How teachers construct teaching-learning sequences in chemistry education in the Further Education and Training phase

by

Doras Sibanda

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PREFACE

The work described in this thesis was carried out in the School of Education, University of Kwazulu-Natal from December, 2009 to November, 2013 under the supervision of Prof Paul Hobden. This study represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others, it is duly acknowledged in the text.

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Candidate: Doras Sibanda Date

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Supervisor: Prof Paul Hobden Date

ABSTRACT

The purpose of this study was to understand how teachers design and implement teaching-learning sequences. A teaching-learning sequence can be described as a well-coordinated step by step series of teaching and learning activities designed to improve chemistry knowledge. This study investigated how physical science teachers plan teaching-learning sequences for chemical bonding in the Further Education and Training Phase (Grade 10 to 12). In South Africa, learners in grades 10 to 12, study Physical Science which is a combination of physics and chemistry topics. The main goal of the study was to understand the different patterns of teaching-learning sequences used by physical science teachers to teach chemical bonding and establish the reasons for using such sequences. A convenience sample of 227 practising physical science teachers completed a survey questionnaire, and 11 participants were selected for semi-structured interviews. This mixed method study also included an analysis of policy documents and a popular textbook. Qualitative and quantitative data were analysed separately and outcomes were compared, combined, and discussed. In this thesis, I present an argument about how teachers design and implement teaching-learning sequences for chemical bonding. I propose a teaching-learning sequence for teaching chemical bonding in the FET Phase. Three aspects emerged on sequencing chemistry topics or concepts. Firstly, teachers suggested a variety of different sequences for teaching both the topics in general chemistry and for the concepts in the specific topic of chemical bonding. There were some similarities among the sequences. In general the sequences suggested did not match that provided in the curriculum documents. Secondly, teachers indicated that they used policy documents to establish the prescribed general chemistry content to be taught but their teaching of the topic of chemical bonding was usually based on previous teaching sequences and they make minor changes every year. Thirdly, they gave various reasons why they used different teaching-learning sequences. For example, sequencing to facilitate learning requires a logical order of topics and recognition of prior knowledge. They indicated that chemical bonding was particularly problematic and teachers' knowledge was considered a significant factor to the design and success of a teaching sequence.

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DEDICATION

To my husband Precious, and our children Simiso and Sindiso.

ABBREVIATIONS

ACE	Advanced Certificate in Education
ANOVA	Analysis of Variance
B.Ed.	Bachelor of Education
BSc	Bachelor of Science
CAPS	Curriculum and Assessment Policy Statement
CoRes	Content Representations
ERM	Education Reconstruction Model
FET	Further Education and Training
FDE	Further Diploma in Education
GET	General Education Training
KZN	Kwa Zulu Natal
NSTE	Norms and Standards for Teacher Education
PaP-eRs	Pedagogical, and Professional-experience Repertoires
PCK	Pedagogical Content Knowledge
PK	Pedagogical Knowledge
PGCE	Postgraduate Certificate in Education
NCS	National Curriculum Statement
OBE	Outcomes Based Education
SMK	Subjects Matter Knowledge
SPSS	Statistical Package for Social Sciences
STD	Senior Teacher Diploma
TIMSS	Trends in International Mathematics and Science Study
TLS	Teaching-learning Sequence
VSEPR	Valence Shell Electron Pair Repulsion Model

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CHAPTER 1 INTRODUCTION

The teaching and learning of chemistry is considered to be difficult because it involves the use of different representations and models (Johnstone, 1991). According to Johnstone (1993) there are various reasons why chemistry knowledge is difficult for learners. For example the methods of teaching is one of the reasons cited as contributing to learning difficulties experienced by learners. According to Johnstone, there is evidence that efforts have been made to improve the quality of teaching, but not enough attention has been given to the nature of the chemistry content. The nature of chemistry knowledge is different from other sciences like physics, because chemical knowledge is mainly based on models that are used to understand the qualitative aspects of matter (Scerri, 1996). The teaching of chemistry requires teachers to have a deep understanding of these models in order to be able to assist learners to make sense of chemistry concepts. Most chemistry topics are abstract and require teachers to organize the sequence of teaching activities so that knowledge of the new topic draws on the prior knowledge from a previous topic (Jonstone, 1991). Consequently, chemistry teachers need advice and expertise in organizing and presenting teaching-learning sequences (Leach & Scott, 2002). However, a minority of the research in chemistry education has focused on teaching-learning sequences. Most research in chemistry education centres on issues of subject matter, misconceptions, chemical language, and pedagogical content knowledge. There would appear to be a need to understand both the teaching-learning sequences of the general topics in chemistry and the teaching-learning sequence to develop the concepts within particular topics e.g. chemical bonding, which topic is the focus of this research study.

This chapter provides an overview of teaching and learning issues in chemistry education, the background of the study, purpose of the study, personal motivation to undertake the study and problems the study intends to address.

1.1 Background of the study

In South Africa there are challenges of teacher quality, with science teaching and learners' achievement in science being significantly below that of comparable developing countries such as Brazil and India (TIMSS, 2011). There are also philosophical issues pertaining to some of the problems experience in the teaching of chemistry. For example, the First International Conference on Philosophy of Chemistry was held comparatively recently, only in 1994 (Erduran, 2001). Learners usually view science, particularly chemistry, as a difficult subject since it generally involves many new and unfamiliar concepts (Jonstone, 1993). Previous studies have focused extensively on students' conceptions of science and this has resulted in extensive documented evidence on topics perceived to be difficult for students to learn and understand (see for example, Bradley, Gerrans, & Long, 1990; Chui, Guo, & Treagust, 2007).

There is growing worldwide concern about the lack of improvement in learners' performance in science and their general lack of interest in chemistry education. According to Bucat (2004), science education research has not had the impact on science teaching that we might have hoped for and is still in search of direction. In response, some countries have made an effort to encourage researchers to seek a deeper understanding of what happens in the classroom and to explore ways of improving the performance by both learners and teachers (Osborne & Collins, 2001). Most of the approaches followed monitoring what happens in the classroom and aim to provide activities that assist learners to experience and see chemistry as relevant to their learning needs. For example, research into teaching-learning sequences has been employed to understand learners' experience and the purpose of lessons at every step of the teaching and learning process (Bulte, Westbroek, Van Rens, & Pilot, 2004). Consequently, there is a need for studies on how these teachers choose teaching-leaning sequences.

1.2 The purpose of the study

The purpose of this study was to understand how teachers design and implement teaching-learning sequences. In this study a teaching-learning sequence means a well-coordinated step by step series of teaching and learning activities. A teaching-learning sequence can also be described as a complex activity that involves the interaction between knowledge, learning, and teaching (Buty, Tiberghein, & Le Marechal, 2004). In addition, Meheut and Psillos (2004) described a teaching-learning sequence as a linkage between proposed teaching and what students are expected to learn during topic-oriented lessons. A more detailed description of teaching-learning sequences is given in Chapter 2.

Focusing the study on teaching-learning sequences provided an opportunity for this research to contribute to knowledge production since it appears that very little documentation exists on the decisions made by teachers to design and use particular teaching-learning sequences to teach various topics in science (Meheut & Psillios, 2004). This idea was further echoed by Lijnse and Klaassen (2004) who insisted that there was still little information published internationally about teaching-learning sequences. Lijnse and Klaassen argued that specific aims for teaching chemistry have been agreed upon, but there is still no agreement on the best ways to teaching a particular topic. It has been shown in previous research that the order in which learners encounter the concepts makes a difference in terms of how successfully they achieve the learning outcomes (Contreras, 1988; Shayer & Adey, 1981; Taber, 1997). In other words the order or sequencing of chemistry concepts plays an important part in concept building. Consequently, it can be argued that there is a need to study teaching-learning sequences in chemistry at high school level in order to improve the quality of teaching in this discipline.

This study focused on the topic of chemical bonding and its associated concepts in the FET Phase i.e. Grades 10 to 12. I decided to focus this study on the topic of chemical bonding because it is one of the central topics in chemistry and, in particular, topics such as acids and bases, chemical energy, thermodynamics, carbon chemistry, proteins and polymers are dependent on the understanding of chemical bonding (Nahum, Malo-Naaman, Hofstein, & Krajcik, 2007). Furthermore, chemical bonding is viewed as difficult by students, teachers, and chemists (Taber, 1998). In addition, a review of the literature about how chemical bonding was taught and learnt showed that the topic was neither easy to teach nor to learn. Some of the problems associated with teaching chemical bonding emanate from the traditional approach of teaching the topic and the manner in which content was presented in the chemistry textbooks worldwide (Nahum, Mamlok-Naaman, Hofstein, & Taber, 2010).

1.3 Motivation to undertake the study

The motivation to carry out this study was guided by two desired outcomes; personal development, and discipline oriented conceptual issues. The personal motivation and impetus to carry out this study draws substantially from my twelve years of personal experiences as a high school physical science teacher. Learners generally battled to understand various chemistry concepts and I wanted to find possible ways of teaching chemistry content that can be easily understood by most learners.

Concerning the discipline factors, firstly chemistry is perceived to be a difficult subject compared to other sciences, and so most students have shown a lack of interest to study it at higher institutions of learning in South Africa and elsewhere (Smith, 2006). The teaching and learning of chemistry continue to present challenges for educators (Costa, Marques, & Kempa, 2000). Secondly, knowledge plays a pivotal role in the teaching and learning of concepts (Rollnick, Bennet, Rhemtula, Dharsey, & Ndlovu, 2008; Wandersee & Griffard, 2002). Educators are expected to be familiar with content knowledge in chemistry, and to translate their chemical content knowledge into teachable content knowledge in order to promote students' understanding. For example the knowledge required to teach stereochemistry is different from the knowledge for teaching thermodynamics, yet all these topics fall within the discipline of chemistry.

Considering studies reviewed by Meheut (1997), content knowledge was used as a starting point for the design of teaching-learning sequences. In these studies, authors also made reference to student learning difficulties, students' common sense understandings and the manner in which they reason when given a particular problem to solve. Evidence from institutions of higher learning has shown that students in chemistry experience learning difficulties with many concepts. Taber, (2001) observed that students fail to transfer information learned in one lesson to another. There is evidence that some students' difficulties with chemical bonding emanate from the use of different models. For example, students' have difficulties "finding a model of melting and vaporization, which enabled bonds to form when particles were in close contact" (Nahum et al., 2010, p. 185). There is need for teachers to plan teaching sequences particularly carefully in order to promote better understanding.

In spite of the apparent need, there has been very little published on teaching-learning sequences (Meheut & Psillos, 2004; Millar, Leach & Osborne, 2000). This was confirmed in the review of three international journals in science education from 1998 to 2002 by Tsai and Wen (2005). These authors found that the "research topic of conceptual change and concept mapping were the most studied topics, although the number of publications has slightly declined in the 2000's' (p. 315). Similar trends were also observed by Lee, Wu and Tsai's (2009) study on trends in science education from 2002 to 2007. The study by Lee et al. was a follow up to that of Tsai and Wen (2005). Lee et al. found that science researchers showed "relatively more interest in research topics involving the context of student learning" (p. 1999). There would appear to be a need to undertake more research on the different teaching strategies that teachers use to focus on concept building and knowledge construction (Lijnse & Klaassen, 2004; Tiberghien, Vince, & Gaidioz, 2009). Previous research (Meheut, 1997) has shown that teaching-learning sequences studies tended to focus on the students' point of view about a particular topic sequence, while very little has been documented on the role played by the teacher in the design and evaluation of these teaching-learning sequences. There is a variety of ways in which researchers design and validate teaching-learning sequences. For example, Meheut's review (1997) showed that previous studies focused on developing, testing and evaluating specific teaching learning sequences, using an experimental approach to design and evaluation.

The current study differs from some of the studies reviewed in the literature in terms of the method used to study teaching-learning sequences. It tried to understand how teachers design and implement teaching-learning sequence for chemical bonding in the FET Phase. As mentioned above, there appears to have been very little research aimed at the detailed analysis of teaching-learning sequences in chemistry education, particularly in the South African context. The rationale to use a different approach from previous studies was governed by the desire to understand how teachers plan teaching-learning sequences with a view to developing teaching-learning sequences for teaching chemical bonding based on the teachers' knowledge of chemical bonding.

In summary, the current study provides a description of patterns of teaching-learning sequences used by South African physical science teachers to teach chemical bonding in the FET Phase. Firstly, the study aims at providing descriptions of different topics and concept sequences in the teaching of chemistry in the FET Phase. Secondly, the study provides an understanding of how teachers construct teaching sequences to teach chemical bonding in the FET Phase. Thirdly, the study seeks to understand why teachers tend to use particular teaching-learning sequences for teaching chemical bonding.

Research Questions

In accordance with the purpose of the study, which is to understanding the nature of the patterns of teaching-learning sequences used by teachers in the FET Phase, the aim of the current study was to provide answers to the following four research questions :

1. What teaching-learning sequences are used by teachers to teach general chemistry in the FET Phase?
2. What teaching-learning sequences are used by chemistry teachers to teach in the case of chemical bonding in the FET Phase?
3. How do the teachers construct the teaching-learning sequences to teach chemical bonding?
4. Why do the teachers use these teaching-learning sequences to teach general chemistry and in particular chemical bonding, in the manner that they do?

Scholars in mixed methods research such as, Johnson and Onwuegbuzie (2004) and Teddlie and Tashakkori (2003) advocate the use of pragmatism as a paradigm for mixed methods studies. After a review of different paradigms for mixed methods, I was convinced that the appropriate philosophical stance for the current study was pragmatism. The reason for locating the study within the pragmatic paradigm was because this paradigm, according to Creswell (2003) allows the researcher to mix data collection methods and data analysis procedures within the research process. The pragmatic paradigm has what Creswell (2003) described as permission to study areas that are of interest, embracing methods that are appropriate and using findings in a positive manner in harmony with the value system held by the researcher. According to Creswell (2003) pragmatist researchers link the choice of approach directly to the purpose of and nature of the research questions. Based on the reasons above, the use of mixed methods fits with the pragmatic approach to the current study. Details about the research design and methodology are presented in Chapter 3.

1.4 Structure of the thesis

The thesis is made up of seven chapters. Chapter 1 has presented an introduction to, the background of the study, the purpose of the study and the motivation to undertake the study. Chapter 2 presents the theoretical framework that underpins the study and a review of the associated literature. Chapter 3 explains the research design and the methods employed to collect both quantitative and qualitative data and how the analysis of data was conducted. The findings of the study are reported separately in the following three chapters. Chapter 4 reports the results of the first and second research questions. Chapter 5 reports the results of the third research question and Chapter 6 reports the results of the fourth research question. The results are reported in line with the methodology, whereby quantitative results are reported first followed by qualitative results. In Chapter 7, conclusions of the study, its limitations and implications are presented.

CHAPTER 2
LITERATURE REVIEW AND THEORETICAL FRAMEWORK

The previous chapter provided the rationale and background of the study. This chapter reviews literature dealing with teaching-learning sequences and the theoretical frameworks that were selected from the literature on previous studies. It examines four broad issues relating to teaching-learning sequences. Firstly, the chapter attempts to describe on the meaning of teaching learning sequences, secondly, it examines the context of the study and thirdly, it describes the theoretical framework and related studies. Finally, there is a review of the literature on the teaching of chemistry and specific misconceptions related to chemical bonding.

2.1 Meaning of teaching- learning sequence

There are different ways of studying and interpreting teaching-learning sequences. Some researchers, for example, Leach and Scott (2002) view a teaching-leaning sequence as consisting of stages within a particular lesson. These stages involve the following aspects: (a) staging the scientific story, (b) supporting students and (c) handing over responsibility to students. Similarly, Viennot and Rainson (1999) described a teaching-leaning sequence as a way of ranking teaching activities whilst Lijnse (1995) suggested that teaching-leaning sequences were cyclic learning processes drawn from research data. Other researchers, for example Meheut and Psillos (2004) describe a teaching-leaning sequence as an "interventional research activity and product" (p. 516). In this study, I adopted a definition which is closest to that of Viennot and Rainson (1999) because the current study viewed the order of teaching activities as important in conceptual development of chemistry knowledge. In this study teaching-leaning sequences were viewed as a systematic way of presenting learning activities to students in a series of activities aimed at concept development.

There is need for teachers need to plan and organise their teaching activities in order to make it easy for learners to follow the teaching sequences in each lesson. The discussions indicate that teaching-leaning sequences are defined differently, by different researchers. The context at which teaching and learning take place is crucial. The following section discusses the context of current study.

2.2 The context of the study

The context of the study was framed by aspects that have a direct influence on sequencing in chemistry education. For example the availability of resources and teacher quality has a direct influence on the quality of education (TIMSS, 2011). The following section discusses three aspects that contribute to the context of the current study, namely, the quality of education in KwaZulu-Natal, the chemistry education curriculum and outcomes-based education.

2.2.1 The quality of education in KwaZulu-Natal

The KwaZulu-Natal Provincial Treasurer commissioned a study of how to improve the quality of education in the province (Hugo et al., 2010) and this report provides a picture of schooling in the province within which the current study took place. Amongst other things, it reported on the type and number of schools, poverty levels, and teachers' qualifications. The data indicate that about 61% of the teachers are qualified with matric plus four years of training. This is what is considered as a "qualified teacher" in the report. The study further revealed that if a degree was a requirement, 80% of the teachers would not be considered "qualified". This is of concern to South African authorities because studies such as Trends in International Mathematics and Science Study (TIMSS, 2011) have shown that better performing countries have teachers with a bachelor degree or postgraduate qualifications. The KZN study showed that about 12000 educators were under qualified. Comparison of teacher qualifications in rural and urban schools showed that rural teachers were less qualified. For example, the rural area at Vryheid, had 48% qualified teachers compared to Pinetown, which is urban, where 69% of the teachers were qualified.

In terms of school resources, the KZN study found that 54% of the schools were rated as excellent, 17% were rated as good, 14% were said to be poor and 15 % of the schools were very poor. If the results are aggregated for good and excellent schools 71% of the schools have adequate teaching facilities. The recent trend in South Africa is that textbooks are viewed as important and teachers are encouraged to rely on them (Chisholm, 2012). One of the recommendations from the KZN study was that teachers should be supported with well sequenced teaching materials that promote conceptual understanding of the subject taught (Hugo et al., 2010, p. 113).

Most schools that were built before 1994 can be presumed to have fewer resources due to the then current apartheid resource allocation model. In particular, when considering the teaching of Physical Science, most of these schools did not have science laboratories. On the other hand, in the new South African dispensation, schools built after 1994 (end of apartheid) should have laboratories. However, the KZN study indicated that the rate of infrastructure development has been rather slow; for example from 2006 to 2009 only 49 school laboratories were built in KwaZulu-Natal.

Consequently it can be assumed that the current study took place in a context in which some schools have under qualified teachers and inadequate resources. The teaching of physical science in KZN could be considered to be compromised; for example lack of resources implies that little practical work is carried out at school and this has in all likelihood affected the quality of teaching and learning. The following sections discuss the chemistry education curriculum.

2.2.2 The chemistry education curriculum

The curriculum policy documents inform the teaching of chemistry at high school. Chemistry is taught as part of the Physical Science curriculum in South Africa. It is given equal emphasis to Physics in the published curricula. The current study was carried out during the period of implementation of the National Curriculum Statement (Department of Education, 2006) and all policy documents and teacher references in this study refer to this curriculum (NCS). Currently a new curriculum is being introduced called the National Curriculum and Assessment Policy Statement (Department of Education, 2011). The first stages of implementation in the FET took place after the study data had been collected. While the chemistry content is virtually identical, the curriculum is seen as more detailed and very specific on what needs to be taught. In this study the use of the term "chemistry education" refers to the study of teaching and learning of chemistry in schools whilst the term "chemistry" is used to refer to the content and methods associated with the branch of science concerned with understanding what matter is made of.

In general, the NCS curriculum document provides list of topics or concepts, without necessarily showing their interrelation. For example, in chemistry education, the meaning of a concept is usually determined by the way in which it is related to other concepts. According to De Vos, Berkel and Verdonk (1994) the coherence of concepts was often neglected in both curricula and textbooks. In particular, these authors analysed textbooks and course outlines from various countries and found that the textbooks and various teaching documents did not provided a coherent interrelationship of concepts.

The literature also shows that, in some cases, textbooks are written by people who do not focus on accessibility of content to the learners. To be specific, Yoblinski (2003) analysed topic sequences in seven general chemistry textbooks at first year university level and found that the first four to five chapters had identical sequences. He also requested students to comment on the topic sequence found in the textbooks. The students' comments showed that some topics were not linked during the teaching of chemistry. As an example, a student suggested that the topic on enthalpy should be taught in the same semester as thermodynamics. Yoblinski's study indicates that when teaching and learning activities are not properly sequenced in a course, students are frustrated and less motivated to study chemistry. Similarly, in the De Vos, Berkel and Verdonk (1994) and Yoblinski (2003) studies, the issue of topic coherence was considered. There is an indication from the two studies that textbooks do not always provide a coherent teaching sequence. Yoblinski then recommended that college teaching and learning of chemistry should follow a carefully considered teaching sequence. In terms of the context of the current study it is not clear how carefully the sequences were considered before publishing the curriculum.

The chemistry curriculum is only one component of a national curriculum. Consequently, the prevailing national system of education and associated curriculum policy will influence the nature of the implemented chemistry curriculum. Understanding the context in which chemistry is taught requires understanding South African outcomes-based education policy. The following section discusses outcomes-based education.

2.2.3 Outcomes based education

The South African education system has gone through a number of curriculum changes within a short period of time, all embracing the notion of outcomes-based education. The curriculum C2005 was the South African strategy for implementing OBE. This was revised in 2010, but its effects were still felt at time of data collection for the current study. Studies such as TIMSS 2011 indicate that the system has not produced improvements in the classroom. Lack of funding and resources for teaching physical science are put forward as the reasons for slow progress (Rogan & Grayson, 2003). In general, an outcomes based curriculum encourages teachers to design their own teaching sequence that leads to the achievement of teaching outcome.

The National Curriculum Statement (Department of Education, 2006) states that "outcomes based education (OBE) forms the foundation for the curriculum in South Africa, it strives to enable all learners to reach their maximum learning potential by setting the learning outcomes to be achieved by the end of the education process, OBE encourages a learner-centered and activity-based approach to education" (p. 2). In other words, the premises of OBE are very noble and make the teaching of any learning area focus on learners, rather than the topics. If the notion of OBE is to encompass all learners, then the issue of relevant teaching resources, as shown in the previous section becomes even more significant in South Africa.

In terms of the curriculum content, Donnelly (2007) lamented the fact that an OBE curriculum does not state clearly what the teacher should teach and this has caused confusion amongst the teachers as to what to teach. Along these lines, Berlach (2004) examined how OBE was interpreted and implemented in Western Australia and so identified some perceived deficits of OBE. He found that amongst other problems the guides developed in Australia to supplement the OBE curriculum documents did not provided well sequenced content, "teachers ended up teaching anything at any time" (p. 8).

