituted amines;

	maximum eight carbon atoms in the longest alkyl substituent (unbranched); use the longest chain as stem in unsymmetrical secondary and tertiary amines, indicate the other alkyl groups attached to nitrogen using the prefix <i>N</i>- or <i>N,N</i>-
	○ *Amides – alkyl-substituted amides; maximum of 8 carbon atoms in the stem i.e. the chain containing the carbon atom of the acyl group; if nitrogen is further substituted, name the substituents (maximum three carbon atoms) first preceded by <i>N</i> to identify them as directly substituted to the nitrogen, followed by the name of the parent amide ○ *Aldehydes – maximum eight carbon atoms in the longest chain; branched aldehydes with maximum three alkyl substituents; maximum two carbon atoms per alkyl group; number longest chain beginning at end nearest to carbonyl group ○ *Ketones – maximum of eight carbon atoms in the longest chain; branched ketones with maximum three alkyl substituents; maximum two carbon atoms per alkyl group; number longest chain beginning at end nearest to carbonyl group ○ *Arenes (benzene rings) – maximum three alkyl substituents (NO other functional groups); maximum two carbon atoms per alkyl substituent • Explain the terms functional group, hydrocarbon, saturated, unsaturated, homologous series and isomer (structural isomers only). • Identify compounds that are saturated, unsaturated and are isomers (up to eight carbon atoms).
*Structure and physical property relationships	• Recognise and apply to particular examples (for compounds listed above) the relationship between: ○ physical properties (e.g. melting points, boiling points, vapour pressures, viscosities) and intermolecular forces (hydrogen bonding, Van der Waals) ○ physical properties (e.g. melting points, boiling points, vapour pressures, viscosities) and number and type of functional groups ○ physical properties (e.g. melting points, boiling points, vapour pressures, viscosities) and chain length ○ physical properties (e.g. melting points, boiling points, vapour pressures, viscosities) and branched chains
Substitution, addition and elimination reactions	• *Addition reactions: Unsaturated compounds (alkenes, cycloalkenes, alkynes) undergo addition reactions: ○ Hydrohalogenation: Addition of HX to an alkene e.g. $\text{CH}_2 = \text{CH}_2 + \text{HCl} \rightarrow \text{CH}_3 - \text{CH}_2\text{Cl}$ Reaction conditions: HX (X = Cl, Br, I) added to alkene; no water must be present (During addition of HX to unsaturated hydrocarbons, the H atom attaches to the C atom already having the greater number of H atoms. The X atom attaches to the more substituted C atom.) ○ Halogenation: Addition of X_2 (X = Cl, Br) to alkenes e.g. $\text{CH}_2 = \text{CH}_2 + \text{Cl}_2 \rightarrow \text{CH}_2\text{Cl}-\text{CH}_2\text{Cl}$ Reaction conditions: X_2 (X = Cl, Br) added to alkene ○ Hydration: Addition of H_2O to alkenes e.g. $\text{CH}_2 = \text{CH}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_3 - \text{CH}_2\text{OH}$ Reaction conditions: H_2O in excess and a small amount of HX or other strong acid (H_3PO_4) as catalyst (During addition of H_2O to unsaturated hydrocarbons, the H atom attaches to the C atom already having the greater number of H atoms. The OH group attaches to the more substituted C-atom.) ○ Hydrogenation: ➤ Addition of H_2 to alkenes e.g. $\text{CH}_2 = \text{CH}_2 + \text{H}_2 \rightarrow \text{CH}_3 - \text{CH}_3$