Furthermore, class time in OBE was overloaded with assessment. Consequently, teachers' workload increased under OBE because they have to keep a trail of evidence about each learner. Some countries have designed coherent teaching materials that focus at improving students' understanding of chemistry, as shown by Ware (2001). She studied the notion of teaching chemistry from a societal perspective, looking at two chemistry courses, namely Chemistry in the Community and Chemistry in Context. She found that both courses focused on;

> Presenting chemistry starting from a societal context (US cultural context).
> Macroscopic and particulate levels of comprehension of chemistry (e.g. computer animations, models and graphs).
> Inquiry based laboratory activities (investigations).
> Symbolic representations of chemistry (chemical equations).

She concluded that the manner in which the chemistry content was presented in the two courses made chemistry knowledge accessible to students and it improved their interest in chemistry. The link between the current study and Ware's study is that both studies focus on the sequence of presenting science concepts within an OBE curriculum.

Another criticism of OBE curricula is their lack of clarity (Donnelly, 2007). The South African Physical Science National Curriculum Statement (NCS) is open to this criticism. It does not explain how teachers should teach scientific knowledge to learners. As an example, the NCS grades 10-12 states one learning outcome as "the learner is able to state, explain, interpret, and evaluate scientific and technological knowledge and apply it in everyday contexts" (Department of Education, 2006, p. 44). This learning outcome is, however, not linked directly to specific concepts that are taught. For example, for the unit "Atomic combinations: molecular structure", the suggested topics to be taught, listed in the NCS document, indicated that "a chemical bond is described as the net electrostatic force between two atoms sharing electrons; chemical bonds as explained by Lewis theory and represented using Lewis diagrams, electronegativity of atoms to explain the polarity of bonds" (Department of Education, 2006, p. 45). There is no specific link between the learning outcome and how teachers should teach the specific concepts so that the outcomes are achieved. Recently this problem of lack of clarity in the policy documents was partially addressed by the introduction of the Curriculum and Assessment Policy Statement (CAPS) which gave more clarity on what the teachers should teach about a particular topic. To illustrate, the topic on chemical bonding has specific content descriptions such as covalent bonding, ionic bonding, and metallic bonding aligned to the activities that the learners should be engage in (Department of Education, 2011, p. 26).

The discussions above indicate that because teachers were operating within this OBE curriculum policy framework, they were influenced in their individual design of teaching-leaning sequences in chemistry education. OBE policy encouraged teachers to design their own teaching-learning sequences by failing to provide detailed curriculum topic sequences and instructions.

2.3 Theoretical frameworks

The literature review presented in section 2.4 will illustrate that studies on teaching-learning sequences tend to use a particular theoretical framework as a basis for analysing and understanding sequences. Consequently, it is relevant to outline the role of theoretical framework in this current study at this stage.

A theoretical framework is a theory that guides the conducting of the research and interpretation of the data. The choice of a theory is influenced by the researcher's understanding of the problem and by the research paradigm in which the researcher is situated. The framework is used by researchers as a lens or tool to understand, make sense and make meaning of the findings (Guba & Lincoln, 1994; Smyth, 2004). In the current study the model of educational reconstruction was used as the primary theoretical framework to interpret data. The learning demand tool and the theory of pedagogical content knowledge (PCK) were used as ancillary theoretical frameworks in the analysis and interpretation of the data. The decision to use learning demand was determined by the researcher's need to understand the steps applied by the teachers during the design of teaching-learning sequences. The PCK model was used to explain teachers' understanding of chemical bonding and how they teach it (Van Dijk & Kattmann, 2007). This study was diverse in the sense that it encompasses theories of teaching chemistry content, planning, organizing of teaching activities and the actual teaching of chemistry in the classroom. Given the diverse areas of focus, these multiple theoretical lenses were, in my opinion, appropriate for this study.

2.3.1 The Model of Education Reconstruction

The Model of Education Reconstruction (MER) is a framework for improving instructional planning and science education research (Duit, 2007). It has been used by different researchers to study the development and evaluation of teaching-learning sequences (Komorek & Duit, 2004). According to Duit (2007), MER can also be used to facilitate a balance between the subject matter and other educational issues. MER can also be used as a tool and a theoretical framework for designing and evaluating teaching-learning sequences. One of the strengths of MER is that it 'shares features with other models of instructional design that aim at improving practice' (Duit, Gropengieber, Kattmann, Komorek & Parchmann, 2012, p. 25) and it explicitly draws views from well-established theories such as the constructivist framework (Driver & Oldham, 1986; Duit & Treagust, 2003). The constructivist theory views a student as capable of constructing his/her own knowledge based on everyday experiences and suggests that the ideas that students bring to the classroom must be used as a basis for constructing new knowledge. A diagram of the model of educational reconstruction appears in Figure 2.1.

The MER, as shown in Figure 2.1, consists of three main components. These are analysis of content structure, research on teaching, learning and development and the evaluation of instructional design. Each of these is described below.

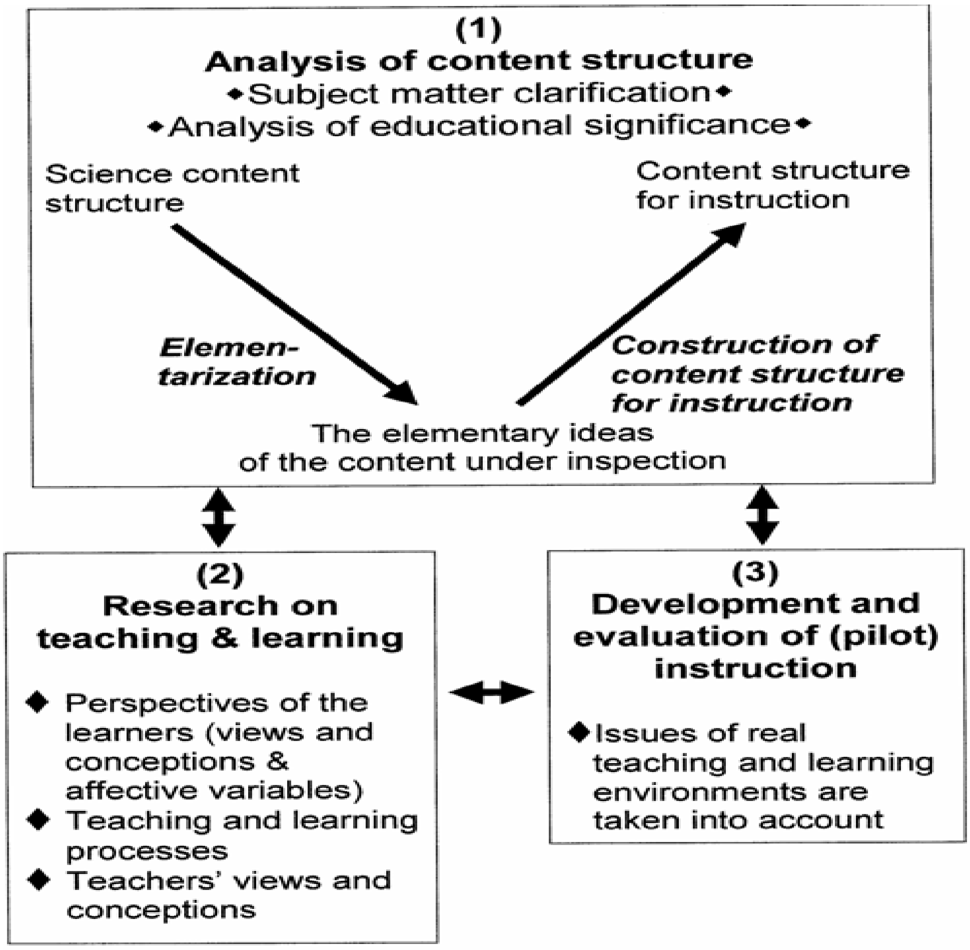

Figure 2. 1 Model of Educational Reconstruction (Duit, 2007, p. 6)

Analysis of content structure

At the analysis stage of planning a teaching-learning sequence, subject content can be reorganized through the process of elementarization in order to prepare content for instruction at a particular grade. According to Duit et al. (2012), the process of elementarization, illustrated in Figure 2.1, brings out the basic ideas of science content in a topic, which in turn inform the "construction of the content structure for instruction, indicate a special contribution of the model" (p. 26). For example, MER can be used to interpret the content for teaching, the teaching process, and the nature of science and the application of science in society. It can also be used to interrogate content for the intended curriculum (what needs to be taught according to the policy document) and the implemented curriculum (what is actually taught in the classroom).

Research on teaching and learning

Apart from the analysis of subject content, the MER requires the inclusion of research which explains how students learn science, as well as their beliefs and conceptions about different science topics. As illustrated in Figure 2.1, Component 2 of MER (research on teaching and learning), can be used to provide explanations of teachers' thinking during lesson preparation, actual teaching, and why teachers act in a particular manner during the teaching of a sequence. Component 2 can be used by researchers to focus attention on teachers' views on teaching and learning processes in their own classroom situations. It can also be used to explain and interpret the use of different instructional methods and monitor students' academic progress (Duit, 2007). In the current study, component 2 of the MER was used to provide an understanding on how teachers design and implement teaching-learning sequences.

Development and evaluation of instructions

In addition, MER can be used in the design and evaluation of teaching sequences. According to Duit (2007), the third component of MER provides an explanation for the relationship between development, research, and instructional practices. Component 3 of MER was largely developed around the need to engage research techniques in both developmental and instructional methods of teaching and learning of science. However, this study did not use this aspect of MER.

The advantage of using MER as a theoretical framework is that it is cyclic and this allows researchers to evaluate a teaching-learning sequence at any stage (Duit, 2007). The MER thus makes it possible for the researcher to reconstruct scientific knowledge both before and after the knowledge is taught to the learners. The MER can also be used to explain teachers' thinking and their actions and their views on teaching and learning process. It can also offer a reasonable explanation of the design and evaluation of learning activities and teaching-learning sequences. In the current study only two components of MER are relevant, that is analysis of content structure and research on teaching and learning. The study does not consider the evaluation of the instructional teaching nor how learners respond to such instructions. Rather, in the current study, the MER was used to interpret and understand how teachers design and implement teaching learning sequences for teaching chemical bonding in the FET Phase.

Many studies on design and evaluation of teaching-learning sequences have used the MER as a theoretical framework. To illustrate, Meheut (1997) presented an analysis of two teaching-learning sequences on the particle models of gases, each of which provided a clear description of the teaching-learning sequence. Following this analysis, Meheut used the MER as a framework to develop and evaluate both teaching-learning sequences. In Meheut's study learners carried out prescribed tasks and an experimental approach was used to obtain information about the effectiveness of the teaching-learning sequences used. Some of the students were taught using the teaching-learning sequences prescribed by Meheut and others were taught using a traditional approach. Meheut compared the efficiency of short-term (at the end of a teaching-learning sequence) and long term (two years later) learning by assessing the learners at the end of each stage. The findings showed that learners who participated in Meheut's teaching sequence used a particulate model more often than those who did not participate in his teaching learning sequence study. Meheut's findings suggest that the use of teaching-learning sequences might result in better understanding of chemistry concepts by learners. In a follow up study; Meheut (2005) also used the MER as a theoretical framework for the design of teaching-learning sequences. In this study Meheut specifically asked students to develop particle models, explain these models and to predict physical events based on the listed models. Meheut further asked students to pay attention to the following information to guide them in the design of the models:

> Features of the particle model of matter
> Students were to use their rational rather than empirical origins of particles of matter
> Students were asked to use the statutes of the model as instruments for thinking rather than providing explanations based on observations
> Students were asked to provide features of the models based on their mechanical analogy (Meheut, 2005)

Meheut's study indicates that teaching-learning sequences designs are guided by the inclusion of relevant information about the activity. The limitation of Meheut's study was that students were asked to work on specific ideas while other issues, like the role of teachers in the design of teaching-learning sequences were not considered. The current study is different from Meheut's study in the sense that it did not provide teachers with guidelines to work from, but tried to establish the nature of the teaching-learning sequences already used by teachers.

The teaching-learning sequences in nonlinear systems in physics were studied by Komorek and Duit (2004) who used the MER as a theoretical framework. They used teaching experiments as a research method to investigate the teaching and learning process that took place within a particular topic. Their research focused on four phases such as; explicit expectation before the first presentation, individual explanation after the first test, generalization phase I, and generalization phase II. They developed a teaching unit on nonlinear systems as the final product of the research and the teaching unit included reflections on students' conceptions and learning difficulties on the topic of nonlinear systems. The focus of Komorek and Duit's study is similar to Meheut's (1997, 2005) since both studies emphasized the design and evaluation of teaching-learning sequences using set guidelines designed by the researchers.

In an extension of the earlier work by Komorek and Duit (2004), the MER was used by Starvou, Duit and Komorek, (2008) as a theoretical framework to develop teaching sequences based on the analysis of scientific content. They proposed a teaching-learning sequence about the interplay of chance and determinism in nonlinear systems. A pilot study was carried out on students' conceptions of chance and teaching experiments were used to investigate the students' learning path within the teaching sequence. Komerek and Duit's study thus indicates that it is possible to use only some components of the MER within a study.

In a similar way, Saarelainen and Hirvonen (2009) designed teaching-learning sequences for electrostatics at undergraduate level; again using the MER as a theoretical framework. Their study focused on designing teaching-learning sequences aimed at assisting students to understand electrostatics. They used tests to assess students' achievement of the learning outcomes. Data analysis concerned one aspect of the MER, component 1**,** which focuses on analysis of content structure**.** Their analysis of content was guided by three questions proposed by Klafki (1995). These questions were: what is the general idea represented by the content; what is the significance of the immediate content experience developed by the course content in students' lives; and what is the significance of the content in students' future lives? The authors interpreted the results using elementarization in component 1 of the MER. They concluded that the MER was ideal for designing interventions at undergraduate level. Saarelainen and Hirvonen's study and Komorek and Duit's study have both shown that it is possible to focus on one or two aspect of MER as illustrated in Figure 2.1. In the current study two aspects, the analysis of content structure and the research on teaching and learning of the model were used. The development and evaluation of the instruction aspect was not used because learners were not directly involved in this investigation.

Although a close analysis of MER shows that it provides an appropriate tool for the design and evaluation of teaching-learning sequences and the role of teachers in their design and evaluation of teaching-learning sequences, the researcher felt that an explicit step by step tool to look deeper into the design of sequences should be designed. To this end, the learning demand tool was used.

2.3.2 Learning Demand

The learning demand is used as a tool for theorising the process of designing and evaluating teaching sequences (Leach & Scott, 2002). The learning demand's origins are linked to the conceptual, the epistemology and the ontological aspects on learning. The learning demand may arise because of differences in conceptual tools such as epistemology and ontology. For example, a conceptual learning demand arises when learners use their everyday experiences instead of scientific knowledge to explain a phenomenon, while an epistemological learning demand arises when learners fail to apply conceptual tools to different aspect of science learning. An ontological learning demand is created when students fail to distinguish a process from a property of an object (Leach & Scoot, 2002, Palmer, 1997; Viiri & Savanainen, 2008).

The learning demand tool focuses on both individual and socio-cultural views of teaching and learning science, as noted by Leach, Ametller, Leach and Scott (2007).

> "Learning demand draws directly upon our social constructivist perspective on learning in that it involves making a comparison between two social languages, namely the social language of school science and the social language that school students are likely to use discussing phenomena and events at a given point in their science education" (p. 484).

According to Leach and Scott (2002), teachers play an important role in providing mediation during the learning of new scientific ideas. They suggested that teaching-learning sequences cannot be effective without taking into account the role played by teachers. Their proposed learning demand tool was based on the assumption that instructional designs start with analysis of the science content to be taught, followed by the learning demand analysis. Leach and Scott (2002) claim that a teaching-learning sequence that is informed by the learning demand tool should have at least four steps or phases. These are:

1. Identifying the school science to be taught.
2. Considering how this area of science is conceptualized in the everyday social language of students.
3. Identifying the learning demand by appraising the nature of any differences between steps 1 & 2.
4. Developing a teaching sequence to address each aspect of the learning demand (p. 127).

The learning demand tool thus provides insights into the conceptual issues used by designers to address or support the teaching of new ideas in the classrooms (Ametller, Leach, & Scott, 2007, p. 484). In this manner, Leach and Scott (2002) used the learning demand tool to design and evaluate a teaching sequence for simple electric circuits. In an effort to illustrate how the learning demand tool can be used to design and evaluate teaching sequences, they provided clearly labeled steps. The following steps illustrate the learning demand steps used by Leach and Scott to design and evaluate the teaching-learning sequences for simple electric circuits.

Step 1: School science knowledge to be taught.
This knowledge is usually drawn from the policy documents.

Step 2: Students' everyday views of the concepts
The students' views are drawn from the literature and they are related to the concept under the study.

Step 3: Identification of learning demands
In this step social language of school science is compared with everyday social language of the students.

Step 4: Planning the teaching sequence
This step is further broken down into teaching goals, staging a scientific story, supporting students' internalisation and handing over responsibility to the students (p. 130).

The learning demand tool, therefore, allows for the evaluation of the lesson teaching sequence. Consequently, the learning demand tool can be used to design teaching sequences during planning for teaching. As a result, the learning demand tool may be used to understand and interpret how teachers plan teaching-learning sequences. In the current study, interviews were used to identify what teachers claimed to do during planning of teaching-learning sequences.

Planning for teaching studies have been carried out on the design of teaching-learning sequences using the learning demand tool. For example, Sebastia and Torregrosa (2005) designed a teaching-learning sequence for the sun-earth model using students' observations. Then they instructed students to reinvent and evaluate the model based on previous observations. Their findings indicated the students who followed the teaching-learning sequence proposed by Sebastia and Torregrosa "attained a rich understanding of the sun-earth model" (p. 124). These findings indicate that well planned teaching-learning sequences can improve students' understanding of scientific concepts.

To sum up, both the learning demand tool and the MER are established frameworks for the design and evaluation of teaching-learning sequences. A comparison of the learning demand tool and the MER is presented in Table 2.1.

Table 2. 1 A comparison of the learning demand and Model of educational reconstruction

Aspects	Learning demand	Model of Educational reconstruction (MER)
Role of the scientific content	Less systematic on analysis of the science content	A strong point analysis initially only from the point of views of science; the historical development of the scientific content is also considered
Role of educational theories	Vygotskian ideas and social cultural framework	Draws from the German "didaktik" tradition and culture of pedagogy and science education
Role of history of science	Not important	Important in reconstructing the science content
Students' ideas	Valuable aid to teaching/learning; Conceptual, epistemological, ontological aspects, included in the learning demand analysis and planning the teaching	Valuable aid to teaching/learning; taken into account during the elementarisation and when science content to be taught is reconstructed
Student motivation	Not explicitly mentioned	Mentioned explicitly together with attitudes
Teaching methodology	Not explicitly mentioned, but related to communicative analysis	Not explicitly mentioned
Cyclic process, iteration	Not mentioned	Yes
Science content vs. school science to be taught	Teaching analogy maybe developed to address the learning demands identified	Simpler than the science content structures of the science content are adequately matched
Aim	To develop an evidence-based TLS	To develop an evidence-based TLS

Source: Virri & Savinainen (2008, p. 85)

From Table 2.1, the MER provides a more global framework for research based teaching-learning sequence than the learning demand tool. Specifically, the main focus of the MER is the scientific knowledge, while the learning demand tool provides more detailed information about the actual teaching in the classroom (Virri & Savinainen, 2008, p. 85).

Teaching methodology is not explicitly mentioned by either learning demand tool or MER. The failure by both frameworks to address issues related to teaching methodology means that they cannot be used as the only frameworks to underpin this study. Consequently, a third framework is needed in order to explain why teachers design teaching-learning sequences the way they do. Shulman’s (1986) ideas on pedagogical content knowledge (PCK) can be used to explain teachers’ actions revealed during the study.

2.3.3 Pedagogical Content Knowledge

Pedagogical Content Knowledge (PCK) refers to knowledge about the teaching and learning of particular subject matter, and it takes into account the learning demands of specific subject matter (Bucat, 2004; Shulman, 1986). PCK can be viewed as a knowledge domain that is related to a specific topic and how that topic is being taught (Van Dijk & Kattmann, 2007). Furthermore, according to Gess-Newsome (1999) there is a reciprocal relationship between PCK and the knowledge domain. The relationship is such that the knowledge domain informs PCK while, correspondingly, PCK influences teachers’ knowledge on the subject, how the subject is being taught and the context in which the subject is taught. In addition, Davis and Krajcik (2005) claim that the definition of PCK should also include discipline specific elements because they affect the manner in which teachers teach different science topics. Furthermore, previous studies on teachers’ knowledge have shown that pedagogical content knowledge (PCK) affects the manner in which teachers conceptualise the lesson, organize teaching materials and actually teach learners (Davis & Krajcik, 2005; Friedrichsen et al., 2009). According to these arguments, in this study, PCK was a suitable tool to understand the different teaching actions employed by physical science teachers when teaching chemical bonding.

Shulman’s (1986) PCK model has three major components. These components are; pedagogical knowledge (PK) which is directly linked to the subjects matter knowledge (SMK). The SMK requires the teachers to have an understanding of the discipline and educational principles of the subject they teach. The teachers are also required to have knowledge about students' understanding; this includes knowledge of misconceptions in the subjects, learning processes and difficulties experienced by the learners in the subject. Magnusson, Krajcik and Borko (1999) argued that PCK was basically a teacher's "understanding of how to help students to understand specific subject matter" (p. 96). Thus a teacher's PCK plays an important role in promoting learners' understanding of scientific knowledge.

However, Shulman's PCK model has been criticized as not specific enough for teaching science. In this regard, researchers such Magnusson et al. (1999) and Loughran, Mulhall, and Berry (2004) made an effort to extend Shulman's PCK model to five components. To be specific, Magnusson et al. (1999) identified the components as orientation towards teaching science, knowledge of science curriculum, knowledge of science students' understanding of science, knowledge of assessment of scientific literacy and knowledge of instructional methods. In Magnusson's model these components were further subdivided into subcomponents, for example assessment had two components. However, the components proposed by these authors did not explicitly mention PK and SMK as part of the PCK model. Similarly, Loughran et al. (2004) proposed extending Schulman's PCK model to include a further two major components, which they termed Content Representations (CoRes) and Pedagogical and Professional-experience Repertoires (PaP-eRs) aspects. The CoRes and PaP-eRs components were considered to be teaching activities used by teachers. For example, the CoRes emerged from activities such as content specific teaching, role-play, laboratory work, demonstrations, and conversations with teachers about their teaching and classroom observations. The CoRes component can be used as a tool for assessing science teacher's ways of understanding science content, and how they present science content to learners. This study focused on how teachers order, organize and present chemistry content knowledge so that it is teachable to learners. The PaP-eRs component emerged from the teachers' classroom practices and it is linked to how the teachers go about teaching a particular topic. This aspect also offers some understanding of the different learning situations that arise within a topic and attempt to explain some of the decisions that underpin the teacher's actions that are aimed at helping learners understand science (Loughran et al., 2004).

Although both Magnusson et al. (1999) and Loughran et al. (2004) proposed PCK models with five components relevant to scientific teaching, there are both differences and similarities in their point of focus. For the purpose of this study, components that were relevant to high school teaching were selected and modified. Ideas mainly from Loughran et al. (2004) were used to develop a coding rubric (Kind, 2009) for analysing the teachers' knowledge of teaching chemical bonding in the FET Phase. In particular, in the current study only the CoRes component was used to explain the actions taken by physical science teachers. Loughran et al. (2004) cited five CoRes components that can be used to measure the teachers' PCK. These components are: an overview of the main ideas, knowledge of alternative conceptions; insightful ways for teaching for understanding; known points of confusion; effective sequencing and important approaches to framing ideas. I used ideas of subcomponents proposed by Magnusson et al. (1999) to expand the CoRes main components. The ideas of subcomponents allowed me to unpack the interview data using a rubric designed to understand physical science teachers' PCK.

Researchers have shown interest in studies that focus on the nature of PCK. For example, Van Dijk and Kattmann (2007) suggest that PCK "acquired through teaching practice was different to the so called "PCK" since the normal teachers' PCK was drawn from "knowledge, beliefs and experiences of individual teachers" (p. 893). This indicates that PCK acquired by student teachers during teaching practice was not based on the experience of an individual teacher. Kagan (1990) reviewed literature on different methods of investigating teachers' cognition and suggested that, in order to gain a better understanding of teachers' knowledge and beliefs, multi-method research designs should be employed. Most research designs used to study teachers' knowledge include Likert-type questionnaires, interviews, experimental tasks and transcripts of lesson plans. Studies that have been carried out to understand teachers' PCK tend to focus on a particular topic or aspect of science content. Three examples of such studies are described below.

In the first study Kozma and Russell (1997) compared perceptions of experts and novice teachers on a variety of chemical representations. In this study they found that novice teachers favoured only one form of representation and could not easily move to other forms, while expert teachers were able to move from one form of representation to another with ease. They also found that novices used mostly surface features such as lines, numbers and colour to classify the representations, whilst experts used a more meaningful basis for categorizing representations, namely, verbal description for any given representation.

In another study, Padilla and Van Driel (2011) worked with university professors' PCK in quantum chemistry. They interviewed six professors who taught undergraduate students quantum chemistry. The main thrust of their research was to establish the relationship between how students learn quantum chemistry and their professors' knowledge of curriculum, knowledge of instruction, and knowledge of assessment, and instructional strategies. The research interview questions were based on concepts such as the atomic model, wave particle duality, and atomic orbitals. The authors transcribed the interviews and then read through the transcripts repeatedly, and analysed these by means of a coding rubric they developed from Magnusson's model. They found that the six professors had similar orientations towards teaching, didactics and academic rigor. Their findings indicated that the professors considered assessment to be less important than students' understanding, curriculum and instructional strategies.

The third study, by Rollnick et al. (2008) investigated the PCK of two high school teachers and a college lecturer. The study focused on two chemistry topics, namely the mole concepts for high school and chemical equilibrium for an access university course. They conducted interviews before and after lesson observations. They used Loughran et al. (2004)'s PCK model, in particular the Pedagogical and Professional-experience Repertoires (PaP-eRs) and Content Representations (CoRes), to portray the teachers' PCK. They found that the knowledge of one teacher on students' misconception of chemical equilibrium was not based on literature since the teachers had no science education background, but rather used ideas derived from experience. Moreover, this teacher displayed strong PCK, good subject matter knowledge (SMK) and was able to use innovative approaches to help students understand chemical equilibrium despite lack of science education background.

The current study differs from that of Rollnick et al. (2008) and Padilla and Van Driel (2011) in the sense that in the interviews teachers were simply asked to talk about how they teach chemical bonding without specific questions being based on a particular PCK model. Instead the PCK model of Loughran et al. (2004) was used to interpret teachers' interview responses on how they plan teaching-learning sequences.

2.3.4 Summary of theoretical frameworks

The context of the study is the KZN education system where physical science teaching is still held back by poorly resourced and under qualified teachers. Consequently teachers have not been able to deliver an adequate outcomes based curriculum. In particular they have little guidance concerning their teaching-learning sequences. Analysis of the literature indicates that the MER has been used extensively by researchers to design and evaluate teaching-learning sequences. It has been argued that both the MER and learning demand tool are suitable theoretical frameworks for the design and evaluation of teaching-learning sequences. It is evident that it is possible for researchers to focus on one aspect of MER during interpretation of results. For example, the MER forms the basis for providing an overview of understanding teaching-learning sequences. On the other hand, the learning demand tool provides more fine-grained information on steps to be followed during planning phase of teaching-learning sequences and it can be used to establish what happens in the classroom. It is evident that teaching-learning sequences based on research made a difference in students' understanding of scientific concepts and they merit further research.

Teachers' PCK plays an important role in how they plan teaching-learning sequences and teach lessons on particular topics. The discussion above shows that studies on science teachers' PCK were mainly focused within a specific topic or content area, and that a variety of research methods was employed.

It was felt that using three interpretive frameworks would contribute to greater insight from the results. In the current study the MER was used to understand how the teachers sequence topics and concepts for teaching chemical bonding. The learning demand tool was used to unpack how teachers plan teaching-learning sequences for teaching chemical bonding. The PCK model was used to reveal why teachers were sequencing the concepts for chemical bonding differently.

There is need to understand the nature of research carried out by previous researchers on teaching and learning of chemistry. The following section discusses the literature review on teaching of chemistry.

2.4 Literature Review of Chemistry Teaching

There are different reasons for researchers reviewing literature. In this study the researcher reviewed the literature in order to have a good understanding of prior research in the area of teaching learning sequences internationally and locally. The reviewed literature then acted as a benchmark for the researcher to compare the findings with those from previous studies (Creswell, 2009). This section presents some illustrative literature on chemistry teaching, misconceptions about chemical bonding and teaching learning sequences.

2.4.1 Teaching general chemistry

The search for better ways of presenting chemistry knowledge is a worldwide area of research (Danipog & Ferido, 2011). According to these authors, students are more keen to learn chemistry if they have a clear understanding of its relevance to everyday life. For instance Treagust, Chittleborough and Mamiala (2003) found that students did not always understand the role of the different representations used by the teacher. In their research on the use of sub microscopic and symbolic representations in chemistry education explanations, these three authors found that students' understanding required the use of both sub microscopic and symbolic representations of chemistry explanations. This affirmed Johnstone's assertion that chemistry is understood using three different levels of representation; macroscopic, particulate and symbolic (1991).

Gabel (1999), however, noted that in the United States' some introductory chemistry teaching focused on one form of representation, often principally symbolic. With reference to the teaching of specific concepts, Gabel found that while textbooks present chemistry knowledge in a variety of ways, the most common method used in the textbooks was to present a theoretical concept of atomic theory and chemical bonding at microscopic level first, followed by the descriptive chemistry which was usual presented at macroscopic level. She claimed that the "complex nature of chemistry has implications for the teaching of chemistry today" (p. 548).

Studies on ranking general chemistry topics at high school indicate that there are certain topics viewed as fundamental knowledge. For example, Zimmerman (1998) presented participants with a list of topics and requested that they select the most important topics for first year chemistry students, and how these topics should be taught in such a course. The participants proposed the following topics as important for learning chemistry at undergraduate level: atoms and molecules, acid and bases, Le-Chatelier's principle, equilibrium, solubility, concentration/molarity, reactions (simple organic), thermodynamic, reaction mechanisms and kinetics. The findings of Zimmerman's study indicated that while there were levels of agreement on the topics to be taught in first year university chemistry, participants could not agree on one single teaching approach from the three approaches presented to them. These approaches were topic oriented, microscopic to macroscopic, and macroscopic to microscopic. This could mean that all the three approaches could be used to teach chemistry at the same time, or that the order of using the approaches does not matter.

Similarly, Deters (2003), in trying to understand how teachers teach high school chemistry, used a survey and requested both high school teachers and professors to rank chemistry topics that they felt were necessary to include in high school chemistry. Deters found that, amongst others, seven particular general chemistry topics were ranked highly by most of the participants. These topics can be listed as follows: basic skills (units, significant figures, moles (molar mass), dimensional analysis, stoichiometry, naming and writing formulae, atomic structure, and balancing equations. Deters' study is similar to one component of the current study in the sense that it used a survey and asked participants to rank high school general chemistry topics. In both the Zimmerman (1998) and Deters (2003) studies, participants showed some agreement on the list of topics that should be taught at high school and university. Deters' study is different from the current study because the current study focused on sequencing of topics in relation to chemical bonding while Deters focused on the important topics that should be taught at high school.

The discussions indicate that there are different ways of representing chemistry knowledge. Organising content knowledge is necessary in the teaching of chemistry and the complex nature of chemical knowledge contributes to the difficulties experienced in the teaching and learning of chemistry. It is necessary to understand how chemical bonding should be taught. The following section describes some relevant studies carried out on teaching chemical bonding.

2.4.2 Teaching chemical bonding

The teaching of chemistry remains under scrutiny because despite scientific and technological developments, students' interest and ability in chemistry declined worldwide (Smith, 2006). Many international studies on chemical bonding indicated that the traditional approach to its teaching or it was problematic (Nahum et al., 2007). The literature showed that students, teachers and chemists all view chemical bonding as a very complicated concept (Taber, 2001). Furthermore, the lack of understanding of fundamental topics is considered to lead to difficulties in understanding more advanced related topics (Jonstone, 1991). Consequently, attempts have been made to try and reduce the level of difficulty of topics such as chemical bonding.

Studies have been carried out to look at possible ways of teaching chemical bonding. For example, Nahum et al. (2007) conducted a study to develop a new teaching approach. They suggested that the teaching of chemical bonding should be based on elemental principles of atoms and used the idea of a continuum of bond strengths rather than dichotomous classification of bonds. Nahum et al. (2007) proposed five issues that should be included in the new approach for teaching chemical bonding. These issues are described separately below:

> *General approach to presenting the concept*
> Starting from the key concepts and elemental principles that are common for all chemical bonds between two atoms and then progressing to molecules and lattices
>
> *Teaching covalent and ionic bonds*
> Start with presenting a continuous scale of chemical bonds
>
> *Teaching hydrogen bond*
> Start with the emphasis on the unique characteristic of H bonds. Not only with NOF atoms. They may occur in a single molecule between different parts of the molecule
>
> *Teaching metals*
> Start with mentioning that metallic elements may have only a few common characteristics. Although the bonding orbitals in these elements are delocalized, the bonding is basically covalent
>
> *Type of questions regarding teaching chemical bonding*
> Developing new tasks based on learning performance, which examine deep understanding and improve students' ability to apply these concepts to a variety of situations (p. 597).

A variety of concepts are required to understand chemical bonding. According to Nahum et al. (2007), models for chemical bonding should include concepts such as: intra-molecular bonding, the octet rule, electronegativity, Valence Shell Electron Pair Repulsion Model (VSEPR), and some types of inter-molecular bonding such as, dipole-dipole, van der Waals and hydrogen bonding. However, the concepts associated with chemical bonding and structure such as covalent bonds, molecules, ions, giant lattices and hydrogen bonding are abstract and an understanding of these concepts requires students to be familiar with the mathematical aspects associated with bonding concepts such as: electronegativity and bond polarity (Nahum et al., 2007).

There is a variety of different suggestions for the teaching of bonding. Two models will be presented here. Firstly, the model in Figure 2.2 illustrates the sequence framework suggested by Taber (2001).

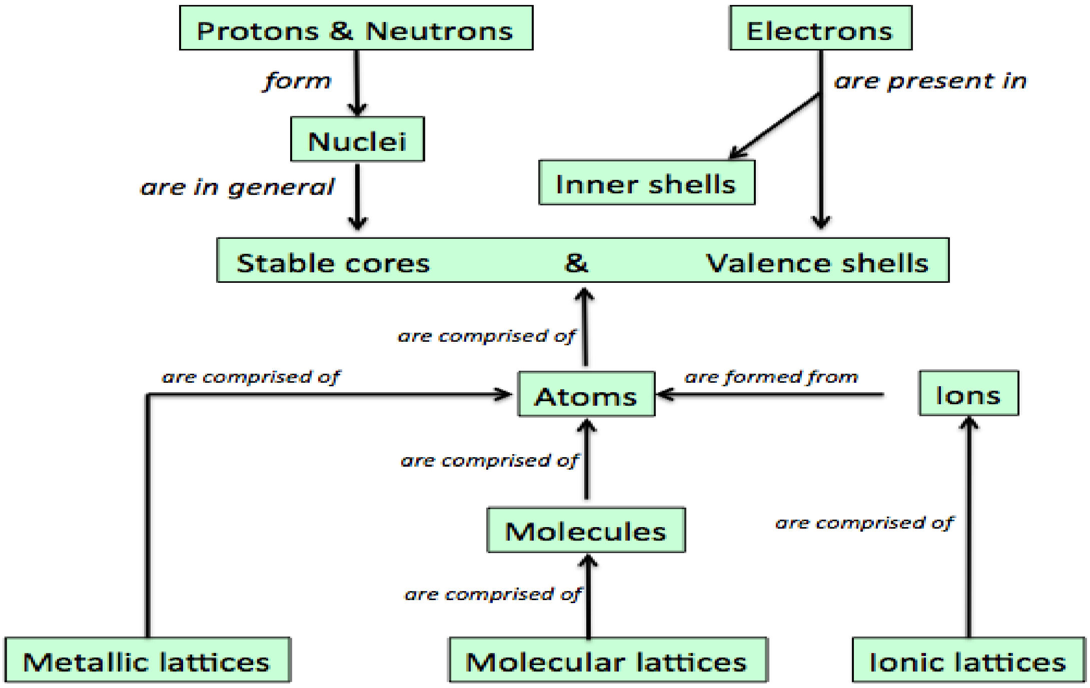

Figure 2. 2 An alternative chemical bonding framework (adapted Taber, 2001, p. 145).

As can be seen in Figure 2.2, Taber's model for teaching chemical bonding has two possible starting points: subatomic particles or lattice structures. According to this model, when starting a teaching sequence from lattice structures, the next stage will be to describe molecules, then atoms and ions. The next stage would be to discuss valence shells, nuclei, inner shells and lastly protons and electrons. The reverse is true when the teaching sequences starts from the subatomic particles.

Secondly, the model by Nahum, Mamlok-Naaman, Hofstein, and Kronik, (2008) who suggested a new "bottom-up framework" for introducing chemical bonding. This involves five steps that focus on electrostatic forces and chemical stability expressed as being reduced energy levels as shown in Figure 2.3.

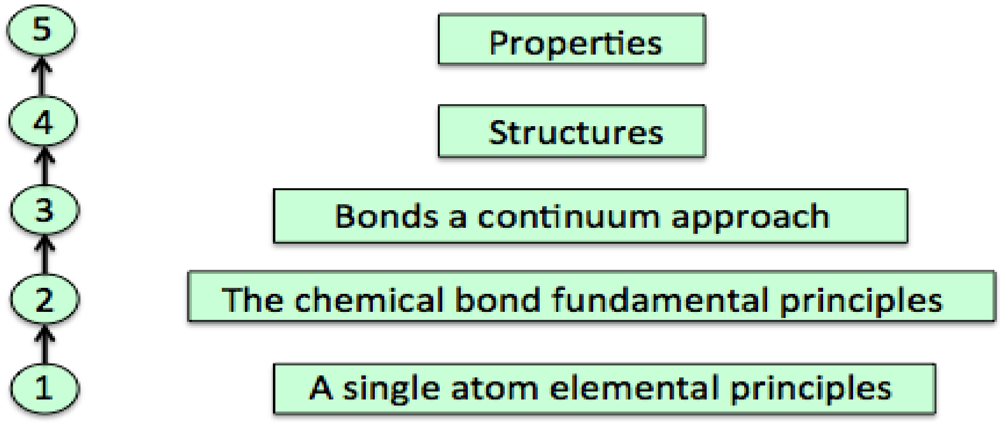

Figure 2. 3 The "bottom-up framework" (Nahum et al., 2008, p. 1682).

The bottom up framework starts from the elemental principles of a single atom and then moves to chemical bonds between the atoms. The next stage (3), presents the different types of bonds using a continuum approach. This approach removes the divisions between types of bonds created by the traditional methods of teaching chemical bonding. The students need to know the first three stages before being introduced to molecular structures and properties of materials. For example, students use their knowledge of chemical bonding to explain why sodium chloride is soluble in water, but insoluble in benzene. The advantages of the bottom-up approach proposed by Nahum et al. (2008) was that it allowed the possibility of using different models to illustrate concepts such as, valence bond and molecular orbital theory for chemical bonding. This framework allows for an immediate emphasis on electrostatic interactions and the nature of chemical bonding.

There were some similarities between the frameworks suggested by the Taber (2001) and Nahum et al. (2008) in that both have a focus on molecules, lattice structures and electrostatic interactions. However there are also differences between the models. The model proposed by Taber (2001) had several starting points, one of which was individual atoms and the other was the lattice structures, whereas that of Nahum et al. (2008) focused specifically on concepts of single elementary atoms. Despite their differences, both the models present information for teaching chemical bonding in an organised sequence.

The discussions above indicate that there is no single agreed way of teaching chemical bonding. I would suggest that the research on teaching difficult chemistry topics such as chemical bonding should continue until it can show that there is a better way of teaching chemistry at high schools than that which is currently practiced resulting in many learner misconceptions. The following section discusses some of the misconceptions on chemical bonding that arise when using current teaching learning sequences.

2.4.3 Misconceptions about chemical bonding

There are various difficulties in learning chemistry ranging from the abstract nature of the content and representations, as was shown in Section 2.3.1. Chemical bonding is viewed as one of the chemistry topics that most students find problematic resulting in many misconceptions (Taber & Coll, 2002). Students' misconceptions have been a major concern amongst science education researchers in the past decades. The misconceptions in chemistry education are well-documented and research has shown that these misconceptions act as a hindrance for learning new information because students' pre-existing scientific knowledge influences how they learn new ideas (Taber, 2001). Concerning the particular topic of chemical bonding, Ozmen (2004) reviewed misconceptions in this topic and found the following most common misconceptions:

> Chemical bonds form in order to produce filled shells rather than shells being the consequence of the formation of many bonds
>
> Atoms are filled shells
>
> Molecules form from isolated atoms
>
> There are only two kinds of bonds; covalent and ionic bonds. Anything else is just a force "not a proper bond"
>
> Na^{+} and other ions are stable because they have filled outer shells (p.150).

In his study, Ozmen (2004) then identified further misconceptions about covalent bonding in particular, held by grade 11 and 12 students. These misconceptions are listed below;

> Equal sharing of electron pairs in all covalent bonds
>
> Ionic charge determines the polarity of the bond
>
> The shape of a molecule is due to the repulsion between the bonds
>
> Intermolecular forces are the forces within a molecule
>
> Nitrogen atoms can share five electron pairs in bonding (p, 149).

In addition, Taber and Coll (2002) contributed a chapter on learners' conceptions about bonding, which they asserted had pedagogical origins, in that they derived largely from the manner in which the concepts had been sequenced and taught. Based on these findings about learners' misconceptions, the authors made recommendations concerning a particular sequence of bonding concepts. They suggested that, in order to reduce the levels of misconceptions, a teaching sequence should start with metallic bonding, followed by ionic bonding and then covalent bonding. The different types of intermolecular forces are then taught after covalent bonding, and should include van der Waals Forces and hydrogen-bonds. They indicated that the high levels of misconceptions held by students about chemical bonding indicate that the topic was abstract and neither easy to teach nor easy to understand.

From the discussions above, it is evident that sequencing of concepts within the topic of chemical bonding is important in reducing the level of misconceptions. The following section focuses on studies on teaching-learning sequences

2.4.4 Teaching-learning sequences

The research on teachers' knowledge has generated international interest amongst researchers (Lee, Wu, & Tsai, 2009), because teachers' knowledge play an important part during the planning and teaching of science. In trying to understand what teachers do during planning, Sanchez and Valcarcel (1999) studied teachers' views and practices in planning for teaching. They used individual interviews and written comments to gather information. The verbal information was then compared with written comments. They interviewed teachers who were attending an in-service training course: the group of 27 teachers comprised 13 diploma holders and 14 graduates, most of whom had taught for more than 10 years. They found that teachers planned their lessons mostly from textbooks rather than curriculum documents. They also found that teachers used their experience as a guide on how to plan a lesson, but neglected to think about assessment at the planning stage.

Previous studies on teaching-learning sequences have focused on a variety of topics such as how content was presented within a single lesson, the ordering of lessons within a topic, the sequencing of topics within a school term and the ordering of topics within a year (Contreras, 1988). Some recent studies have however shifted focus to topic specific teaching-learning sequences rather than whole curriculum based teaching-learning sequences

(Andersson & Bach, 2004; Lijnse, 1995). Within the literature researchers refer to different ways of sequencing teaching content i.e. teaching content can be logical or randomly sequenced. However, Cartwright (1971) argued that a random sequence demands greater general intellectual abilities of students, whereas a logical sequence would require specific intellectual abilities of students. This indicates that teachers should be aware of the learning abilities of students before selecting an appropriate sequence. In general, research on sequencing has shown that the use of logical sequences of the subject matter has resulted in increased students' interest in a subject and a decline in errors made by students on science content (Lam-Fat, 1980). Nevertheless, despite the importance of logical sequences having been established more than three decades ago, illogical sequences still prevail in chemistry education.

Building on the importance of logical sequences, Yuruk, Sahin, and Bozkurt (2000) compared inductive and deductive reasoning teaching-learning sequences. These had the same content and the researcher measured students' achievement in chemistry education. In the Yuruk et al. study, students were taught the same content by using two sequences, which were the reverse of each other. The content taught in both the inductive and deductive sequences included topics such as,

Unit 1 Structure of atom and the periodic table;

Unit 2 Chemical bonding and the concept of were presented as follows; metallic bond, ionic bond, covalent bond theories, valence shell theory, and molecular orbit theory.

Unit 3 Intermolecular attractions and properties of liquids

Unit 4 Matter (p. 179).

The deductive sequence was the reverse; it started from matter through to structure of the atom. In the current study, the ordering of teaching activities was viewed as important because there was a need for the material taught in a single lesson and subsequent topics to be closely related to each other so that there is building of chemistry knowledge and provision for easy follow-on of ideas.

The evidence from the studies reviewed above, indicates that chemistry concepts are difficult and abstract to the learners. Consequently, teachers need to plan and organise their teaching activities so that they make it easy for the learners to follow the stages in each lesson and to be able to build knowledge from the previous lesson or topic.