	Reaction conditions: alkene dissolved in a non-polar solvent with the catalyst (Pt, Pd or Ni) in an H₂ atmosphere ➤ Addition of H₂ to alkynes e.g. $\text{CH} \equiv \text{CH} + 2 \text{H}_2 \rightarrow \text{CH}_3 - \text{CH}_3$ Reaction conditions: alkyne dissolved in a non-polar solvent with the Pt, Pd or Ni as catalyst in an H₂ atmosphere
	• *Elimination reactions: Saturated compounds (haloalkanes, alcohols, alkanes) undergo elimination reactions ○ Dehydrohalogenation: Elimination of HX from a haloalkane e.g. $\text{CH}_2\text{Cl}-\text{CH}_2\text{Cl} \rightarrow \text{CH}_2 = \text{CHCl} + \text{HCl}$ Reaction conditions: heat under reflux (vapours condensate and return to reaction vessel during heating) in a concentrated solution of NaOH or KOH in pure ethanol as the solvent i.e. hot ethanolic NaOH/KOH (If more than one elimination product is possible, the major product is the one where the H atom is removed from the C atom with the least number of H atoms) ○ Dehydration of alcohols: Elimination of H₂O from an alcohol e.g. $\text{CH}_3 - \text{CH}_2\text{OH} \rightarrow \text{CH}_2 = \text{CH}_2 + \text{H}_2\text{O}$ Reaction conditions: Acid catalysed dehydration – heating of alcohol with an excess of concentrated H₂SO₄ (or H₃PO₄). Gaseous alkenes e.g. ethene can be produced easier when ethanol vapour is passed over heated Al₂O₃ powder: (If more than one elimination product is possible, the major product is the one where the H atom is removed from the C atom with the least number of H atoms) ○ Cracking of hydrocarbons: Breaking up large hydrocarbon molecules into smaller and more useful bits. Reaction conditions: high pressures and temperatures without a catalyst (thermal cracking), or lower temperatures and pressures in the presence of a catalyst (catalytic cracking). • *Substitution reactions: ○ Interconversion between alcohols and haloalkanes: ➤ Reactions of HX (X = Cl, Br) with alcohols to produce haloalkanes: Reaction conditions: - Tertiary alcohols are converted into haloalkanes using HBr or HCl at room temperature e.g. $\text{C}(\text{CH}_3)_3\text{OH} + \text{HBr} \rightarrow \text{C}(\text{CH}_3)_3\text{Br} + \text{H}_2\text{O}$ - Primary and secondary bromoalkanes: Treat primary and secondary alcohols with concentrated H₂SO₄ and solid NaBr (or KBr). The H₂SO₄ and solid NaBr react to form HBr: $\text{H}_2\text{SO}_4 + \text{NaBr} \rightarrow \text{HBr} + \text{NaHSO}_4$ The HBr reacts with the alcohol to form the bromoalkane: e.g. $\text{CH}_3\text{CH}_2\text{OH} + \text{HBr} \rightarrow \text{CH}_3\text{CH}_2\text{Br} + \text{H}_2\text{O}$ ➤ Reactions of bases with haloalkanes (hydrolysis) to produce alcohols e.g. $\text{C}(\text{CH}_3)_3\text{X} + \text{KOH} \rightarrow \text{C}(\text{CH}_3)_3\text{OH} + \text{KX}$ Reaction conditions: Haloalkane dissolved in ethanol before treatment with aqueous sodium hydroxide and warming of the mixture; the same hydrolysis reaction occurs more slowly without alkali, i.e. H₂O added to the haloalkane dissolved in ethanol ○ Haloalkanes from alkanes (prior knowledge from Grade 11) Reaction conditions: X₂ (X = Br, Cl) added to alkane in the presence of light or heat

Appendix J: Examination guidelines

Knowledge Area	Theme	Marks
Matter and materials ($\pm 33\%$)	Organic molecules	± 50
Chemical change ($\pm 50\%$)	Energy and chemical change Grade 11 Rate and extent of reaction	± 75
	Electrochemical reactions	
Chemical systems ($\pm 17\%$)	Chloro-alkali industry Fertiliser industry Batteries	± 25
TOTAL		150

Appendix K: Pacesetter for term 2

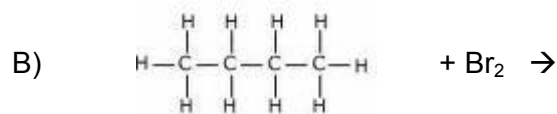
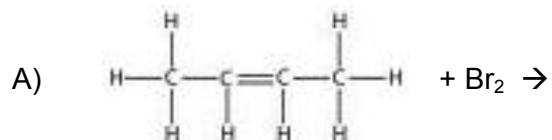
TERM 2							
WEEK 12 12– 16 Apr	WEEK 13 19 – 23 Apr	WEEK 14 26–30 Apr	WEEK 15 3 – 7 May	WEEK 16 10 – 14 May	WEEK 17 17 – 21 May	WEEK 18 24 – 28 May	WEEK 19 31May– 4 Jun
Organic Molecules	Organic Molecules	Organic molecules + Colour	2-D and 3-D Wavefronts + Doppler Effect	Doppler Effect Revision Gr11 Electrostatics and Electric Circuits	Electrical Machines + AC Current	Exams	Exams

University of Cape Town

Appendix L: Sample question from a June Chemistry examination

QUESTION 5

Consider the following reactions



5.1 What will you observe in reaction A? (2)

5.2 Name the homologous series in which A belongs. (2)

5.3 Draw structural formula of the product in reaction A and name it. (3)

5.4 Which reaction will occur readily? (FAST) (1)

[8]

QUESTION 6

Study the three organic molecules given with their boiling points and molecular masses.