To date, a substantial amount of research has been done on teaching-learning sequences, but most of this prior work focuses on development and evaluation of these sequences within a topic (Leach & Scott, 2002; Lijnse, 1995). For example, some studies looked at scientific knowledge in different educational settings and among a cross section of learners that included junior, senior secondary and university students (Meheut & Psillos, 2004). Some of the topics for which the teaching-learning sequences have been investigated include the following: the structure of matter (Lijnse, 1995), fluids (Psillos, Tselfes & Kariotoglou, 2004); solubility (Leach & Scott, 2002); changes of state and thermo-elastic properties of gases (Meheut, 1997); non-linear physics systems (Komorek & Duit, 2004); geometric optics (Andersson & Bach, 2004); chance and non-linear systems (Starvou, Duit, & Komorek, 2008); mechanics (Tiberghien et al., 2009), and electrostatics (Saarelainen & Hirvonen, 2009). As can be seen, more of the research done on teaching-learning sequences tended to focus on physics topics.

Few studies mentioned above involved a focus onteacher's design of teaching-learning sequences, for example, Lijnse and Klaassen (2004) described the relationship between teaching methods and research on teaching-learning sequences. They focused mainly on teaching sequences that can be put into classroom practice in the teaching and learning of a particular topic. In Lijnse and Klaassen's study, the teaching sequences started from generalization of radioactive substances and not from theoretical knowledge as most textbooks do. The authors then analysed the content to be taught from the position of students' of understanding of the process involved in radioactivity. They were also able to measure the quality of teaching and learning of students using teaching activities developed by teachers. This study is similar to the current study in the sense that teachers were asked to design teaching-learning activities. The role of the teacher in the design and evaluation of teaching-learning sequences is not clearly defined in some of the other studies (Komerek & Duit, 2004; Meheut, 1997). Previous studies showed that there are different ways of designing and evaluating teaching-learning sequences. These differences indicate that there is need for further research to understand the effects of teaching-learning sequences.

Many common methods of data collection were employed by previous researchers, for example a majority of studies on teaching-learning sequences used pre-test and post-test, or interviews as methods of evaluating the effectiveness of a teaching-learning sequence. Interviews were used to elicit learners' experiences of teaching learning sequences. In these studies, the MER provided a theoretical framework for teaching-learning sequences (Duit, 2007; Komorek & Duit, 2004; Saarelainen & Hirvonen, 2009). Similarly, the current study used surveys and interviews to collect data. As described in Section 2.2.1, the model of educational reconstruction is judged to be suitable as a theoretical framework to interpret teachers' understanding of content and educational issues during the teaching of chemistry in the FET Phase.

Most of the studies carried out on teaching-learning sequences focused on establishing positive effects of teaching sequences. Very little research appears to have been done to try to assist teachers to improve practice through a focus on teaching learning sequences. In most cases, teachers are faced with problems of selecting appropriate subject matter rather than sequencing teaching activities in order to achieve the learning outcomes. There is very little work that has been done in South Africa on teaching- learning sequences for different topics in chemistry. For example, Vankat, Adler, Rollinick, Setati and Vhurumuku (2009) reviewed journal articles containing South African research in mathematical and science education from 2000 to 2006 and they found that science education articles could mainly be grouped as tertiary science teaching and learning, school level science teaching and learning and the relevance of nature of science and indigenous knowledge science (p. 15). Within this particular review or that done by Malcolm and Alant (2004), research topics on teaching-learning sequences were not explicitly identified.

The discussions above indicate that there are different ways in which researchers designed and evaluated teaching learning sequences. Most studies focused on designing sequences to maximize learning, with content knowledge being used as a starting point for designing teaching sequences (Meheut, 1997). Most studies also used an experimental approach to design and evaluate teaching-learning sequences. The rationale to use a different approach in the current study from previous studies was governed by the desire to both understand teachers' strategies for sequencing and to develop teaching-learning sequences for teaching chemical bonding within the South African context. The approach taken by this study was likely to result in the development of more than one possible teaching-learning sequence for teaching chemical bonding. The literature showed that development of teaching sequences has set guidelines, for example stages involved in developing teaching sequences, testing and evaluating of teaching sequences are lengthy and such a process was not suitable for the current study due to time constraints. Although, different models for teaching chemical bonding have been suggested, but there is still no single agreed way of teaching the topic.

To sum up the discussions, one would say that the reviewed literature showed that teaching-learning sequences can be developed from two different approaches; the researcher could enter the field with a pre-designed teaching-learning sequence with the purpose of testing and evaluating the sequence, or instead the researcher could enter the field with prepared teaching-learning sequences to be completed by the students followed by the evaluation of the tasks or assessment to learning (Meheut, 1997). In this study the researcher entered the field with instruments designed to establish the patterns of teaching learning sequences already used by the teachers to teach chemistry, which lead to framing of proposed teaching sequence. A diagrammatic comparison between previous studies and the current study appears below in Figure 2.4.

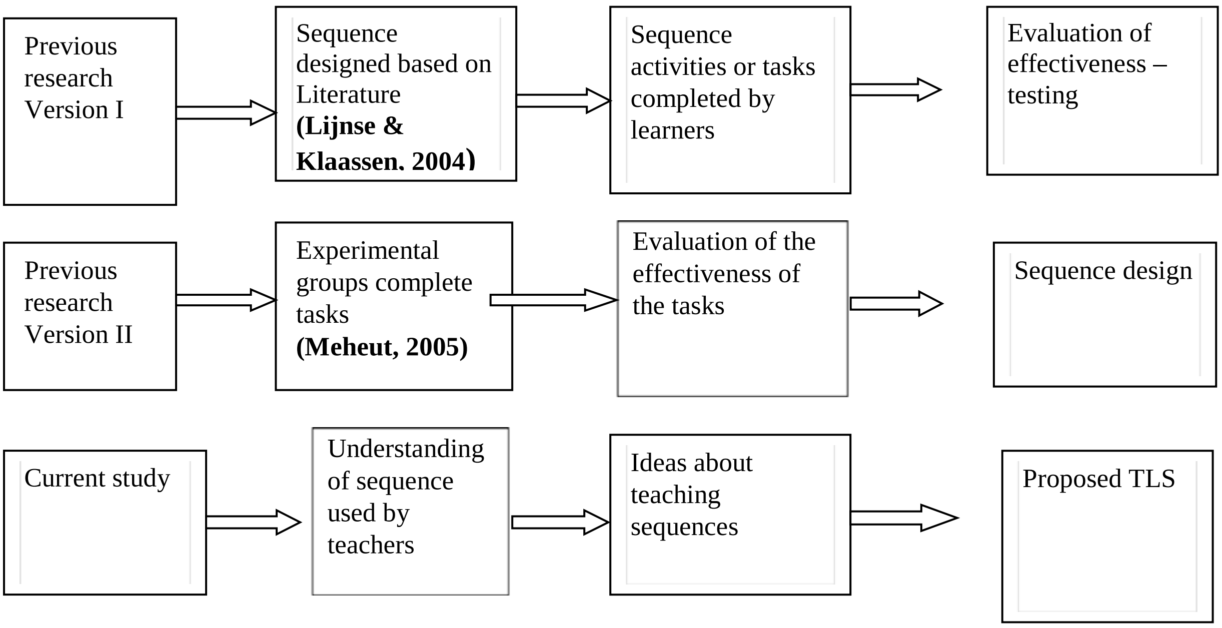

Figure 2. 4 A comparison of research designs for previous studies and the current study

2.5 **Summary of chapter two**

This chapter started by discussing the context of the study. The context highlights the context within which teachers work and how this might influence the planning of teaching sequences. The chapter proceeded to describe the frameworks used by researchers to guide the design and evaluation of teaching-learning sequences. It was also argued that the teachers' PCK plays an important part in how they teach chemistry and could be used in understanding why they design sequences in the way they do. The literature showed that teaching-learning sequences can improve and add value to the teaching and learning of science in high schools and at higher education levels and so research in this area would have value. The teaching of chemistry seems to be complex, in particular chemical bonding. There is no agreed single way of designing and evaluating teaching-learning sequences. In this study, the guidelines informed the development of a teaching-learning sequence for teaching chemical bonding. The design of the study follows in Chapter 3.

CHAPTER 3 RESEARCH DESIGN

In Chapter 1 the reasons for adopting a pragmatic paradigm were outlined briefly. The aim of this chapter is to further justify that paradigm and to consider the methodology underpinning each aspect of this study in order to justify the methods described. The purpose of this chapter is thus threefold: firstly, the methodology appropriate for each stage of this study is provided. Then this methodology is used to justify the research design and finally, the sampling techniques, research instruments and data analysis techniques are described and validity issues are discussed. By these means the chapter reveals the research design used to arrive at answers to the four research questions, repeated below.

What teaching-learning sequences are used by teachers to teach general chemistry in the FET Phase?

What teaching-learning sequences are used by chemistry teachers to teach chemical bonding in FET Phase?

How do the teachers construct the teaching-learning sequences to teach chemical bonding?

Why do the teachers use these teaching-learning sequences to teach chemical bonding in the manner that they do?

The methodology for any study is a result of particular views of epistemology and ontology (Denzin & Lincoln, 2003). In this regard, Guba (1990) refers to a paradigm as a worldview or "basic set of beliefs that guide the researcher's action" (p. 17). Creswell (2009) indicates "world views are mostly shaped by the researcher's past experience, expertise, discipline, and the background of the advisors" (p. 6) and in particular, they influence the type of research methods adopted by the study. Thus, any research perspective emanates from three types of questions; ontological, epistemological and methodological. Guba and Lincoln (1994) described ontological questions as seeking to understand the form and nature of reality. In this study the ontological aspect was informed by the need to understand the nature of the patterns of the teaching sequences used by physical science teachers to teach chemistry. The epistemological focus is on how the researcher and the participants interact in the study in order to find the truth. In this regard, the current study seeks to understand how teachers construct the teaching sequences to teach chemistry. The methodological questions focus on how the researcher finds the answers to the research questions for the study.

Different world views or paradigms may be adopted by researchers to provide answers to research questions. Greene, Caracelli, and Graham (1989) argue that it is not necessary to adopt a single research paradigm, particularly when the need for a mixed methods approach (both quantitative and qualitative) is indicated. The ongoing debate on paradigms for mixed methods is further addressed by researchers such as Johnson and Onwuegbuzie (2004) who assert that in a mixed methods approach the research question is more important to the study than the paradigm for research design. Creswell and Plano Clark (2011) argue that "pragmatism allows the researcher to adopt a pluralistic stance of gathering all types of data required to answer the research questions" (p. 46). Therefore, because the nature of the study required both qualitative and quantitative data, a pragmatic paradigm as described by Creswell (2009) was adopted for this research study to allow for a mixed method approach.

The choice of an appropriate world view can also allow the researcher to make interpretations of data and find meaning for what is happening, without being judgmental of the participants. In this study, I am trying to understand how teachers design and implement teaching-learning sequences to teach chemical bonding in the FET Phase. In other words I am approaching the study without any intentions of judging what teachers are doing but, rather, to learn from their teaching experiences. In trying to gather the most relevant information for this study, I operated within both the post-positivist and the constructivists' world views. For example, when designing the questionnaire I positioned myself as a post-positivist because I was guided by the literature concerning existing categories for teacher responses (Avramidis & Norwich, 2002; Deters, 2003; Grosser, 2007). A post positivist researcher believes that they can reach an understanding based on experiment and observation. The researcher tests the theory by specifying the hypothesis. The collection of data can support or refute the hypothesis (Creswell, 2009). Later on, positioning myself within a constructivist viewpoint allowed me to interpret the teachers' interviews in order to understand their viewpoint about how they design TLS.

3.1 Mixed methods

Mixed methods research can be described as an inquiry that combines both qualitative and quantitative approaches to data collection. By collecting and analyzing both numerical and textual data the researcher can address different aspects of a research problem and so provide more complete meaning for the data (Maree & Pietersen, 2007a). The argument to use mixed methods in this study is that the quantitative data, cannot explain why certain teachers are doing things differently from others. Moreover, according to Creswell, Plano Clark, Gutmann, and Hanson (2003), by allowing the researcher to operate within more than one philosophical world view (so within a pragmatic paradigm), a mixed methods approach makes it possible for the researcher to mix results within a single study, so that "collection or analysis of both quantitative and/or qualitative data in a single study in which data were collected concurrently or sequentially, are given a priority, and involved the integration of data at one or more stages in the process of research" (p. 212). Thus, a mixed methods approach is based on the assumption that a body of research on a topic is enhanced by more than one research approach. In this study a sequential research design in which results at an earlier stage informed the type of data to be collected later. The qualitative data was also used to help interpret the quantitative data and provide greater understanding of the situation under review.

Different research designs are used in mixed methods studies. Research designs can be experimental or non-experimental (descriptive), depending on the nature of the study, the researcher and the data that is required to answer the research questions. According to Cresswell (2009), design of mixed method research involves different broad steps; these are outlined below:

> Step: 1: requires the researcher to make decisions whether or not to include an explicit theoretical lens. In this study the overall research study theoretical lens refers to the research approach or paradigm, which was pragmatism
>
> Step: 2: requires the researcher to identify data collection procedures and what to prioritize. The quantitative and qualitative data were collected sequentially with priority given to quantitative data.
>
> Step: 3: requires the researcher to identify data analysis and integration procedures. In this study data analysis and integration occurred by analysing data sets separately with the qualitative data analysis informed by the quantitative analysis.

In summary, this study draws from the explanatory mixed method design, in which both quantitative and qualitative data are collected. The qualitative findings are used to further explain the quantitative data. A sequential explanatory design was used as a guide to the design process. This means that quantitative data was collected and analysed first which informed the design of the interview protocol. The second phase, (focusing on collection and analysis of qualitative data) was viewed as complementary to the quantitative data.

3.1.1 Methodological procedures

Mixed methods studies require the researcher to clarify procedures at the beginning of the study. In this study clarity on procedural issues was outlined at an early stage of the research in order to avoid confusion about what should be done first and how it should be done. These issues are; priority, implementation and integration, and are described in the following sections.

Priority

According to Creswell (2003) priority refers to the stage at which the researcher gives more weight to either a quantitative or qualitative approach throughout the data collection and analysis procedures. In this study priority was given to quantitative data. The decision to give priority to quantitative data sources was influenced mainly by the initial focus of the study, which was to describe the nature of existing teaching-learning sequences used and determine how teachers actually construct them for teaching chemistry in the FET Phase. The first phase of the study thus focused mainly on gathering quantitative data on how teachers plan and use different teaching-learning sequences.

Implementation

Implementation or timing of the study refers to the order in which data was collected and analysed (Greene, Caracelli, & Graham, 1989). In the Greene et al. study a sequential explanatory design was used. In this design, data was collected over a period of time in two phases (quantitative and qualitative). The reason for following up the quantitative phase with a qualitative phase was to gain an in-depth understanding of the quantitative results and to understand why the teachers used their teaching-learning sequences and why they planned in the way they did.

Integration

In this study, the integration phase started when survey results were used to develop some of the interview questions. According to Greene et al. (1989), integration refers to the research stage in which quantitative and qualitative data are mixed. During this stage the two data sets were merged through comparison of the themes (Creswell, 2009). In this study, the quantitative results were presented first and the interview results are presented as either supporting or contradicting the survey findings. A diagram, based on Ivankova et al. (2007) summarizing the research method appears in figure 3.1

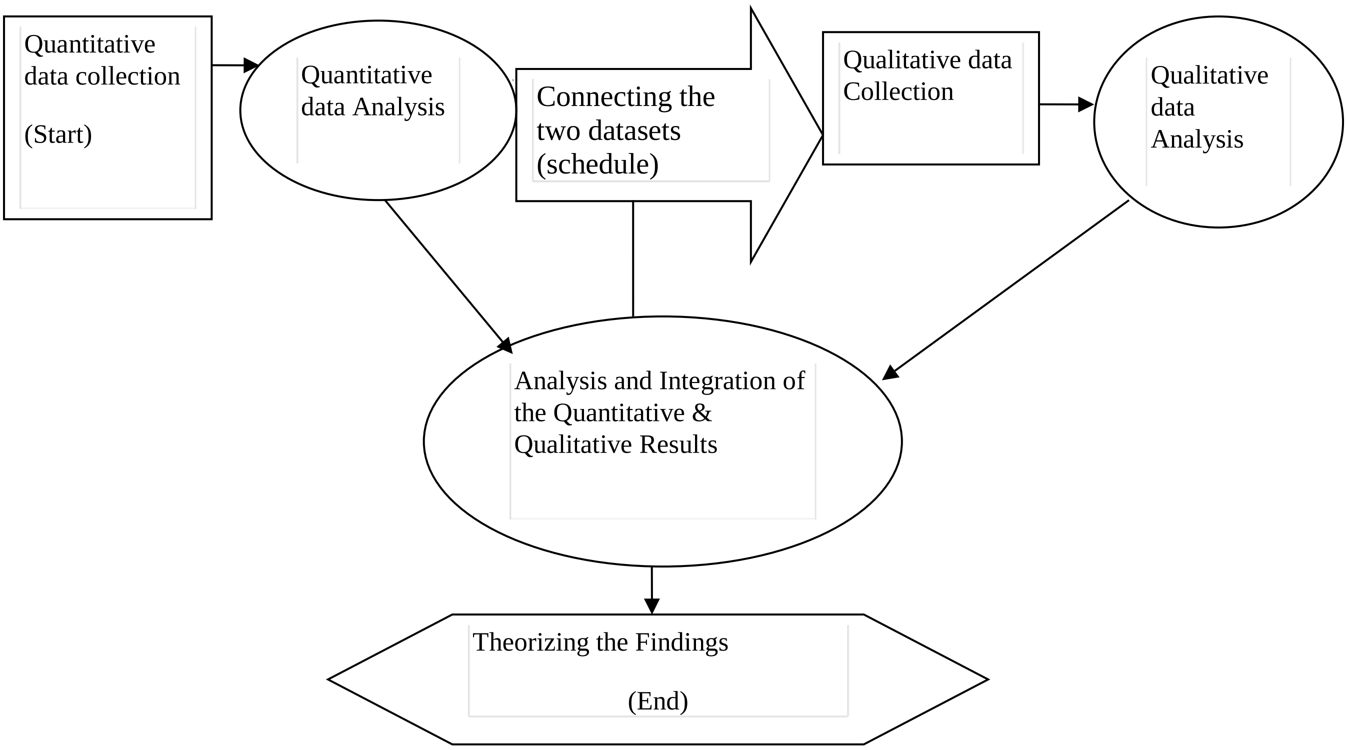

Figure 3. 1 Steps involved in a sequential explanatory design (adapted from Ivankova et al., 2007, p. 267).

3.2 Description of the sample

Based on the accessibility of the schools, time frames and the cost involved in carrying out a study of this nature, the study was limited within KwaZulu-Natal (KZN). As described in Section 2.2.1, KZN is one of the Republic of South Africa provinces. In this province there were about 1550 high schools; of which five hundred and sixty five were combined schools (these were schools with both primary and high schools on the same premises) (Hugo et al., 2010). The schools in the province fall within twelve districts, namely; Amajuba, Empangeni, Ilembe, Obonjeni, Pinetown, Sisonke, Ugu, Umlazi, Umgumgundlovu, Umzinyathi, Othukela, and Vryheid. While most of these districts cover more rural schools than urban, some districts have a predominance of urban and peri-urban areas. Consequently some of the schools have adequate teaching recourses while others have fewer resources or even none at all. Furthermore, teachers from all twelve districts have opportunities to attend in-service workshops or development courses which allowed the researcher easy access to them.

The target population of this study was physical science teachers in KZN. Banerjee and Chaudhury (2010) defined a target population as "population from which the sample has been properly selected" (p. 60). In other words the target population is the group or individuals to whom the survey findings apply (Kitchenham & Pfleeger, 2002, p. 170). I argue that the teachers that participated in my study are a representative sample of KZN teachers. The majority of the participants were sourced from physical science teachers enrolled for an in-service course (Advanced Certificate in Education (ACE) at the University of KwaZulu Natal) and those attending departmental and nongovernmental workshops. This sample of teachers (as shown in the findings chapter) had very similar characteristics to the general population of teachers in KZN as reported by Hugo et al. (2010). These characteristic are: qualifications, location and availability of teaching facilities. It is argued that the findings of the current study can be generalized to the population of physical teachers in KZN.

Convenience sampling was used in this study; Creswell (2009) describes a convenience sample as that which is drawn from volunteers. A convenience sample can provide useful insight into the study, but it has limitations in terms of accuracy and it cannot always be generalized to larger populations, but can be applicable to the target population. However data derived from a convenience sample and data collected from other methods (interviews) may produce similar results. If this happens, the potential to generalize from a convenience sample increases. With regards to cases where results from a convenience sample and other methods diverge, this discrepancy pushes the researcher to re-examine the chosen theoretical base, which could subsequently improve the methods used in the study (Abowitz & Toole, 2010). The use of a mixed methods approach in this study allowed the use of a convenience sample.

The convenience sample used in this study included only those teachers who were keen to participate; that is, they were all volunteers as shown by their completing and returning the research instrument questionnaire. Questionnaires were distributed to FET physical science teachers and they were invited to participate in the study. I worked closely with subject advisors (these were government officials in charge of physical science subject for each district) to try and target teachers attending workshops. In this way, at workshops it was easy for me to talk to teachers about my study and to be able to collect completed questionnaires on the same day. Those teachers who did not have interest in the research simply opted not to receive a copy of the questionnaire. In order to improve the representativeness of the sample I contacted a number of individuals by email and extended an invitation for them to participate in the study. Those teachers who were interested in taking part in the study replied and requested a copy of the questionnaire, which they then completed and e-mailed back to me. The return rate on requests to participate was low as many of the teachers' email addresses were found not active at the time. The numbers and description of participants is described in the next chapter.

3.3 **Ethical issues**

Researchers in social sciences and science educations are expected to conduct themselves in a particular manner and obey certain ethical considerations throughout the investigations. Ethical considerations play an important part on the credibility and quality of the study. According to Cohen, Manion and Morrison (2000), researchers need to observe certain considerations during an investigation and these ethical issues can be restated as follows.

> It is important for the researcher to reveal fully his or her identity and background,
> the purpose and procedures of the research should be fully explained to the subjects from the outset of the study and it should be clear if the research benefits the subjects or the researcher in any way.
> Where necessary ensure the research does not harm the subjects in any way and possible controversial findings need to be anticipated and where they ensue, handled with great sensitivity.
> The research should be as objective as possible. This will require careful thought being given to the design, conduct and reporting of research. Informed consent should be sought from all participants in writing.
> Subjects should have the option to refuse to take part and should know this; and have the right to terminate their involvement at any time and should know this and an arrangement should be made during initial contacts to provide feedback for those requesting it.
> The dignity, privacy and interests of the participants should be respected throughout the study. (p. 71)

Further to the considerations above, the study was approved by the University of KwaZulu-Natal ethical committee (see Appendix 1). Permission to use teachers involved in the study was obtained from KwaZulu-Natal Department of Education. In attempting to follow ethical considerations, as explained in Section 3.2, the teachers participated voluntarily in the study, in that they were invited to complete the questionnaire; and were also requested to indicate if they were interested in participating in the second phase of the study, by providing contact details. The purpose of the study was explained to the teachers, they were requested to sign a consent form for both the survey and the interviews (see Appendices 2 and 3) and they were also given the contact details of the researcher and the supervisor. The names of participant teachers remained confidential and pseudonyms were used to identify the teachers throughout the thesis.

3.4 Quantitative data collection methods

There are different methods used to collect data. A survey can be designed to provide both quantitative and qualitative data. It can be used to understand data trends for a particular sample within a population (Creswell, 2009) and also to be able to generalise the findings from a sample to a population. Thus, surveys can be used to provide both descriptive and explanatory results (Babbie & Mouton, 2001; Cohen, Manion, & Morrison, 2000). Furthermore, in South Africa surveys are popular research instruments (Babbie & Mouton, 2001) which suggest that the teachers participating in the study would already be familiar with this type of data collection. In view of these arguments, a survey was chosen because it allowed the researcher to give numerical descriptions of trends within population by studying a sample of that population.

Babbie and Mouton, (2001) suggested that it is important to design valid survey instruments because, if these are not well designed, useless data can be collected. For the purpose of this study both closed and open-ended questions were used in the survey. Survey research often yields highly reliable measures and results can be generalizable if a representative sample was used (Kitchenham & Pfleeger, 2002). However, surveys can also be subject to errors during reporting and so could have limited ability to establish casual relationships (Abowitz & Toole, 2010). The use of closed-ended questions has an advantage over open-ended questions because they can provide uniformity in the data collected

(Creswell, 2009) but because the study aimed at understanding why teachers use particular teaching learning sequences, open-ended questions were also necessary.

The survey results were also used to identify experienced teachers to participate in the second phase of the study and to guide the formulation of the interview questions.

3.4.1 The survey

Given that there was no existing survey instrument on which to base the current study questionnaire, the literature was searched for applicable ideas and focus questions. The questions were then constructed guided by the ideas from the literature, by the research questions and by the theories associated with the theoretical framework. For example, the theoretical frameworks focus on content and how it should be organized led to a number of questions with a focus on content (see section 2.3). The questionnaire went through numerous draft phases in which the specific questions were discussed with the study supervisor. The most important criteria for inclusion or deletion was their appropriateness in providing data to answer the research questions.

The questions were formulated and grouped into four categories; (a) biographical data, (b) sequencing of general chemistry topics and chemical bonding concepts, (c) use of teaching-learning sequences by teachers, sequences and (d) teaching activities for teaching chemical bonding in the FET Phase. Creswell (2009) suggests using Likert type items in a survey questionnaire with categories of response such as strongly agree to strongly disagree. Several different statements, as Likert type items were designed to measure the teachers' views on the use of different teaching activities, how they organize different topics and their views on sequencing teaching-activities during the teaching and learning of chemistry, were included in the questionnaire. The results obtained from this section of the survey questionnaire were also used to identify participants suitable for the second, qualitative, phase of the study.

There are different ways of developing survey questions, for example, in studying the effectiveness of teaching of functions, Grosser (2007) explain the use of different categories to guide the development survey questions. Scheaffer, Mendenhall and Ott (1986) suggest that when designing closed questions for the questionnaire, it is better to use open ended questions in a pre-test and then use answers obtained in the pre-test as alternatives for closed ended questions in the survey. In this research, most of the questions included in the instruments were identified through the review of literature on the design and evaluation of the teaching-learning sequences (Meheut & Psillos, 2004), the theoretical frameworks and the need to provide answers to the research questions.

3.4.2 Piloting the instruments

The self-developed questionnaire was piloted in order to improve content validity of the instrument and quality of questions, as recommended by Creswell (2009). Content validity indicates how well a test measures what it is intended to measure. In this study piloting was used to improve the validity of the instrument. As noted by Creswell and Plano Clark (2011) "to assess validity of a study, investigators establish the validity of their instruments through content validity and of their scores through criterion related and construct validity procedures" (p. 210). The reliability of the instrument was measured by examining the responses and using the scores (on Likert type items) suggested by the participants. In any research the reliability of "scores need to be determined before the assessment of their validity" (Creswell & Plano Clark, 2011, p. 236).

Content validity of the instrument was improved by critical reading of the survey questions in order to improve the wording and to establish that the response categories provided in the questions were suitable. The critical reading of the survey instruments was carried out in stages. Firstly, three critical readers (two lecturers and one teacher) were requested to specifically assess whether the questions were meaningful to the teachers and the wording was suitable. Finally, the critical readers were requested to give general comments about the questions in the questionnaire. The comments made by the first critical readers were incorporated in the new version of the questionnaire. Then, two other critical readers were asked to review the questions of the new version of the questionnaire and their comments were incorporated into the final version. Finally, one critical reader commented on the purpose of the research, and what the research was trying to elicit from the questions. Some issues of face and content validity were also addressed during critical reading stages of the questionnaire. The piloting of the study was done in order to assess the validity and reliability of the instrument. The first pilot study was carried out with 13 physical science teachers. I decided to use practicing physical science teachers with more than ten years of teaching physical science to answer the questions because they were considered to be experienced and could give full answers. Their responses revealed that the questionnaire needed further development because no clear categories of different options had been included in the original design, resulting in difficulties with coding the results. The second issue that arose from the analysis of the pilot data was the difficulty of linking the survey questions with the research questions. The pilot study findings resulted in major adjustments of questions in the questionnaire. The re-designed questions included response categories (Maree & Pietersen, 2007b) and closer linking of survey questions to research questions. The difficulties experienced while capturing open-ended data on the number of years teaching physical science resulted in the inclusion of response categories for the number of years teaching physical science.

The second pilot was then carried out with two teachers in order to further check the wording of questions and responses categories. The second pilot indicated that some of the questions were still not completely relevant and so these questions were removed from the questionnaire. In summary, the final survey instrument comprised three parts. The first part dealt with demographic data of the teachers, while the second consisted of questions relating to teachers' teaching-learning sequences and the third part dealt with sources for planning of teaching-learning sequences. The final questionnaire is given in Appendix 2. The next sections explain the rationale behind the chosen questions.

3.4.3 Collecting demographic data on teachers

For the purpose of characterizing the participants and looking for underlying factors determining responses, demographic information that included years of teaching experience, qualifications, location of schools and availability of teaching facilities were included in the first part of the survey instrument.

Firstly, the teachers were divided into three different groups using the number of years of teaching physical science at high school. The literature does not give a clear indication of teaching experience based on the number of years teaching. However, categorizing teachers is not new to this type of study, as for example, Hattie (2003) suggested that teachers can be classified into three groups such as; expert, experienced and novice teachers. According to Costa, Marques, and Kemp (2000) personal experience contributes to teachers' pedagogical knowledge. The literature on studies of pedagogical content knowledge (PCK) showed that teachers with different number of years teaching science had been investigated by different researchers. For example Rollnick et al. (2008) studied PCK of teachers with less than seven years' experience. This contrasts with a similar study where Lee and Luft (2008) studied the PCK of a teacher with more than 10 years' experience. There is no agreement of what constitutes a developed teachers' PCK and how this relates to the number of years spent teaching science. Nevertheless, I used the ideas from the literature to determine the three categories used in this study. For example, the first category (1-6 years' experience) in the questionnaire was designed based on the literature; the middle category (7-12 years' experience) was chosen, based on addition of an equal number of six years, and the last category (more than 13 years' experience) is a continuation of the same trend.

Secondly, the teachers in this study were classified into three categories of qualified status, namely qualified, under qualified and unqualified. An adequately qualified teacher can be loosely described as someone with a teaching qualification, for example someone with a teaching degree. Thus, a qualified physical science teacher would be someone with at least a bachelors' degree specializing in physical science. In South Africa, the current Norms and Standards for Teacher Education (NSTE) define "a newly qualified teacher as someone with four years of post-secondary teacher education" (Hugo et al., 2010, p. 129). These post-secondary school qualifications may include the Bachelor of Education (B.Ed.) degree, which is a four year university education degree, or a three-year degree plus a professional qualification. In the South African context, acquisition of the Advanced Certificate in Education (ACE) or Further Diploma in Education (FDE) is currently considered to confer qualified status on a teacher. An under qualified teacher is described in the NSTE as someone with a Bachelor's degree but with no professional qualification or a teacher with a three year senior teacher diploma (STD) qualification (Hugo et al., 2010, p, 129). The classifications from NSTE were used to categorize teachers regarding their qualifications.

Thirdly, data concerning school location and resources available were also sought through the survey instrument. Data categories for location of schools were pre-selected, so that in the questionnaire, teachers were requested to indicate where their schools were situated by ticking an appropriate box, for example, "Where is your school situated? Township, rural, or urban & small town school" (see Appendix 2). Fourthly, teachers were characterized in terms of access to teaching resources. Resources are part of the organization level of education in South Africa (Rogan & Grayson, 2003). Consequently, it was also necessary to include questions on resource availability. The teaching facilities in the current study were defined in terms of aspects such as teaching space, teaching equipment and chemicals. For example, the first such question was “Do you have gas in the rooms you teach physical science in your school?” Teachers were requested to tick yes or no (see Appendix 2). Data was captured as 0 for yes and 1 for no. The nine responses concerning facilities were then added together and a total of 9 would mean that the teachers did not have any teaching facilities, whereas a total of 0 meant that teachers have nearly all appropriate teaching facilities. Categories for this data were allocated from these totals. I decided to categorise the teachers into three groups based on the scores. Thus the first group of teachers, with scores of 1 to 3, were considered to have adequate teaching facilities, the next group of teachers had score of 4 to 6 (some facilities), and the last group of teachers had scores from 7 to 9, considered to have no facilities. The data categories on facilities were then coded by number; adequate facilities being coded as 1, some facilities was coded as 2 and no facilities was coded as 3. In this study adequate teaching facilities would mean those schools with good teaching space, teaching equipment and chemicals whereas some teaching facilities would mean schools with teaching equipment and chemicals, but with inadequate teaching space. The codes were assigned to each teachers and the information was captured on computer software for further analysis.

3.4.4 Questions for the survey instrument

Research question one focused on sequencing of general chemistry topics and concepts, such as chemical bonding in chemistry education. In the survey the teachers were then requested to respond to different statements using a seven point Likert-type item, which ranged from strongly disagree to strongly agree (see Appendix 2). There were three statements. The first question concerned statements about teaching sequences. For example, the first question was “Using a variety of teaching activities in one lesson leads to better learning and learners are more involved in their learning.” The teachers were also requested to respond to statements about resources that might have influenced their decision to use a particular teaching sequence, such as “I follow a topic sequence provided by the learning programme guidelines of the national curriculum statements”. A third question required teachers to respond to statements on sequencing topics during the teaching of chemical bonding in the FET Phase. As an example, the first statement was "In general, I try to link the teaching learning activities of each concept to previous tasks." Teachers were requested to use a seven point Likert-type response scale to indicate how teachers' sequence concepts. The last question required teachers to respond in a dichotomous way by ticking yes or no to three statements on chemical bonding as a problematic topic. Finally, two open-ended questions were included in the questionnaire in order to establish the patterns of general chemistry topic sequences and concepts for teaching chemical bonding in the FET Phase.

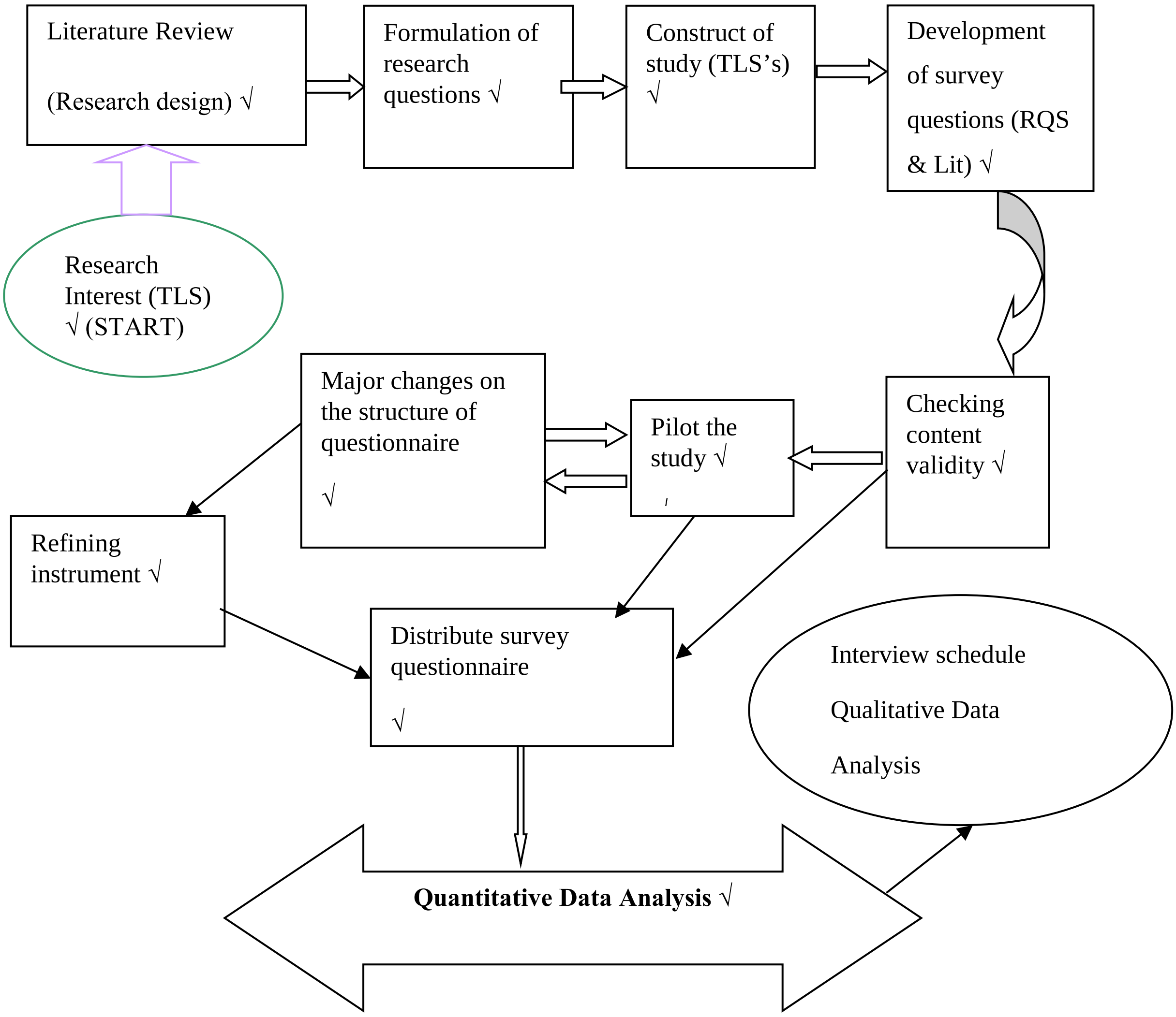

Figure 3. 2 Stages involved in the development of research instruments

A diagrammatic representation of the stages involved of the development of the questionnaire and collection of quantitative data is given in Figure. 3.2. The ticks were used to indicate the processes that were completed. Analysis of the quantitative data derived from the survey informed the design of the qualitative phase of the research, as explained in the section that follows.

3.5 Qualitative data collection

There are different methods used to collect qualitative data. In this study some of the survey questions, interviews, and document analysis were used to further explore the quantitative data. The teaching documents were analysed in order to identify if there is a link between the order of the teaching-learning sequences used by teachers and those prescribed in the textbooks. The interviews were carried out in order to develop and understanding of what teachers say they do and what actually happens in their everyday teaching and learning of chemical bonding in the FET Phase.

Qualitative data analysis involves synthesizing meaning out of a text, or in other words drawing patterns and images from the data. This process allowed the researcher to present and interpret data. Data analysis involved more than one stage because qualitative data was generated through a survey, interviews and documentary analysis. For example, the analysis of interview data using the learning demand tool proceeded in two stages.

Firstly, I tabulated the ideas from the theoretical frameworks into a schedule, and then I used the schedule as a lens to look for evidence in the interview transcripts for each teacher. Lastly, I marked a cross on a grid to indicate an evidence match for that aspect of the schedule and what the teachers said. A blank indicated that there was no evidence found on the teacher’s transcripts.

3.5.1 Interviews

According to Nieuwenhuis (2007) an interview is a two way conversation between the interviewer and the participants. In this conversation, the interviewer asks the participants questions in order to collect data and learn about the beliefs and views of the participants on a particular issue. The main purpose of semi-structured interviews is to allow the researcher to see the world through the eyes of the participant. These interviews can thus be a valuable source of information (Cohen & Manion, 2000; Nieuwenhuis, 2007). In this study face to face, semi-structured interviews were conducted in order to confirm, and elaborate on, quantitative data and to access more detailed understanding of teachers’ views on sequencing chemistry topics in the FET Phase. Thus, the main reason for interviews was to get an enhanced understanding of the quantitative data and the focused categories or patterns that emerged from survey data.

In this study eleven teachers were interviewed about how they sequence chemistry topics in a particular manner, how they plan teaching sequences, their understanding of teaching-learning sequences to teach chemical bonding and how they teach general chemistry concepts in the FET Phase. I decided to stop the interview process after interviewing eleven teachers because the responses were consistent. The design of the questions used in the interview schedule arose mostly from the responses given in the survey. There were some questions that could not be asked in the questionnaire and these were included in the interviews in order to get a deeper understanding on how teachers plan teaching sequences (see Appendix 3, Part 3).

3.5.2 Documentary analysis

Teaching documents can provide a valuable clue as to what happened in past or present situations. The importance of documentary analysis as a research tool was recognized by studies such as the Trends in International Mathematics and Science Study (TIMSS), which analysed textbooks from all participating countries in order to learn about different topics taught in the general education training (GET) phase in each country. According to Ross, Lakin and Callaghan (2000) documentary evidence might include lesson plans, schemes of work, teaching notes, textbooks, and students' notes. In this study teaching documents were limited to textbooks and policy documents. Policy documents here refer to the three official physical science policy documents, Policy General, Physical Science Content and the Programme Guidelines (Department of Education, 2006). As shown by the survey data, the documents were available to most teachers as a source of information for physical science to teach chemistry in the FET Phase. Documentary analysis was used to identify the relevant chemistry topics taught in the FET Phase and identify particular concepts within the topic of chemical bonding. The policy documents were also used to compare teaching-learning sequences suggested by teachers and the topic sequences prescribed or indicated in the policy documents.

3.6 Quantitative Data analysis

The quantitative data obtained from the survey were captured, coded as numbers, as a Microsoft Excel file, as explained in Section 3.4.3. The file was then exported into the computer software Statistical Package for Social Sciences (SPSS). The data were then analyzed using both SPSS and Excel.

The analysis of the data was limited to descriptive statistics and basic inferential statistics. Initially, the data set was examined. For example percentiles were calculated to identify outliers, or extreme cases (Ivankova, Creswell, & Plano Clark, 2009). There are different statistical tools that can be used to summarise data. The descriptive statistics used in this study consist of statistical mean, standard deviation, and frequencies. Both nominal and interval quantitative data were input for analysis through the coding of the survey questions and the output tables of statistics for each question were copied to a Microsoft Word file. The data on each question were further analysed by sub-group looking for any inferential relationships.

Quantitative data analysis was used to establish cases that can be followed in the qualitative phase; that is, to develop semi-structured interview questions. For instance, specific responses from some outliers that emerged from the quantitative data analysis were used to design some of the interview questions (Lieberman, 2005). The qualitative analysis, which will be described in Section 3.7, provided a deeper understanding of the cases identified during quantitative analysis.

3.6.1 Descriptive statistics

Descriptive statistics, according to Nagele (2001), are a way of describing a sample without making any reference to the population from which it is drawn. The mean values were used to indicate average views of the teachers on each statement and the standard deviation informs us about the distribution of teachers' responses around the mean. The mean and the standard deviation were used to describe teachers' views on various statements pertaining to the use of teaching-learning sequences. Cross tabulation was used to show the relationships between the teachers who responded yes or no to the questions on chemical bonding and their characteristics, such as qualification and years of teaching experience.

3.6.2 Inferential statistics

Inferential statistics allow the researcher to use sample data to make generalization about a population. There are different forms of inferential statistics that can be used to analyse data emanating from Likert scale type items. The questions used in their study required participants to respond to Likert type items. However, they used a five point item, contrasting with the seven point Likert type item used in this study.

It is generally accepted that if you have 5 or more categories on a semantic scale you are safe using parametric statistics on items. To minimize the risks, a seven point scale was used so that the data could be treated as interval data for some statistical analysis (Velleman & Wilkinson, 1993). In this study one way Analysis of Variance (ANOVA) was used to explore questionnaire data. An ANOVA is one of the most widely used statistical tools since it can be used for testing differences amongst sub-group means and is suitable for different types of research designs (Rutherford, 2001). Other reasons for choosing ANOVA in this study were that it did not restrict the number of sub-groups that could be compared (Dancey & Reidy, 1999; Rutherford, 2001) and it could also be used to compare the average scores of the sub-groups (Maree & Pietersen, 2007).

ANOVA has been used by researchers to study issues on human behavior, such as determining differences between the performance of 1st year, 2nd year and 3rd year students (Dermirbas & Bozdogan, 2009); to measure teachers' attitudes towards the aims of science education (Yildiz Akpinar, Aydogdu, & Ergin, 2006) and to illuminate teachers' positive or negative experiences teaching science at secondary schools (Hodson, Usak, Fancovicova, Erdogan, & Prokop, 2010). Cakir and Carlsen (2007) also used ANOVA to establish the effectiveness of a particular teaching method in different schools. The analysis was based on the assumption that the p-value of an ANOVA test is the size of the type I error. This is the probability of rejecting the null hypothesis when it is actually true. For example, when the null hypothesis was a statement indicating that the effect that an identified possible factor has no effect on the responses (Rogan, personal communication, 2013).

3.6.3 Matrix analysis- general chemistry topics

The term matrix was introduced in the 19th-century by an English mathematician, James Sylvester. Encyclopedia Britannica (2013) describes a matrix set of numbers arranged in rows and columns so as to form a rectangular array. The numbers are called the elements, or entries, of the matrix. Matrices have wide applications in engineering, physics, economics, statistics and various branches of mathematics and can contain different forms of information such as quotes, memos and data formulated around a research interest. According to Zeintek and Thompson (2009) matrix summaries can enhance findings in educational studies. Matrix analysis is viewed as a powerful interpretive tool and has been used by different disciplines such as physics, economics, mathematics, health science, engineering, information science and communication in science to summarise knowledge generated (Klopper, Lubbe, & Rugbeer, 2007). The literature indicates that matrix analysis is used differently within a discipline, for example in communication science Rugbeer (2004), used matrix analysis to determine semantic features that English deception words share. Govender (2004) used concept matrix analysis to understand the perception of participants about the causes of conflicts between educators and their employer. In this study matrix analysis was used to understand how teachers positioned topics within a particular sequence.