NAME	Condensed structure	Molar mass (g.mol ⁻¹)	Boiling point (°C)
Methanol	CH ₃ -O-H	32	65
Ethanol	CH ₃ -CH ₃ -O-H	46	78
Dimethylether	CH ₃ -O-CH ₃	46	-23

6.1 Explain the difference in boiling points of methanol and ethanol. (2)

6.2 Discuss the difference in boiling points of methanol and dimethylether. (4)

6.3 In which homologous series does methanol belong and what is their functional group? (2)

6.4 Which of the above organic compounds will have the lowest vapour pressure? (2)

[10]

Appendix M: Ethics application

EBE Faculty: Assessment of Ethics in Research Projects

Any person planning to undertake research in the Faculty of Engineering and the Built Environment at the University of Cape Town is required to complete this form before collecting or analysing data. When completed it should be submitted to the supervisor (where applicable) and from there to the Head of Department. If any of the questions below have been answered YES, and the applicant is NOT a fourth year student, the Head should forward this form for approval by the Faculty EIR committee: submit to Ms Zulpha Geyer (Zulpha.Geyer@uct.ac.za; Chem Eng Building, Ph 021 650 4791). Students must include a copy of the completed form with the thesis when it is submitted for examination.

Name of Principal Researcher/Student: **René Toerien**

Department: **Chemical Engineering**

If a Student: Degree: **MPhil**

Supervisor: **A/Prof Jenni Case**

If a Research Contract indicate source of funding/sponsorship: **N/A**

Research Project Title: **A case study of the development of the pedagogical content knowledge of in service science teachers in two South African secondary schools**

Overview of ethics issues in your research project:

Question 1: Is there a possibility that your research could cause harm to a third party (i.e. a person not involved in your project)?	YES	NO
Question 2: Is your research making use of human subjects as sources of data? If your answer is YES, please complete Addendum 2.	YES	NO
Question 3: Does your research involve the participation of or provision of services to communities? If your answer is YES, please complete Addendum 3.	YES	NO
Question 4: If your research is sponsored, is there any potential for conflicts of interest? If your answer is YES, please complete Addendum 4.	YES	NO

If you have answered YES to any of the above questions, please append a copy of your research proposal, as well as any interview schedules or questionnaires (Addendum 1) and please complete further addenda as appropriate.

I hereby undertake to carry out my research in such a way that

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

Signed by:

	Full name and signature	Date
Principal Researcher/Student:	René Toerien	6 April 2010

This application is approved by:

Supervisor (if applicable):		21/7/2010
HOD (or delegated nominee): Final authority for all assessments with NO to all questions and for all undergraduate research.		
Chair: Faculty EIR Committee For applicants other than undergraduate students who have answered YES to any of the above questions.		21/6/2010

ADDENDUM 1:

Please append a copy of the research proposal here, as well as any interview schedules or questionnaires:

Draft Research Proposal

1. Title

A case study of the development of the pedagogical content knowledge of in-service science teachers in two South African secondary schools

2. Focal research questions

1. What is the science teacher's pedagogical content knowledge with reference to organic chemistry?
2. What are the implications of the findings in (1) for the development of course material to develop the teachers' PCK?
3. What is the efficacy of a workshop for in service science teachers in terms of their conceptual understanding of organic chemistry?
4. How do science teachers improve their practice? How has a workshop intervention contributed towards the development of PCK of the in-service science teachers?

Questions 1 and 2 will be addressed in the Masters Study and questions 3-4 in the PhD study.

3. Rationale

South Africa introduced a new school curriculum recently and the first cohort of Grade 12's under the new system completed their schooling in 2008. The implementation of this new curriculum and the philosophy underpinning it has been under regular public debate over the last few years. The challenges in implementing the new curriculum coupled with the continuing poor Matric results for Physical Sciences urges us to look more closely at what is happening in our science classrooms.

We have therefore chosen the Grade 12 Organic Chemistry section as the topic of our study. It provides an almost stand-alone section with clear boundaries. This section has historically been considered a 'difficult' section for both teachers and learners and we hope to document what happens when it is taught. This could shed some light on the challenges that exist in our classrooms and guide us in finding effective ways to address the challenges.

4. Conceptual or Theoretical framework

We will be using Shulman's notion of pedagogical content knowledge (PCK) (Shulman, 1986) as a framework for the study, with specific reference to the development of PCK in in-service teachers (Van Driel et al 1998). Shulman constructed this framework to show the interaction between the content that is taught (subject matter knowledge) and the way it is taught (pedagogical knowledge) in a specific context.

The focus of this study will be the interaction of subject matter knowledge and pedagogical knowledge and how these influence the development of PCK for two teachers in a South African context. Rollnick (2008) emphasises the importance of subject matter knowledge in any study on PCK in the South African context since we have a science teacher body with limited content training.

5. Research Design

Data collection

In this study we plan to observe two experienced science teachers in two secondary schools in Cape Town. One school is situated in a township, the other closer to the city, but predominantly drawing on learners from the nearby townships. The two schools form part of UCT's MSEP project and permission to work in these schools have therefore been obtained through MSEP's intervention agreement with the Western Cape Department of Education.

Organic Chemistry is taught in a 2-3 week block during the second term in the Grade 12 year. For the masters study data collection will include lesson observations and semi-structured teacher interviews with each teacher. This data (year 1) will form the baseline for the PhD study. Further classroom observations, interviews as well as pre- and post-workshop surveys will also be conducted during the PhD study.

Included below is the timeline for the study:

Term 2 Year 1 Classroom observations (baseline determination), teacher interviews and development of workshop material

Term 1 Year 2 Teacher's training workshop (pre- and post-surveys)
 Term 2 Year 2 Classroom observation and interviews after the first workshop
 Term 1 Year 3 Follow-up workshop (pre- and post-surveys)
 Term 2 Year 3 Classroom observation and interviews after the second workshop

Instruments used

Lesson observation: All the lessons on organic chemistry will be video-recorded.

Semi-structured interviews will be conducted with each teacher. Three interviews will take place, one before, one during and one after teaching the section.

Interview schedule

The first interview with teacher 1 is scheduled to take place on 12 April and the first round of lesson observations at school 1 will commence on the first day of the term. Lesson observations at school 2 will start on in May for 3 weeks. The first interview with teacher 2 is scheduled for 3 May.

The aim of the interview is to shed light on the following issues:

- The teacher's background in terms of teacher training and teaching experience
- The teacher's view on the context in which he/she is teaching and the constraints he/she experiences
- The teacher's view on what should be taught in this section and how it should be done (Interviews Year 1)
- The teacher's perceptions on the success of his/her teaching (Interviews Year 2 and 3)
- To identify areas that the teacher feels he/she needs additional assistance to improve their practice. This will be incorporated into the course material and discussed in the workshops.

6. Analysis of data

The video recordings of the lessons in year 1 will be analysed to identify the current practices as demonstrated by each teacher. Areas will be identified where a workshop intervention could possibly play a role in developing the teacher's pedagogical content knowledge. The lessons recorded in year 2 and year 3 will be analysed and compared to the baseline from year 1 to identify areas of development and the role that the workshop has played.

7. Research ethics

Throughout the study we will strive to protect the rights of the participants and ensure that the results and consequences of this study will cause no harm to any of the participants.

Teachers have been invited to participate in the study (see letter of invitation attached). Participation is therefore voluntary. The participants will be able to withdraw from the study at any stage without needing to justify themselves.

The participants will be fully informed about the purpose of the study as well as the procedures and time involved, informed consent will therefore be obtained from all participants.

All communication with the teachers, videos of lessons, transcripts of interviews and completed surveys will be handled in confidentiality and will not be made available to anyone not directly involved in the study.

The teacher's names or the names of the schools will not be used to ensure anonymity. Pseudonyms will be used instead.

Although the interviews will be conducted by the researcher, transcriptions will be done by an uninvolved third party.

8. References:

- Abell, S. K. (2008). Twenty Years Later: Does pedagogical content knowledge remain a useful idea? *International Journal of Science Education*. 30 (10) 1405 – 1416.
- Rollnick, M. et al. (2008). The Place of Subject Matter Knowledge in Pedagogical Content Knowledge: A case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education*. 30(10). 1365 - 1387.
- Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4–14.
- van Driel, J.H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching*, 35, 673–695.

ADDENDUM 2: To be completed if you answered YES to Question 2:

It is assumed that you have read the UCT Code for Research involving Human Subjects (available at <http://web.uct.ac.za/depts/educate/download/uctcodeforresearchinvolvinghumansubjects.pdf>) in order to be able to answer the questions in this addendum.