3.7 **Validity issues**

In any research there is a need to pay attention to methodological research designs and issues of validity. The issue of validity is treated differently in all methods. For example, as noted by Bezeley (2004),

> As with any research validity stems more from the appropriateness, thoroughness and effectiveness with which those methods are applied and the care given to thoughtful weighing of the evidence than from the application of a particular set of rules or adherence to an established tradition (p. 9).

In mixed methods designs Onwuegbuzie and Collins (2007) suggested that there are four potential major validity crises; namely, representation, legitimation, integration, and politics. First, a representation crisis mostly arises from sampling problems experienced in both qualitative and quantitative research. Representation crises include “difficulties experienced by researchers in capturing lived experiences by text and numbers” (Onwuegbuzie & Collins, 2007, p. 303). They indicated that in the quantitative phase of a study, representation crises usually arise from the use of a small sample size or a non-random sampling. The representation of quantitative data could be further compromised by the use of convenience sampling, where individuals volunteered to participate in the study. In this study random sampling was not suitable for an understanding of complex issues relating to how teachers design and implement teaching sequences (Marshall, 1996). Nevertheless, in this study the sample size was fairly large (i.e. $N = 227$), to justify generalization of the findings to the accessible population (Onwuegbuzie & Leech, 2010). In this case the accessible population would refer to physical science teachers in KwaZulu-Natal.

Secondly, legitimation issues arise in mixed methods as noted by Onwuegbuzie and Collins (2007), when the researcher has difficulty arriving at reasonable findings or "making inferences that are credible, trustworthy, dependable, transferable and confirmable" (p. 304). Thirdly, integration crises arise during the mixing of quantitative and qualitative approaches, the way research questions address the purpose of the study and from the politics of persuading the stake holders and policy maker to accept the results obtained from both quantitative and qualitative studies (Onwuegbuzie & Collins, 2007). In this study the integration of the results was planned at the research design phase (see Section 3.4). The political aspects of validity, the fourth possible crisis of validity, will be dealt with at the publication phase and are not discussed in this study.

In mixed method designs the conclusions are usually confirmed by different sets of data. Validity in qualitative research is viewed as being honest, having depth, richness and reflecting the scope of data set. In this study, both qualitative and quantitative data were collected and the issue of validation considered both kinds of data collection procedures. The validity of the quantitative data was improved through the use of appropriate sampling, instrument design and data analysis (Cohen, Manion, & Morrison, 2000). Validity in quantitative research means that one can make meaningful inferences from scores obtained from a particular instrument (Creswell, 2009). In this study, the validity of data was further improved because the study employed both quantitative and qualitative data. For example, data were collected from both open- and closed-ended questions; the qualitative data information was used to provide explanations to the numerical data collected in the survey. I ensured that the data were valid by accurately capturing all the information from the questionnaire into a MS Excel spread sheet and also allowing the data to inform the findings of this study. The interview audio tapes were transcribed completely, word for word, into text before the analysis. In summary, validity in the current study was improved by converging findings from different data sets, by ensuring the sample was representative of the population, and by ensuring all data had been recorded before analysis.

3.8 Conclusion

The chapter started by discussing the theoretical frameworks for the methods used in the study. Adhering to methodological procedures helped the researcher to plan and carry out mixed methods research. The guidance provided by ethical issues on how to carry out research and the use of reliable computer software improved the quality of the results. The demographic information of the participants and description of the sample was presented. Both quantitative and qualitative data were collected, but priority was given to quantitative data. The use of different data sources resulted in the improvement of the quality of the results because it was felt that this would lead to a better understanding of the data.

The findings of the study, generated by the research methods presented in this chapter are reported in chapters four, five, and six. In chapter four the survey, interview, and documentary analysis findings are presented and interpreted. To produce the outcomes, the results of the analysis of quantitative and qualitative data were compared and relationships were noted. The first level of data integration occurred at the formulation of research questions and then generation of interview questions was based on some of the findings of the quantitative data. The outcome statements presented with the findings were generated from the data and they provided a summary of findings. There are different ways of defining outcomes (Chan et al., 2004). In this study the outcomes is referred to as intended or final results. Each main outcome was constructed from sub outcomes and the results of each sub outcome are presented separately.

CHAPTER 4 FINDINGS: TEACHING SEQUENCES

Chapter 4 presents the results of the analysis of the survey and interview data. The data was collected from teachers through a survey instrument and an interview schedule designed for the study. The survey was administered to practicing physical science teachers in KwaZulu-Natal and was completed by 227 teachers. A further eleven teachers were interviewed. This study was guided by four research questions and these questions were answered by analysing and interpreting the data collected from both the survey and the interviews. Data analysis and presentation/interpretation is discussed in this chapter and chapters 5 and 6. This chapter provides answers to the first two research questions:

What teaching-learning sequences are used by teachers to teach general chemistry topics in the FET Phase?

What teaching-learning sequences are used by chemistry teachers to teach chemical bonding in the FET Phase?

As described in Chapter 3, a survey questionnaire was piloted and then distributed to physical science teachers. The survey (shown in Appendix 2) had three parts. The first part dealt with demographic information such as teaching experience, qualifications, and resources. The second part of the instrument focused on teaching-learning sequences. The last part surveyed sources of information used by teachers and their preferences in teaching-learning activities. As described in Chapter 3 questionnaires were distributed and collected from the teachers attending developmental courses (ACE) and the workshops. Data from the questionnaires was captured and analysed using SPSS 18 and Microsoft Excel computer software.

The methods used to distribute and collect the questionnaire differed from group to group. For example, teachers attending the workshops were given the questionnaires on the first day of a five day workshop and the questionnaires were collected on the last day. The teachers attending the ACE courses and teachers attending one day contact meetings returned the questionnaires on the same day. The purpose of the study was explained to all the participants and those who did not want to participate were not in any way discriminated against. A clearance certificate for the study was obtained (see Appendix 1, HSS/0098/10D) and teachers were free to participate or not, in terms stated in the ethical clearance certificate.

There were 103 questionnaires completed by ACE students and 115 were completed by teachers attending the workshops. Nine teachers completed the questionnaire through e-mail or hand post. Overall, out of the 350 questionnaires distributed, 227 were returned (a 65% return rate). Yu and Cooper (1983) reviewed quantitative research design effects on response rate to questionnaires and found that a convenience sample had a lower response rate compared to sampling techniques such as random sampling. They also found that mail surveys had the lowest response rate of about (47%) as compared to telephone (72%) and personal interviews (82%). In this study the response rate was higher than that of a postal survey because the questionnaires were distributed and collected directly from the teachers.

4.1 Characteristics of participants

4.1.1 Characteristics of survey participants

The participants in the survey are described using five different characteristics. These characteristics are qualification, experience, location of school, type of school, and the availability of teaching facilities. The characteristics were included in order to determine if these had an influence in the manner in which teachers answered the subsequent questions. Table 4.1 gives a summary of the characteristics of the respondents.

In reporting and discussing the results presented in Table 4.1, percentages of respondents have been rounded up or down to the nearest whole number for purposes of readability. From Table 4.1, it can be seen that 30% of the teachers had more than 13 years' experience teaching physical science and 28% of the teachers had 7 to 12 years teaching experience. About 40% of the teachers had less than seven years' experience teaching physical science in the FET Phase. This group of teachers was therefore considered to be experienced or novices (see Section 3.2). The categories for qualifications were given in Section 3.4.3. From Table 4.1 it can be seen that about 60% of the teachers were qualified and 35% were under qualified. Only four percent of the teachers were unqualified. It can further be seen that about 60% of the teachers were from rural schools while 30% were from township schools. Only a small percentage of teachers were from urban and small town schools.

Table 4. 1 Characteristics of survey participants

Characteristics (N=227)	Groups	Frequency	Percentage
Experience	1 to 6 years	89	39.2
	7 to 12 years	64	28.2
	More than 13 years	68	30.0
	No response	6	2.6
	Total	227	100.0
Qualification	Qualified	135	59.5
	Under qualified	80	35.2
	Unqualified	9	4.0
	No response	3	1.3
	Total	227	100.0
Location	Township	68	30.0
	Rural	137	60.3
	urban & small town schools	18	7.9
	No response	4	1.8
	Total	227	100.0
Teaching facilities	Adequate facilities	26	11.4
	Some facilities	125	55.1
	No facilities	76	33.5
	No response	0	0
	Total	227	100.0
Type of school	Built after 1994	46	20.3
	Ex model C	13	5.7
	Private	16	7.0
	Built before 1994	148	65.2
	No response	4	1.8
	Total	227	100.0

In reporting and discussing the results presented in Table 4.1, percentages of respondents have been rounded up or down to the nearest whole number for purposes of readability. From Table 4.1, it can be seen that 30% of the teachers had more than 13 years' experience teaching physical science and 28% of the teachers had 7 to 12 years teaching experience. About 40% of the teachers had less than seven years' experience teaching physical science in the FET Phase. This group of teachers was therefore considered to be less experienced or novices (see Section 3.2). The categories for qualifications were given in Section 3.4.3. From Table 4.1 it can be seen that about 60% of the teachers were qualified and 35% were under qualified. Only four percent of the teachers were unqualified. It can further be seen that about 60% of the teachers were from rural schools while 30% were from township schools. Only a small percentage of teachers were from urban and small town schools. The distribution of schools where the teachers came from show that 65% were from a school built before 1994. About 20% were from schools built after 1994. The results indicate that 6% of the teachers were from ex model C schools and 7% were from private schools. It is evident from Table 4.1 that 55% of the teachers had some facilities and 12% had adequate facilities to conduct practical work or a simple demonstration, while 34% reported that they did not have enough laboratory equipment and/or space for teaching physical science in the FET Phase.

In attempting to develop an understanding of the distribution of the teachers in terms of location, qualification, and experience, a cross-tabulation was made to establish the categories of teachers within the respondent group, for example, were most of the qualified and experienced teachers teaching in urban or rural schools. This analysis is presented in Table 4.2.

Table 4. 2 Cross-tabulation of location of school, experience and qualification of teachers

Location		Experience	Qualified	Under qualified	Unqualified	Total
Township n = 64		1 to 6 yrs.	11	13	2	26
		7 to 12 yrs.	9	11	0	20
		more than 13 yrs.	14	4	0	18
	Total		34	28	2	64
Rural n = 132		1 to 6 yrs.	25	22	6	53
		7 to 12 yrs.	29	10	0	39
		more than 13 yrs.	29	10	1	40
	Total		83	42	7	132
Urban and small town schools n = 18		1 to 6 yrs.	7	1	0	8
		7 to 12 yrs.	2	1	0	3
		more than 13 yrs.	4	3	0	7
	Total		13	5	0	18

The data in Table 4.2 clearly shows little difference between the qualifications of teachers in rural or township schools. The results also indicate that rural school teachers had similar amounts of experience to those in township schools. For example, with more than 13 years' experience, 22% of the teachers were from township schools and 22 % were from rural schools. For this sample of teachers, when it comes to these two characteristics it can be said that township and rural teachers do not differ much.

4.1.2 Characteristics of interview participants

Eleven teachers participated in the interviews and the majority of these teachers were experienced, (17 years). There were three teachers from private schools and one teacher from a rural school, one teacher was from an ex model C school (presumably well-resourced) and five teachers were from urban or small town schools. Three teachers had master's degrees, one teacher had an honors degree, three teachers had ACE or FDE qualifications, and three teachers had a qualification equivalent to a BSc or BPaed and a professional qualification. One teacher had a bachelor of science (BSc) and was studying towards a postgraduate certificate in education (PGCE) with the University of South Africa.

4.1.3 Teaching documents

Teaching and policy documents form the basis of an educational system. The South African national curriculum statement (NCS) documents clearly states that "the educators can choose the sequence as well as the details of the content" (Department of Education 2006 p. 14). In order to establish if teachers had access to teaching documents for the teaching of physical science in the FET Phase, in the survey a question was included to this effect.

Table 4. 3 Percentage of teachers who have access to policy documents

	Access to NCS-General	Access to PSNCS-Content	Access to PSNCS-Learning prog. guideline	Access to PSNCS-Subject Assessment guideline
Personal copy	74.0	71.8	75.8	74.9
School copy	23.3	24.7	22.0	22.9
Other	0.9	0.4	0.4	0.4
No response	1.8	3.1	1.8	1.8
Responses (n =)	223	220	223	216

The results of the survey show that the majority of teachers have access to policy documents. In this study policy documents refer to published curriculum documents distributed to teachers at workshops and to schools such as programme guidelines, general policy and physical science content documents (Department of Education, 2006). The results indicate three quarters of the teachers have personal copies of the policy documents that they may consult during planning, while a quarter of the teachers have access to copies of policy documents that are kept at the school. This indicates that in general, the teachers have access to policy documents and should know what to teach in terms of topics and the level of difficulty of chemistry topics in the FET Phase.

The teachers surveyed were also requested to name a textbook they predominantly used for their planning as well as the one given to learners. The learner's textbook here refers to the textbook issued to learners for the duration of one year. The teachers' copy refers to a book in the teacher's possession and is usually the same book used by the learners. The teachers' responses appear in Figure 4.1.

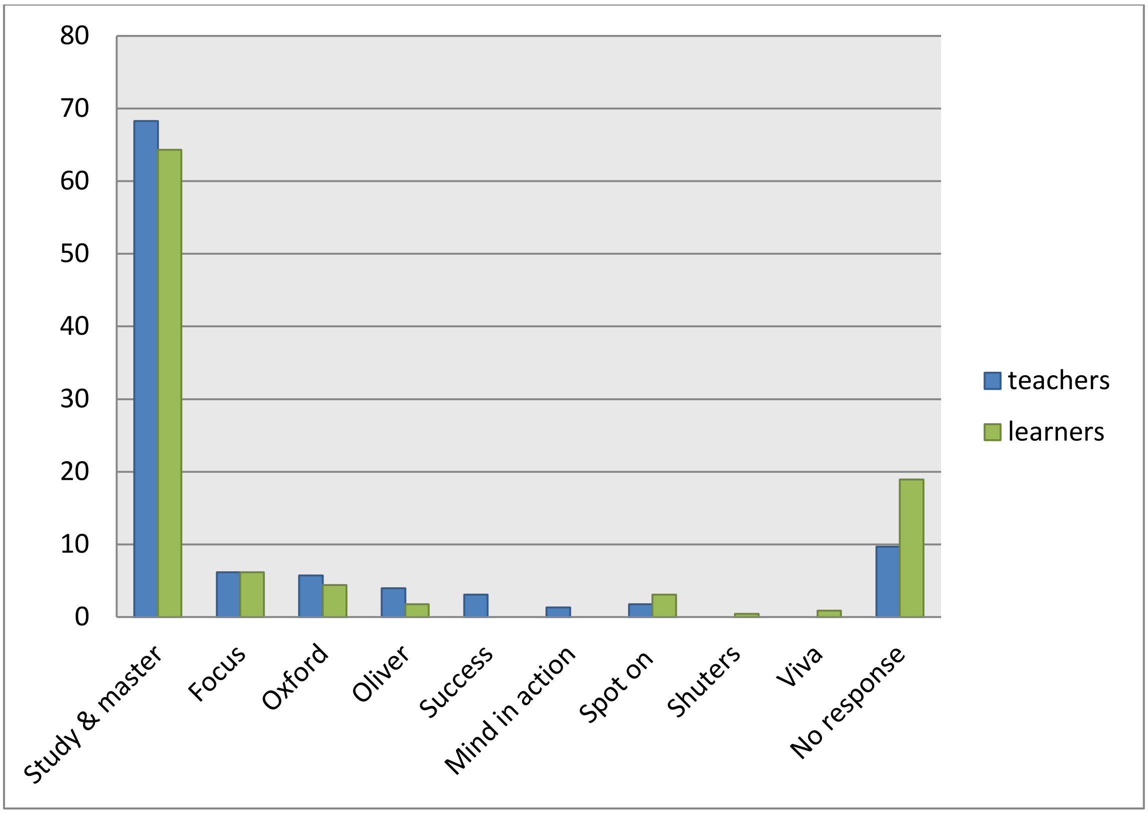

Figure 4.1 Percentage of teachers and learners who use named textbooks

From Figure 4.1, it can be seen that about 65% of the teachers and learners have access to the textbook 'Study and Master' for physical science at high school. For a complete reference to the text books mentioned by teachers, see Appendix 4.

4.2 Sequencing of topics and concepts

The purpose of this section is to present the findings associated with teachers' suggestion for sequencing the teaching of topics in general chemistry and concepts in the topic of bonding. Data collected from the survey and interview responses that provide clues to the answers to the first and second research question, are both presented. The first research question was; "What teaching-learning sequences are used by teachers to teach general chemistry in the FET Phase?" The second research question was; "what teaching-learning sequences are used by chemistry teachers to teach chemical bonding in the FET Phase?" In order to provide an answer to these questions, an outcome statement has been constructed based on the analysis of the survey and interview data. The use of inductive interpretive analysis in this study allows for the formation of general outcomes to provide a summary of the findings.

Outcome statement one:

Teachers suggested a variety of different sequences for teaching both the topics in general chemistry and for the concepts in the specific topic of chemical bonding. There were some similarities among the sequences. In general the sequences suggested did not match that provided in the curriculum documents.

This general outcome statement was formulated from three sub-outcomes that are described separately in the following sections.

4.2.1 Sequencing of General Chemistry Topics

Sub-outcome 1a: There were a variety of sequences, but most of them appeared to be meaningful (not arbitrary or random sequences). There was some consensus among teachers in both the survey and the interview on the following general chemistry topic sequence: *periodic table, structure of atom, atoms and molecules, atomic mass and diameter, mixtures, isotopes, properties of liquids and solids, names and formulae of substances, chemical bonding, molecular forces and balancing chemical equations.*

Support for this outcome came from the survey question that asked teachers to arrange a list of topics into a teaching sequence that they would use, or had used; in teaching physical science to grades 10 to 12 at high school (see Appendix 2, Part 2). Data was also obtained from the interview question that required teachers to organise cards labeled with chemistry topics into a teaching sequence (see Appendix 3, Part 4).

The analysis of data proceeded as follows; firstly, data for each teacher was captured and coded using alphabetic letters assigned to each topic as labels into an Excel spread sheet for example A represents the position of the periodic table and D atoms and molecules within a teaching sequence. Secondly, data was systematically analysed for different patterns of teaching sequences and the tool used to help identify these patterns was Excel computer software. For example, the first patterns of teaching sequence were identified by filtering for label A in the first field of the spreadsheet and on the second field, I filtered for label D. For example, the label A indicates the first topic on the list given in the survey (see Appendix 2, Part 2). I continued the filtration for the remaining labels in the subsequent fields. The teaching sequences that were similar were assigned the same numerical code.

Table 4.4 Topic sequences as indicated by the survey

Code	Topic Sequences		[N=227]									N	%
1	A	D	E	F	G	H	B	C	I	J	K	29	14.29
2	B	C	A	D	E	F	G	J	H	I	K	18	8.67
3	A	E	F	D	H	I	G	J	K	B	C	8	3.52
4	E	F	G	D	A	J	B	K	H	I	C	6	2.64
5	A	E	D	J	K	F	G	H	I	C	B	6	2.64
6	D	E	F	A	G	H	J	I	C	B	K	6	2.64
7	A	B	C	D	E	F	G	H	I	J	K	6	2.64
8	A	J	D	E	F	G	H	I	B	C	K	5	2.20
9	C	B	A	D	E	F	G	I	H	J	K	5	2.20
10	A	E	D	B	C	F	G	H	I	J	K	4	1.76
11	B	C	A	D	E	F	G	H	I	J	K	4	1.76
12	A	B	D	E	F	G	H	I	C	J	K	3	1.32
13	B	A	D	E	F	G	I	H	J	K	C	3	1.32
14	79 teachers provided individual sequences that only matched one or two teachers											79	34.80
15	No response											24	10.57
Total												227	100

The manner in which teachers sequenced the topics has highlighted the fact that there is no one single topic sequence for teaching chemistry at FET phase. There we very little agreement of the teachers on a single topic sequence from the survey results (see Table 4.5).

However, after careful examination of the table data it is evident that there are some discernible patterns of sequences that emerge. The results indicate that more than half of the teachers, 124 out of a possible 227 teachers, had sequences which were similar to at least two or three other teachers and the other 103 teachers placed the topics differently from other teachers or did not provide a sequence. There were two sequences (1 and 2) selected by 18 or more teachers. There were many other sequences that were selected by between three and eight teachers. In sequence 1, the topics were arranged such that, the periodic table, atoms and molecules and the structure of the atom are placed at the beginning of the sequence. In sequence 2, topics were arranged in the following order, mixtures and properties of liquids and solids are positioned at the start of the sequence. The second group of teachers thus starts by teaching science content that is familiar to the learners, in contrast to the first group who started with the periodic table. To obtain further insights into the teachers' choices, it is necessary to analyse the data using other methods such as matrix analysis. This analysis is presented in Table 4.5 below.

Table 4. 5 Matrix summaries of general chemistry survey topics

Positions in sequence	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Matrix sum**
Periodic table	79	24	34	20	23	6	7	3	4	2	0	589
Structure of atoms	33	57	38	33	24	6	6	0	1	1	0	610
Atoms and molecules	29	46	50	39	15	14	4	1	3	1	1	670
Atomic mass & diameter	3	11	29	50	34	30	16	8	6	6	3	985
Mixtures	39	24	12	17	11	15	19	10	13	22	12	1018
Isotopes	1	3	16	22	52	36	34	12	8	7	1	1106
Properties of liquids & solids	17	23	11	9	8	19	13	14	19	25	31	1251
Names and formulae	4	12	5	10	15	25	30	33	19	35	8	1391
Chemical bonding	0	3	2	1	10	33	28	51	29	28	14	1563
Molecular forces	0	0	3	1	3	9	21	34	50	29	34	1615
Balancing chem equations	1	2	4	0	6	7	19	23	35	29	70	1781
Total respondents	206	205	204	202	201	200	197	189	187	185	174	

In table 4.5 the horizontal rows of the matrix represent the position of the topic in the sequence and the vertical column indicates the topic. The first column of the matrix shows the number of teachers who placed the topic in the first sequence. The second column indicates the number of teachers that placed the topic in the second position of the sequence. For example, the first cell contains 79 which indicate that 79 teachers placed periodic table in position one. The matrix score was calculated as follows; 79 topic appearances multiplied by sequence position 1 + 24 topic appearances multiplied by sequence position 2 + 34 topic appearances multiplied by sequence position 3. The procedure was repeated for all the possible positions for the periodic table. A total score of 589 was recorded for the matrix score. In the matrix analysis a topic with the lowest score was first position and a topic with the highest score was placed in the last position. From this analysis, the topics were ranked as shown in Figure 4.2 below.