2.1 Does the research discriminate against participation by individuals, or differentiate between participants, on the grounds of gender, race or ethnic group, age range, religion, income, handicap, illness or any similar classification?	YES	NO
2.2 Does the research require the participation of socially or physically vulnerable people (children, aged, disabled, etc) or legally restricted groups?	YES	NO
2.3 Will you not be able to secure the informed consent of all participants in the research? (In the case of children, will you not be able to obtain the consent of their guardians or parents?)	YES	NO
2.4 Will any confidential data be collected or will identifiable records of individuals be kept?	YES	NO
2.5 In reporting on this research is there any possibility that you will not be able to keep the identities of the individuals involved anonymous?	YES	NO
2.6 Are there any foreseeable risks of physical, psychological or social harm to participants that might occur in the course of the research?	YES	NO
2.7 Does the research include making payments or giving gifts to any participants?	YES	NO

If you have answered YES to any of these questions, please describe below how you plan to address these issues:

2.4 Please refer to section on **Research Ethics** in the research proposal for details on participation, consent, confidentiality, and withdrawal.

ADDENDUM 3: To be completed if you answered YES to Question 3:

3.1 Is the community expected to make decisions for, during or based on the research?	YES	NO
3.2 At the end of the research will any economic or social process be terminated or left unsupported, or equipment or facilities used in the research be recovered from the participants or community?	YES	NO
3.3 Will any service be provided at a level below the generally accepted standards?	YES	NO

If you have answered YES to any of these questions, please describe below how you plan to address these issues:

I am including an explanation here as the type of workshop I am planning could be seen as a service to the community.

Teacher training workshops will be conducted as part of this study. The two teachers involved closely in the study as well as other science teachers will be invited to the workshop. The workshop will be free of charge. The aim of the workshops will be to provide content knowledge and teaching methods to science teachers to equip them for teaching the topic of organic chemistry in the school syllabus.

ADDENDUM 4: To be completed if you answered YES to Question 4

4.1 Is there any existing or potential conflict of interest between a research sponsor, academic supervisor, other researchers or participants?	YES	NO
4.2 Will information that reveals the identity of participants be supplied to a research sponsor, other than with the permission of the individuals?	YES	NO
4.3 Does the proposed research potentially conflict with the research of any other individual or group within the University?	YES	NO

If you have answered YES to any of these questions, please describe below how you plan to address these issues:

University of Cape Town



Department of Chemical Engineering

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Fax: (021) 650 5501

Website: www.uct.ac.za · www.chemeng.uct.ac.za

27 May Year 1

**The Chair: Ethics Committee
Faculty of Engineering and the Built Environment
University of Cape Town**

To Whom It May Concern

Re: Additional information for MPhil Ethics Application: Rene Toerien

The ethics application for my MPhil study was handed in on 6 April Year 1. Subsequently I have commenced with my data collection and two issues, as addressed in this letter, came up. This letter therefore provides additional information to my ethics application.

After the first few lessons of classroom observations I realised that I would need some input from the learners to enable me to fully describe the current pedagogical content knowledge (PCK) of the teacher. I therefore needed to make some adjustments to my data collection strategy to enable a more comprehensive reflection of the status quo with regards to the teaching of organic chemistry for each teacher.

The following adjustments were made:

1. Learner participation

To obtain data that reflect the opinions of the learners with respect to organic chemistry and how it was taught, interviews will have to be conducted. Furthermore, the learners could also provide insight into the school context and constraints from the environment in which the school is operating.

Letters asking the parents/guardians for permission to conduct group interviews were handed out and had to be signed and returned before learners could participate in the interviews. The letters were written in English and isiXhosa and are attached below. Learners were asked to volunteer to be part of the group interviews. The first interview with the group of learners took place immediately after teaching the section, and a further interview is planned after the learners have written their exam in June. A third interview might be necessary after the September exam. Pseudonyms will be used for the learners and the name of the school as outlined in the ethics application.

2. Video recording of the classroom activities

It became evident during the video recording of the lessons that I needed a record of the actions of the learners while the teacher was teaching and when classroom discussions were taking place. This would enable me to describe the pedagogical knowledge of the teacher as well as his/her knowledge of the learners. Therefore, for some of the lessons, an additional video recorder was used to capture the actions of the class. The focus was not to identify individual actions and responses, but rather to get a sense of the reaction of the class in general. For this reason, the recordings were generally done from the back of the room.