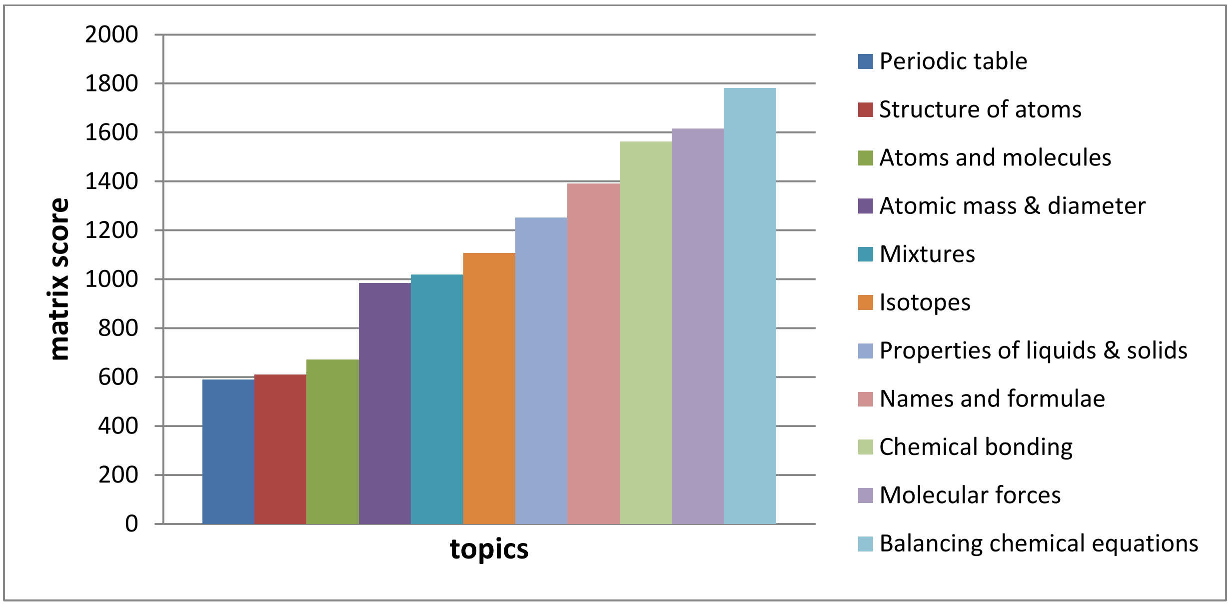

Figure 4. 2 Ranking of matrix scores and general chemistry topics

Figure 4.2 is a histogram representation of the order of chemistry topics sequences for the FET phase derived from the matrix analysis. In the survey most teachers indicated that they teach the periodic table at the beginning and balancing chemical equations at the end of a teaching sequence. The matrix analysis of survey results indicate that there is a general way of sequencing chemistry topics in the FET Phase. The general sequence identified by the matrix analysis can be stated as, periodic table, the structure of the atom, atoms and molecules, atomic mass and diameter, mixtures, isotopes, properties of liquids and solids, names and formulae of substances, chemical bonding, molecular forces and balancing chemical equations.

Interviews

In order to gain further insights into and explanations for the preferred topic sequences, interviews were carried out with eleven teachers. These teachers were selected based on the number of years teaching physical science, qualifications and location of school. However, some of the teachers that were initially selected based on the survey results indicated that they did not want to be interviewed. One of the interview activities involved sorting topic cards into an order. The teachers were given cards labeled with the general chemistry topics and specifically asked to organize the topics in relation to the teaching of chemical bonding and were asked to talk through as they organised the cards. They were asked to arrange the topics in an order that would help learners understand chemistry (See Appendix 3, Part 4). I used eight topics so that the time for the interviews was not too long, but most of the key topics were included in the card sequence. The topics that were left out included isotopes, atomic mass diameter, atoms and molecules. The atoms and molecules topic card having been mistakenly left out, despite this the card sorting provided valuable corroboration to the survey results. Although in the curriculum these topics were placed in arbitrary positions. In the survey the atoms and molecules were placed at the beginning and the other two topics, isotopes and atomic diameter were placed in the in the middle of the sequence.

Table 4.6 **Matrix summaries of general chemistry interviews topics**

Positions in sequence	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Matrix sum**
Periodic Table	2	5	2	0	1	1	0	0	**29**
Mixture	5	0	1	1	0	0	1	3	**50**
Prop of Liquids& solids	0	2	1	0	1	1	3	2	**55**
Structure of atom	1	3	3	1	1	1	1	0	**32**
Chemical bonding	1	0	2	3	0	2	0	2	**47**
Molecular Forces	0	0	0	3	2	1	3	2	**65**
Names &formulae	0	1	2	2	3	1	2	0	**51**
Chemical equations	0	0	0	1	3	3	1	2	**61**

A similar matrix analysis to that used for the survey data was used for the data from the interview card sorting. The results of card sorting are shown in Table 4.6. The matrix results for the survey and the interviews showed that there is an identifiable teaching sequence used by teachers for general chemistry topics in the FET Phase. The interview results support the survey results on the last two sequence topics, where teachers placed balancing chemical equations and molecular forces at the end of the sequence. However, differences were found in topics placed in the middle of the sequence.

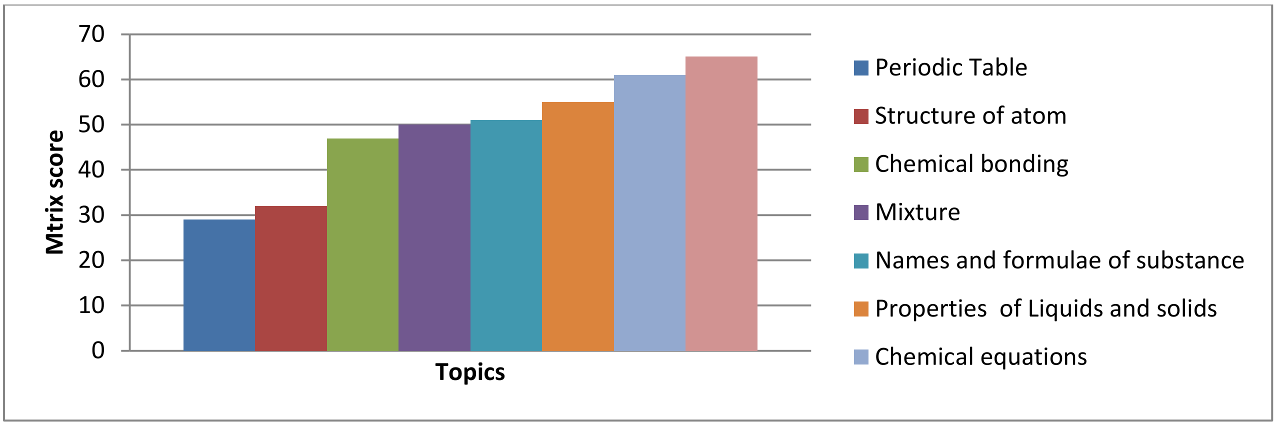

Figure 4. 3 Ranking of matrix scores for general chemistry topics from the interviews

In the interviews teachers spoke about how they sequenced the topic based on what learners had been taught in previous grades. This is represented by the following excerpts;

> They would have learnt the periodic table in grade nine and covered a whole list of known elements in the periodic table. From there we look at the atoms and cover the structure of the atom e.g. what is made up of: the nucleus, electrons, protons, neutrons, isotopes, mass number, atomic number, electronic configuration, and valence – relate it to the group number on the periodic table (Vusi-interview)

Vusi started a sequence by considering learners' prior knowledge based on topics taught in the previous grades. The teacher linked the structure of the atom with the periodic table at the beginning of the sequence. This point is further emphasized by the following excerpt from Saziso's interview;

I would put the structure of atoms first, they know what an atom is, they would know about the number of electrons, why they are put in the periodic table, the way they are, that depends on the number of electrons. Intramolecular forces because that relate to the stable electron configuration. I would not do the intermolecular forces there at all (Saziso-interview).

Saziso started the sequence by teaching the structure of atoms, because she emphasized that learners needed to know about the number of electrons before they are taught the periodic table. She spoke about the need to teach intra-molecular forces separately from intermolecular forces.

The results indicated that there was a miss-match between the survey and the interview results for the topics placed in the middle of the sequence. The following example provides a deeper understanding as to why teachers placed these topics in the middle of the teaching sequence;

If the learner understands how to write formulae, it is going to make his understanding of chemical bonding so much easier when he works out the formula for the compound based on the bonds that are formed. The prior knowledge of the periodic table, the structure of the atom and names and formulae of substance will help in understanding chemical bonding. In order to understand chemical bonding prior knowledge of the above three important topics is required. From there you can proceed to Intramolecular forces: Intramolecular bonding to me is another name for chemical bonding (John-interview).

John's statement indicates that he thinks that a learner's understanding of chemical bonding is linked to his/ her understanding of the formulae of compounds. This teacher reiterated that the learner needs to know the periodic table, the structure of the atom and names and formulae of substance before chemical bonding. The following quote provides further insight as to why topics in the middle of the sequence were differently placed in the two sources of data.

I would look at mixtures as being different from elements and compounds then, because we are dealing with Liquids, Solids and Mixtures, you can start discussing some form of intermolecular forces causing some type of bonding.

> Because you are dealing with phases of liquids and solids you go into intramolecular forces, talking about chemical bonding. (Simi-interview)

In this quote from Simi, the teaching of mixtures is linked to the properties of solids and liquids. The teacher said that intermolecular forces cause a bond to form and has indicated that the properties of solids and liquids are linked to intra-molecular forces and bonding.

Having framed the generally used sequence of chemistry topics, I then analyzed the sequences for subtopics within chemical bonding.

4.2.2 Sequencing concepts for teaching topic of chemical bonding

The second research question was; "what teaching-learning sequences are used by chemistry teachers to teach chemical bonding in the FET Phase?"

Sub-outcome 1 b: In general teachers sequenced individual concepts for chemical bonding differently. The most popular sequence of individual concepts suggested was; attraction forces, covalent bonding, ionic bonding, Lewis notation metallic bonding and molecular shapes.

Support for this outcome came from both the survey and the interviews. In the survey, teachers were presented with a list of six subtopics of chemical bonding and requested to reorganise the subtopics into a teaching-learning sequence that is suitable for their teaching and for improving learners' understanding of chemistry in the FET Phase. The teachers were requested to assign a number from 1 to 6 for each subtopic namely metallic bonding, Lewis notation, molecular shapes, attraction forces, ionic bond, and covalent bonds (see Appendix 2, Part 2). In the interviews, teachers were presented with a list of three sequences from the survey and asked to comment on each sequence (see Appendix 3, Part 5). The data was analysed with the help of Microsoft Excel and findings interpreted using the MER framework.

The manner in which teachers sequenced chemical bonding concepts indicates that there are many ways of sequencing concepts within a topic (chemical bonding). The analysis of the survey and interview data shows that one sequence was more commonly used by teachers than others. The teachers' responses on sequencing chemical bonding concepts appear in Table 4.7.

Table 4. 7 Survey respondents' choices of sequence for chemical bonding concepts (N = 227)

Position	1	2	3	4	5	6	N	%
A.	forces	covalent	ionic	Lewis	metallic	shapes	33	14.54
B.	forces	covalent	ionic	shapes	metallic	Lewis	21	9.25
C.	covalent	metallic	ionic	forces	Lewis	shapes	20	8.81
D.	Lewis	forces	covalent	shapes	ionic	metallic	20	8.81
E.	shapes	Lewis	forces	covalent	metallic	ionic	14	6.17
F.	covalent	ionic	metallic	Forces	Lewis	shapes	11	4.85
G.	ionic	forces	covalent	metallic	Lewis	shapes	11	4.85
H.	covalent	ionic	metallic	shapes	forces	Lewis	7	3.08
I.	covalent	metallic	ionic	forces	Lewis	shapes	7	3.08
J.	Lewis	forces	ionic	shapes	metallic	covalent	7	3.08
K.	Lewis	forces	ionic	shapes	metallic	covalent	6	2.64
L.	metallic	ionic	covalent	forces	Lewis	shapes	6	2.64
M	teachers provided individual sequences that only matched two or three teachers						40	17.62
N	No response						24	10.57
Total							227	100

From Table 4.7 it can be seen that there are some more common patterns of sequences that emerged from the data. For example the first two sequences (A and B) have a sequence starting with attraction forces, followed by covalent bonding followed by ionic bonding. The differences that occur in sequences A and B are at positions 4, and 6. Data indicate that 15% of the teachers organised the concepts into sequence A. Four similar sequences were reported by more than 20 teachers and three patterns of sequences were reported by more than 10 teachers. The other patterns were reported by between six and seven teachers. When aggregated, the percentage of teachers with identifiable sequences is 72% and 28% of the teachers did not arrange the topics into a sequence that could be matched any other sequences. This indicates that a significant number of teachers are using sequences that are unique to them or just a few teachers. In order to have a broad understanding of the different sequences, I further analysed the data using a matrix analysis.

Matrix Analysis- chemical bonding

A matrix analysis was carried out to gain further insight into the survey data. As with the data for general chemistry topics, the matrix table consists of vertical columns representing topics and horizontal rows representing the position of the topic in the sequence.

Similarly, the matrix score was then used to construct a histogram. The results of this analysis for chemical bonding topics appear in table 4.8, together with the resultant histogram in figure 4.4.

Table 4.8 Matrix Results for chemical bonding sequences

Position	1	2	3	4	5	6	Matrix score
Covalent	38	63	56	25	11	12	559
Forces	61	53	32	29	18	13	547
Ionic	21	37	71	20	22	35	708
Lewis	50	26	9	43	39	38	724
Metallic	10	16	35	27	98	18	853
Shapes	25	10	2	61	16	88	903
Total	205	205	205	205	204	204	

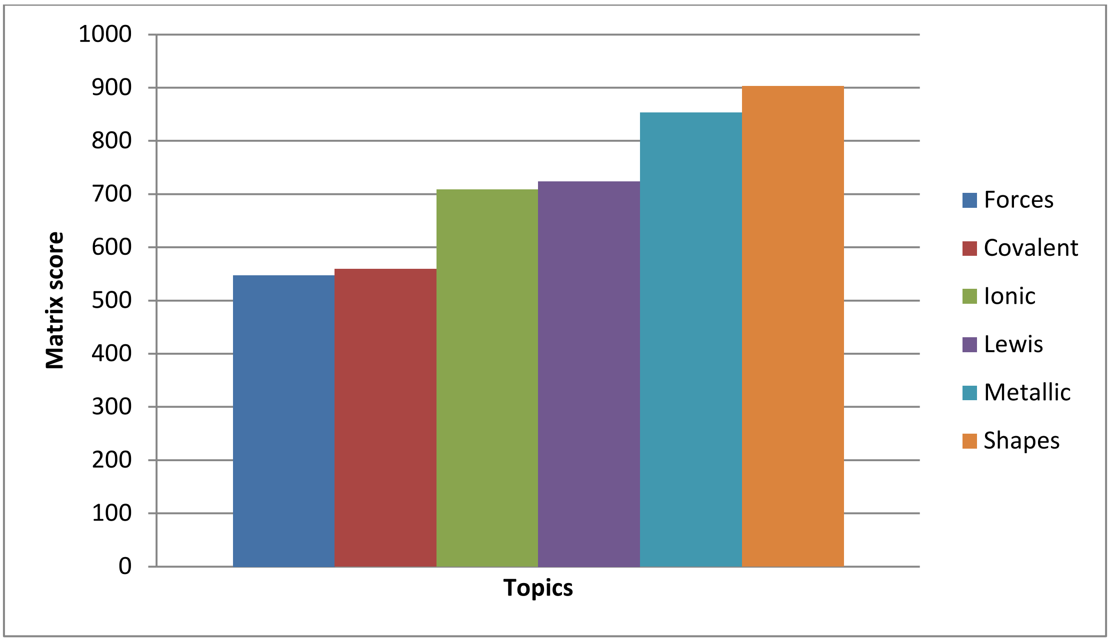

Figure 4. 4 Ranking of matrix scores for chemical bonding topics from the survey

It can be seen from Table 4.8 that the matrix analysis results matched the results obtained by sorting the concepts for sequence A (see Table 4.7).

Interviews

The reasons behind the choices were investigated in the interviews. In the interview, teachers were also presented with three concept sequences (A, D and E) which had each been selected by more than 20 or more teachers.

A: forces →covalent→ionic→ Lewis→ metallic→ shapes

D: Lewis →forces→covalent→shapes→ionic→metallic

E: Shapes→ Lewis→forces→ covalent→ metallic→ionic

The teachers were asked to comment on the three concept sequences. This question was included in order to get a deeper understanding of how teachers sequenced the concepts in a particular order. Eight interviewees indicated that they would teach from a sequence similar to sequence A. Four teachers indicated that they would use sequence A without making any changes. Two teachers indicated that they would use sequence A, but make some changes on the sequence. These two teachers indicated that they would move Lewis notation so that it is taught after covalent bonding and maintain the same order with the other concepts in the sequence. Two teachers indicated that they would make some changes to sequence A, but the changes were different for each teacher.

Three teachers indicated that they would prefer to teach from a sequence similar to E, with two teachers indicating that they would use sequence E without making any changes (see Table 4.8). One teacher preferred to interchange the position of ionic bonding with that of molecular forces .In the interviews none of the teachers selected sequence D. This analysis indicates there was less variation of sequences within chemical bonding. In an attempt to understand the source of topic sequences suggested by teachers in the survey and the interview, I analysed the policy documents.

4.3 **Coherence with National Curriculum Statement**

The purpose of this section was to establish if the general topic sequence suggested by the teachers was similar to the one in the National Curriculum Statement document. In this section I report the results obtained from the analysis of some of the topics stated in the curriculum documents.

Sub-outcome 1c: The topics sequence suggested by teachers was different from that described in the curriculum documents, but the concept sequences for bonding was very similar to that in the policy documents.

General chemistry topic sequence

Support for this outcome came from the analysis of the list of chemistry topics provided in the National Curriculum Statement (NCS) (Department of Education, 2006). I did not include all the chemistry topics found in the NCS document, but selected eleven topics out of 40 possible topics from grade 10 to 12, based on their level of importance and relevance to chemical bonding. The analysis started by identification of sequences of some general chemistry topics at FET phase compared with the topic sequences provided by the teachers in the survey. The results of the matrix analysis sequences were compared with the sequence from the policy documents.

Table 4.9 Comparison of the teaching sequences for general chemistry topics from the survey and the policy document/s

Order	Matrix analysis sequence- survey	Order	Policy document sequence
1	Periodic table,	1	Names & formulae of substance;
2	Structure of atom,	2	Atoms & molecules;
3	Atoms and molecules,	3	Intermolecular & intramolecular forces;
4	Atomic mass and diameter, mixtures,	4	Properties of liquids and solid;
5	Isotopes,	5	Atomic mass & diameter
6	Properties of liquids and solids,	6	Structure of atom
7	Names and formulae of substances,	7	Isotopes
8	Chemical bonding,	8	Periodic table
9	Intermolecular & intramolecular forces;	9	Chemical bonding
10	Balancing chemical equations	10	Balancing chemical equations

Table 4.9 shows that the topic sequence from the policy documents does not match the topic sequence suggested by the teachers for teaching chemistry in the FET Phase. The results indicate that only the position of balancing of chemical equations was similar. As outlined in the previous section, teachers who were interviewed had different topic sequences

from each other. The analysis of teaching documents provided valuable information as to what teachers are supposed to be teaching in the FET Phase. The results confirm the fact that teaching sequences are developed by individual teachers to meet their own teaching needs. The results of the survey showed that each teacher organize the topic into a particular sequence (see Table 4.4). This sequence differed from that in the policy documents, indicating that teachers are not comfortable teaching the topics in the order provided by the policy documents.

The following excerpts illustrate the justification teachers provide for organizing in the way they did. Each quote illustrates a situation where teachers use their own experience to arrange the topics into a suitable teaching sequence.

> In the first module you are teaching about matter and material. So I would start with mixtures and talk about homogenous and heterogeneous, acids and bases, pure substances, elements, compounds and the atom. Properties of liquids and Solids can be on their own, but I would put them with the mixtures because you may have mixtures with two liquids, two solids or a solid and a liquid. Then bring in the periodic table in order for learners to understand the different elements, groups, periods and the names of elements. While discussing the elements in the periodic table, I would bring in the structure of the atom. Learners need to understand that elements are made up of smaller units called an atom, names and formulas of substances; this is basic chemical bonding where you teach learners the names and formulas of as many substances as possible (including ions, polyatomic ions). Then balanced chemical equations would come when you teach chemical change. You'd have to teach learners how to balance equations. Then I would go into chemical bonding and talk about intra-molecular and intermolecular forces. (Themba-interview)

In the quote it can be seen that the teacher starts the sequence by teaching mixtures and then properties of liquids and solids. When Themba spoke about how he would arrange the topics, he was able to justify his sequence mostly based on idea that one topic links to the next. This was supported by the following quote from another teacher.

> Learners would have started with chemical bonding in grade 10. They would have learned the periodic table in grade nine and covered a whole list of known elements in the periodic table. From there we look at the atoms and cover the structure of the atom, e.g. what is made up of: the nucleus, electrons, protons, neutrons, isotopes, mass number, atomic number, electronic configuration, and valence- relate it to the group number on the periodic table. Then we bring in the chemical bonding aspect, relating the idea that all substances turn towards stability and those atoms with incomplete filled orbital will tend to bond with either atoms of the same kind; in a case of an element they form a diatomic molecules; or atoms of different kinds where a compound is formed. Bonding will take place, so we look at different kinds of bonding. In covalent bonding we look at pure and

polar bonding and we explain each of those in terms of orbital overlap and sharing of electrons, pairs of electrons being shared, bring in multiple bonds perspectives. Then ionic bonding involves complete transfer of electrons. Here we bring in the idea of electro negativity. From there we go on to metallic bonding which is the electrostatic force between see of delocalized electrons and the positive ions. We speak about the strong crystal lattices where you have a lot of atoms together creating a giant molecule. We then bring in names and formulae of substances and we teach them how to write correct formulae and identify the valance and cross multiply, introduce them to ions, give them a table of those ions. From there we go on to balancing of chemical equations and this may require some chemical reaction. Some simple examples of something that happens in everyday life e.g. carbon burning in oxygen is commonly used show formation of compounds and balancing equations. Then we go on to intra-molecular forces and this is where we go back to chemical bonding because it relates to intra-molecular forces. We also speak of intermolecular forces and talk about substances of different phases (solids, liquids and gases, etc.) and the properties that relate to it. Because of the properties of solids and liquids you have intermolecular forces. We discuss van de Waal's forces, hydrogen bonds mixtures: properties of solids in particular will determine whether your liquids will mix. If you have a polar and a non-polar liquid, you'll find that they're not going to mix and that relates to the type of bond that they have chemical systems will be to bring everything we have covered and relate it to nature itself (Vusi-interview).