Yours sincerely

René Toerien
MPhil student: Department of Chemical Engineering



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6 May Year 1

Dear Grade 12 parent

I am a researcher at the University of Cape Town. I am investigating how a section of the Grade 12 Physical Sciences syllabus is being taught in schools. As part of this study, I would like to interview some learners about their experiences of learning science. I would also like to copy their workbooks and exam answers.

The interviews will be voice-recorded. All recordings are confidential and the names of the learners and their school will not be mentioned. Participation is voluntary and a learner can withdraw at any stage, without give reasons for doing so.

If you grant your son/daughter/guardian permission to participate, please complete the reply slip below and return it to school.

Yours sincerely

Mrs René Toerien
Research Officer: Schools Project

I, _____, parent/guardian of _____
Name and surname

give permission that _____ may participate in the study as outlined in this letter by René Toerien, dated 6 May Year 1.

Signature: _____ Date: _____



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6 May Year 1

Mzali Obekekileyo Womntwana okuGrade 12

Ndingumphandilwazi kwiYunivesithi yaseKapa. Ndiphanda ngendlela esifundiswa ngayo isigaba sezifundo zePhysical Sciences kwiBanga leshumi elinambini (Grade 12). Ngenxenywe yesisifundo okanye oluphando, ndingathanda ukuba nodliwanondlebe nabafundi besisifundo, ukuze ndifumane izimvo zabo namava abo ngohlobo esithi isisifundo seScience sifundiswengayo kwizikolo zabo. Ndingathanda ukushicilela okanye ukukopa iiWorkbooks kwakunye namaphepha emibuzo neempendulo zeemviwo zabo zeScience.

Oludliwanondlebe luquka ukushicilelwa kwamazwi (i.e. will be voice-recorded). Lonke ucishilelo luyakuthi lube yimfihlo, kwaye namagama abafundi nezikolo zabo akayi kukhankanywa naphi na. Umntu uyazikhethela ukuxhasa nokuba yinxenye yoluphando, kangangoko anganako ukuyeka nangasiphi na isigaba, engakhange anike zizathu zoko.

Ukuba ngaba uyamnika imvume umtwana wakho yokuba athathe inxaxheba koluphando, nceda ugcwalise eliphethshana lingezantsi, uze wakugqiba ulibuyisele esikolweni.

Owenu othembekileyo

Mrs René Toerien

Research Officer: Schools Project

Mna, ... , umzali/mgadi ka
Igama neFani

Ndiyavuma ukuba u angaba yinxenye yoluphando lukhankanywe
ngu René Toerien, umhla 6 May Year 1.

Signature: Umhla/Date:

Appendix N: Teacher confirmation letter



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Telephone: (021) 650 2518
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Website: www.uct.ac.za · www.chemeng.uct.ac.za

[Date]

Dear Nomsa

Thank you for agreeing to participate in this study. This letter serves to confirm some of the details that we discussed at the end of last term.

As agreed, I will be visiting you and observing the organic chemistry lessons that you present to your Grade 12's from the 12th of April for about 2-3 weeks. I would like to observe both your classes and also the afternoon sessions if you teach any of them.

I would also like to arrange an informal interview with you before you start teaching, halfway through teaching the section and then again at the end. The purpose of the interview is firstly to obtain some background on your school and the learners you are teaching and also to get a sense of what you plan to teach. The second and third interviews would probably focus more on what was taught and how it went. The interviews will be voice-recorded.

As far as my classroom observations go, I would like to video record all the organic chemistry lessons so that I have a complete record of all the lessons taught. The video recordings, interview recordings and all other documents that I might collect from you will be treated as confidential and the content thereof won't be disclosed to anyone that is not directly involved in the study.

Your name and the name of your school will not be mentioned, but pseudonyms will be used instead. You will have access to any writing that I do on the project, for my thesis or for research papers should you wish to read any of it.

As discussed in our earlier conversation, your input in terms of the development of resource material for further use in teacher workshops is very important to me. One of the aims of the course material is to address the need that exists in schools and I see this study as having a direct input into this. I believe that you have valuable teaching experience that can be used to inform such resources.

Should you need to discuss anything about this study, please feel free to contact me, or Jenni Case, my supervisor, at jenni.case@uct.ac.za or 021 6502751 or 0794912485.

I am looking forward to spending some time in a classroom again.

Yours sincerely

Signed by candidate

René Toerien

UCT Chemical Engineering Schools Project
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Fax: 086 607 0186
Cell: 083 557 7459
Email: rene.toerien@uct.ac.za