In this extract, Vusi's topic sequence starts with the periodic table because, as he said, learners were introduced to this topic previously at Grade nine (see Table 4.4). The periodic table is taken as prior knowledge for the purpose of introducing the atomic structure. According to the sequence proposed by Vusi, chemical bonding should be taught after the structure of the atom. Molecular forces, mixtures and properties of liquids and solids are taught at the end of the teaching sequence.

Chemical bonding concept sequence

I analysed the NCS documents for Physical Science (Department of Education, 2006) looking at the sequence that was provided. The results indicate that the list of chemical bonding concepts were presented there in a similar order to that of sequence A (see Table 4.7), although the various types of bonding were not explicitly mentioned as individual concepts. Nevertheless, most teachers in this study indicated that they also use a "Study and Master" textbook for their planning (see Figure 4.2). In order to gain a deeper understanding of the source of some of the concept sequences presented by teachers in the survey and in the interviews I looked at the list of concepts for chemical bonding provided in that text book.

The unit entitled atomic combination in the text book (Study and Master for grade 11) started by giving a definition of electrostatic forces and stated that metallic bonding was taught in previous units. In my analysis of the textbook I only looked for the concepts that were used in the survey and I summarized the sequence as follows; metallic bond attraction forces, metallic bonding; Lewis notation; covalent bonding; ionic bonding; and molecular shapes. The results of concept sequences obtained from different data sources appear in table 4.10.

Table 4. 10 Summaries of chemical bonding concepts from survey, policy documents and textbook

Sequence identified from Matrix analysis	Sequence identified in the survey and interviews (Sequence A)	Sequence identified in NCS Policy document	Sequence identified from Study and Master Grade 11textbook
Attraction Forces	Attraction Forces	Attraction Forces	Metallic bonding
Covalent bonding	Covalent bonding	Types of bonding	Attraction forces
Ionic bonding	Ionic bonding		Lewis notation
Lewis notation	Lewis notation	Lewis notation	Covalent bonding
Metallic bonding	Metallic bonding	Metallic bonding	Ionic bonding
Molecular shapes	Molecular shapes	Molecular shapes	Molecular shapes

From Table 4.10, the chemical bonding sequence presented in the popular textbook matches neither what the teachers suggested in the survey or the interviews. Data indicate that the textbook sequence started with metallic bonding, whilst the other sequences positioned metallic bonding at the end of the sequence. The analysis showed that the chemical bonding sequences suggested by teachers were similar to the one proposed by the NCS policy document.

4.4 Discussion of outcome statement one

The findings of this study add support to the notion that there are a high percentage of teachers teaching physical science in the FET phase who are under-qualified (Hugo et al., 2010). Out of a sample of 227 teachers, only 60% of these teachers had relevant qualifications to teach in the FET Phase, while 40% of the teachers were either not qualified or under-qualified. The findings of the current study indicate that the percentage of qualified teachers in this study was similar to that of KwaZulu-Natal province. For example Hugo et al. (2010) found that 61% of the teachers in KwaZulu-Natal (KZN) were qualified. However Hugo et al. study did not establish the teaching specialization of each teacher. In other words Hugo et al. could not ascertain if the teachers were teaching subjects they were qualified to teach at high school.

In terms of the location of schools, about 60% of the teachers were from the rural schools, 30% were from the township and 8% were from urban and small town schools. The distribution of teachers in this study is similar to that described Hugo et al. (2010), where out of a sample of 1092 teachers, 73% were from rural school, 16 % were from township schools and 9% were from urban and small town schools. Consequently the sample of teachers in the study could be considered to be slightly biased away from rural teacher. One of the most important aspects of good science teaching is to have adequate teaching facilities. The current study found that more than 67% of the teachers have some facilities for teaching physical science and 33% of the teachers report that they do not have enough teaching space and laboratory equipment to teach physical science.

When it comes to sequencing, despite the large number of unqualified teachers, they seem to be self-reliant when it comes to topics sequences. Their own way of sequencing topics showed a wide variety of what they judged suitable. In the case of sequencing general chemistry topics, the findings indicate that teachers had different ideas about the sequencing of the topics and as such no single general chemistry topic sequence was identified by the majority teachers in the FET Phase. These findings agrees with Houseknecht's study (2010) where he found that even when comparing sequences in chemistry textbooks certain organic chemistry topics are introduced early and other topics were introduced later.

Despite the variation between chosen teaching-learning sequences, analysis of data using a matrix analysis indicates that there were some similar ways in which teachers sequenced topics. The results indicate that looking at the average position in the sequence, teachers placed topics in the following sequence; *periodic table, structure of atom, atoms and molecules, atomic mass and diameter, mixtures, isotopes, properties of liquids and solids, names and formulae of substances, chemical bonding, molecular forces and balancing chemical equations*. Besides this average sequence, the findings of the matrix analysis indicate that in the current study, teachers tended to place certain identifiable topics at the beginning of the teaching sequence, others tended to be placed in the middle of the teaching sequence while a third group of topics tended to be placed at the end of the teaching sequence. These findings indicate that teachers tend to sequence topics into patterns that they considered appropriate for themselves.

Analysis of sequencing concepts for chemical bonding showed that there is a preferred concept sequence identifiable from both the survey and the interviews. This trend was to sequence the concepts starting with; "*attraction forces; covalent bonding; ionic bonding; Lewis notation; metallic bonding and molecular shapes*". These results are similar to the teaching sequence for chemical bonding proposed by Nahum et al. (2008), where they proposed that covalent and ionic bonds could be taught at the beginning of the sequence, using the continuum approach (see Section 2.3.2). The sequence for teaching chemical bonding identified in the current study, however, contradicts the teaching sequence proposed by Taber and Coll (2002) which starts with metallic bonding, followed by ionic bonding and then covalent bonding. The different types of forces should then be taught after covalent bonding. In the current study the teachers placed covalent bonding first followed by ionic and then metallic bonding.

Based on the results of the analysis of questions on access to teaching documents I have shown that most teachers had access to policy documents. However, the topic sequences identified in the survey and interviews matched the topic sequence in neither the policy documents nor the textbook. The teachers indicated that they used textbooks such as "Study and Master", but the findings indicated that teachers suggest using teaching sequences that are different from the textbook. The failure by teachers to identify and suggest a topic sequence already published in their textbook or curriculum documents might indicate that the South African National Curriculum Statement has given teachers the impression that any order is acceptable. This inference is similar to observations made by Berlach, (2004), where he found that guides developed in Australia to supplement the OBE curriculum documents did not provide well sequenced content, and teachers ended up teaching in any order.

4.5 **Conclusion**

To conclude, the findings from the first and second research questions regarding the patterns of teaching-learning sequences suggested by physical science teachers were derived from data from two open-ended questions in the survey and supported by data from the interviews. The sorting of individual topics using Excel did not establish a common topic sequence for general chemistry topics. However, the matrix analysis findings indicated a consistency in that certain topics were commonly placed by teachers at the beginning of the sequence, or at the middle of the sequence or at the end of the sequence. These findings also indicate that teachers rearranged the topic sequence provided in the policy documents. Further insight into the issue is shown in the second part of the data analysis and presentation of findings for the second research question, which are presented in chapter five.

CHAPTER 5 FINDINGS: HOW TEACHERS PLAN

Planning teaching is an important aspect of the teaching profession and is incorporated in most professional courses. The planning of teaching sequences is governed by what needs to be taught and how learners are assessed, based on the policy documents of a particular country. In general, teachers are expected to plan for teaching by designing teaching activities that motivate learners to study science, and to plan for relevant assessment tasks (Sanchez & Valcarcel, 1999). Teachers are taught how to develop lesson plans at pre-service level. The teachers' views of learners' alternative conceptions and how they learn science both affect the methodologies used in planning teaching sequences (Wenning, 2008). For these reasons teacher planning was also a focus of the study. This chapter provides answers to the third of the four research questions.

> How do the teachers construct the teaching-learning sequences to teach chemical bonding?

In this section, data collected from the survey and interviews provided information to answer the third research question is presented. In order to provide an answer to this question an outcome statement was constructed based on the analysis of the survey and interviews data.

Outcome statement two:

In general teachers indicated that they used policy documents to establish the general chemistry content to be taught. They reported that their teaching of the topic of chemical bonding is usually based on previous teaching sequences and they make minor changes every year. When the manner of their planning was analysed, it appears to be in line with most of the steps of the learning demand tool. When interpreted using the model of educational reconstruction, two components of the model can be recognised in the planning of teaching sequences for chemical bonding.

This outcome was constructed from four sub-outcomes that are described separately in the following sections.

5.1 What is used to plan sequences?

Sub-outcome 2a: The dominant sources of information and ideas for sequencing are curriculum documents such as curriculum statements and programme guidelines. However, during interviews, the role of the textbook was revealed as also an important resource in planning sequencing.

In the survey, teachers highlighted the importance of curriculum documents as a source of information during the planning of a teaching sequence (see Table 5.1). Furthermore, all eleven of the teachers interviewed mentioned that they use curriculum documents together with other resources like textbooks to plan topic sequences.

5.1.1 Survey responses

Support for this outcome came from the survey where teachers were requested to respond to questions 3.1.1 through to 3.1.7 (see Appendix 2). These questions sought to establish sources of topic sequences used by teachers. The teachers were requested to respond to statements in the survey, using a seven point frequency scale in which the options were, “Never” (1);“Almost never “(2), “Seldom” (3), “Sometimes” (4), “Often” (5), “Almost always” (6), “Always” (7). Thus, a response of 7 indicates the most frequently used resources and a response of 1 indicates the least frequently used resource. A response of 4 (sometimes) was referred to as the midpoint or neutral point. A “sometimes” response for the statements was interpreted as indicating that the teacher was not sure about that particular teaching statement. Firstly, data for each teacher was captured and coded numerically as 1 to 7.The numerical values were necessary for statistical analysis, for example, they were used to calculate the mean values and standard deviations. Secondly, data was systematically analysed to determine the most frequently used resources. The analysis was carried out using SPSS computer software. The interpretation of the results was guided by the learning demand tool (see Section 2.3.2). The results reported in Table 5.1 below show the analysis of data given when teachers were requested to rate the six statements about how they use topic sequences.

For the purpose of this discussion, the responses in Table 5.1 were aggregated into three categories which were: seldom used, sometimes used and used often. Data indicate that 83% of the teachers often used programme guidelines and physical science content documents during planning; whereas only a small percentage of the teachers said they seldom used them. Data for statement 3 show that 39% of the teachers often used topic sequences designed by their head of department. The results for statement 4 show that 53% of the teachers seldom used topic sequences similar to the way they were taught at the university.

Table 5. 1 Sources of influence as teachers make choices about topic sequences

	N	Never	Almost never	Seldom	Some times	Often	Almost always	Always	Mean	SD
		Seldom				Often				
1 I follow a topic sequence provided by the programme guidelines of the national curriculum statement	210	1.90	0,48	2.86	11.43	20.95	32.86	29.52	5.66	1.29
2. I follow a topic sequence provided by the physical sciences content of the national curriculum statement document	207	2.42	0.0	1.93	12.56	19.81	28.99	34.30	5.71	1.32
3. I follow a topic sequence provided by my head of science discipline or colleague (self)	197	18.78	8.12	10.15	24.37	11.68	14.72	12.18	3.95	1.98
4. I sequence teaching topics in the same way I was taught at school/ university	200	24	10.50	18.00	24.00	13.50	7.50	2.50	3.25	1.69
5. I use same topics sequence as the that provided by the textbook	206	29.61	8.25	17.96	27.18	8.74	7.28	0.97	3.03	1.66
6. I don't have a topic sequence; I just see what happens during lessons and change to suit learners needs.	202	66.83	7.92	6.93	10.40	3.47	2.97	1.49	1.91	1.52

The results for statement 5 indicate that 56% of the teachers seldom used the textbook topic sequences and 17 % of the teachers indicated that they often used topic sequences provided by the textbook. For the last question, the results indicate that teachers generally do prepare teaching sequence, 82% of the teachers indicated that they seldom teach from an unplanned lesson. The findings indicate that the policy documents (curriculum document, programme guidelines) were the most popular sources and textbooks were the least popular. In the following paragraph further analysis of the data was carried out in order to establish if the different teachers characteristics influence the manner in which teachers answered the questions.

To extend and try to explain the findings shown in Table 5.1, in relation to teacher profiles (see Table 4.), a further analysis for significant differences between groups within a particular characteristic (e.g. qualifications), was carried out using analysis of variance (ANOVA). For convenience the analysis is reported in two consecutive tables (Tables 5.2 and 5.3).

Table 5. 2 A statistical analysis of statements in relation to teachers' qualifications and experience

Statements		Unqualified	Under qualified	Qualified	1-6 years	7-12 years	More than 13 years
I follow a topic sequence provided by; the learning programme guidelines of the national curriculum statement	N	9	69	128	70	76	60
	Mean	6.1	5.7	6.1	5.9	5.8	5.8
	SD	.93	1.5	1.2	1.3	1.5	1.4
		F = 0.799, df(2;203), *p*-value = .451			F = 0.225, df(2; 200) , p-value = .079		
I follow a topic sequence provided by the physical sciences content of the national curriculum statement document	N	9	70	58	71	75	57
	Mean	6.3	5.9	5.9	5.9	5.6	5.8
	SD	1.1	1.5	1.5	1.3	1.6	1.5
		F = 1.255 df (2; 201), p-value = .287			F = 0.961, df(2; 198), p-value =.384		
I follow a topic sequence provided by my head of science discipline or colleague (self)	N	9	71	123	72	74	57
	Mean	5.3	4.5	4.1	4.3	4.1	4.8
	SD	1.4	2.1	2.0	2.0	1.9	1.7
		F = 1.750, df(2; 200), p-value = .176			F = 2.301,df(2; 197), p-value = .103		
I sequence teaching topics in the same way I was taught at school/ university	N	9	65	118	65	72	55
	Mean	3.9	3.3	3.5	3.2	3.2	4.0
	SD	2.1	2.0	1.8	1.6	2.0	1.9
		F = 0.291, df(2; 189), p-value = .748			**F = 3.751, df(2; 185) p-value = .025**		
I use same topics sequence as the that provided by the textbook	N	9	69	124	71	72	59
	Mean	3.2	3.7	3.6	3.2	3.4	4.2
	SD	1.4	1.9	1.9	1.7	2.0	1.8
		F =0.210, df(2;199) p-value .= .811			**F = 5.355, df(2; 196), p-value = .005**		
I don't have a topic sequence; I just see what happens during lessons and change to suit learners needs.	N	9	66	122	67	72	58
	Mean	2.9	2.5	2.7	2.2	2.5	2.9
	SD	2.3	1.7	1.7	1.7	1.7	1.7
		F = 0.217,df(2;194) p-value = .805			F = 2.500, df(2; 191) p-value = .085		

The analysis used four teacher's characteristics and different statements on how teachers use a variety of teaching documents. The different groups' represented in each teachers characteristics were compared using ANOVA and post hoc-tukey testing. As already explained in Section 3.6.2, a post hoc-tukey testing categorises the groups that were significantly different. It was conducted to establish if teachers belonging to different groups responded differently to the questions. The analysis where significance was found, are colour coded.

Table 5. 3 A statistical analysis of statements in relation to school location and facilities at the schools

Statements continued		Township	Rural	Urban and small town	No facilities	Some facilities	Adequate facilities
I follow a topic sequence provided by the learning programme guidelines of the national curriculum statement	N	61	127	17	71	115	23
	Mean	5.9	5.9	5.1	6.1	5.6	6.2
	SD	1.3	1.2	1.0	1.2	1.5	1.0
		F = 3.184, df(2;202) , p-value = .044			F = 3.246, df (2;206), p-value = .041		
I follow a topic sequence provided by the physical sciences content of the national curriculum statement document	N	125	127	17	70	114	23
	Mean	5.7	5.8	5.5	6.1	5.6	5.8
	SD	1.8	1.4	1.1	1.2	1.6	1.5
		F = 0.549, df(2;200), p-value = .578			F = 2.901, df(2;204) p-value = .057		
I follow a topic sequence provided by my head of science discipline or colleague (self)	N	62	125	16	70	111	25
	Mean	4.4	4.2	5.2	4.9	4.1	3.8
	SD	2.1	1.9	1.3	1.7	2.0	2.2
		F = 2.107, df(2;200), p-value = .124			**F = 4.671, df(2;203), p-value = .010**		
I sequence teaching topics in the same way I was taught at school/ university	N	55	119	17	65	106	23
	Mean	3.2	3.5	3.2	3.9	3.1	3.7
	SD	2.0	1.9	1.4	1.8	1.8	1.9
		F =0.537, df(2;188) p-value = .585			F = 3.964, df(2 ;191), p-value = .021		
I use same topics sequence as the that provided by the textbook	N	60	124	17	70	112	23
	Mean	4.2	3.3	3.5	4.3	3.1	3.7
	SD	1.9	1.9	1.2	1.8	1.8	2.0
		F =5.157, df(2;198), p-value = .007			**F = 8.987, df(2;202), p-value = .000**		
I don't have a topic sequence; I just see what happens during lessons and change to suit learners needs.	N	59	121	17	66	110	24
	Mean	2.5	2.4	2.5	2.8	2.4	2.3
	SD	1.7	1.8	1.4	1.8	1.7	1.7
		F =0.954, df(2;194) p-value = .387			F =1.445, df(2 ; 197), p-value = .238		

For example, significance is reported for one item as $p = .005$. The value p = *.005*, indicates that if in the population there were no differences between the three "experience" groups, then the probability of getting this order of difference by chance in the sample is only *.005*. In other words only about 5 samples in 1000 would show this magnitude of difference. Hence it is very probable that these differences do occur in the target population and are related to one of the characteristics under review. The analysis given in Table 5.2 produced few significant differences in how teachers responded to the questions. Qualification level or years of experience of teachers do not appear to influence how they respond to the planning questions. However, what was found to be significant is that more experienced teachers responded that they are more likely to teach the way they were taught and to use the textbook as a resource. Perhaps this is an indication that older teachers are more conservative in their planning.

The results shown in Table 5.3 indicated that teachers' school location and facilities are related to the influence of textbooks on their planning. In township schools, they reported that they sometimes use textbooks while teachers in rural and urban to small town locations reported that they seldom use the textbook in planning. In addition it was found that teachers with no facilities often use sequences provided by the head of department while those with adequate facilities seldom use them. Perhaps this could be explained by rural teachers having few resources and were thus more reliant on colleagues e.g. head of department while teachers in township schools had access to textbooks and so were more likely to use them.

Overall, the results from both Tables 5.2 and 5.3 indicate that experience, location of schools and availability of teaching facilities all can be seen to have some limited influenced on the ways in which teachers plan teaching sequences.

5.1.2 Supporting evidence from interviews

In order to confirm, and possibly explain, the survey results about the use of policy documents in planning, this area was probed in the interviews. They were also requested to comment on sources of ideas they used for teaching chemical bonding in a particular way. The following excerpts from two teachers illustrate how they used teaching sequences indicated by curriculum documents.

> I usually follow the guidelines given by the Department of Education (DoE). The guidelines indicate what to teach in week one, the DoE is most prescriptive they want us to write the same common tests, they want us to do similar things; the kind of planning is sort of done for us in terms of the lessons and the sequence of things (Lungelo-interview).

In this quote, Lungelo indicated that there was pressure to teach according to prescribed programme guidelines, teachers are compelled to follow what was given in the policy documents. This is further illustrated by the following quote

> I usually follow the scope from department of education (DoE), especially in Grade 12 there is a designed programme and you are told which topics to cover by a particular time. But most of the times I teach together all the topics that are linked. Chemistry topics are listed as follows; rate of reaction, chemical equilibrium, electrochemical cells, DOE arranges it in an order that is suitable and I retain it (Sabelo-interview).

In this example Sabelo indicated that he teaches what is prescribed in the curriculum documents. He indicated that he used the teaching sequences that are provided by the guidelines. While, Sabelo indicated that he tried to link the topics that are similar, both teachers indicated that they used the guidelines as they were prescribed by the DoE. These interview results thus support the survey findings, where the majority of the teachers responded they often used the topic sequence provided by policy documents (see Table 5.1).

In the case of teachers indicating the source of ideas for teaching in a particular way, teachers indicated using information obtained from a variety of sources such as, textbooks, curriculum documents and the internet. Interview teachers' responses appear in Table 5.4.

Table 5. 4 Sources of information for general chemistry and frequencies

Source of information	Number of teachers
Textbooks only	2
Textbooks and internet	1
Policy document only	3
Textbooks and policy documents	5

In the interviews teachers were requested to state their sources of information for teaching chemical bonding. Table 5.4 shows that, eight interviewed teachers indicated that they used policy documents as sources of information; five of whom use them in combination with textbooks. The interview teachers did not have similar ideas to the survey concerning using textbooks as sources of information, as illustrated by those expressed in the following two quotes.

> The idea is from textbooks, such as," Brink and Jones" in Grade 12 explains it very well. I do use textbooks as well like "Study and Master" which makes reference to all the approaches I talk about and there must be some truth in what I am saying. I follow the textbook sequence (Vusi-interview).

> I think I developed over the years through reading and I look at the way the sections have been set out in the syllabus and textbooks. I then found a holistic way of making it simpler for the learners to understand chemistry (Simi-interview).

The quotes illustrate that textbooks are also used as sources of information by teachers but most often in combination with the curriculum documents. They are a resource for teaching ideas for teachers. It should also be noted that while the interviewed teachers indicated that they used textbooks as sources of information for planning chemical bonding, they do not necessarily follow the topic sequences described in the textbooks. The difference in response to the survey could be explained by the difference in questions asked. In the survey a general planning question was asked and for that teachers appear to turn to their policy documents for guidance. However, in the interviews they were specifically asked about planning chemical bonding and it could be assumed that they here they turn to their textbooks for sources of ideas to teach concepts.

5.2 Using the learning demand tool to analyse teacher planning

In an effort to understand how teachers plan teaching sequences to teach chemistry in the FET Phase I analysed the data using learning demand tool. I used the interviews to investigate these ideas because I wanted to gain a deep understanding of what teachers do during the planning of teaching sequences. Consequently, this aspect was investigated during the teacher interviews. In the interviews teachers were requested to talk about how they plan for teaching chemistry in the FET Phase. This led to the following outcome being generated from the data analysis:

Sub-outcome 2b: When teachers planning was analysed using the learning demand tool, some steps in the tool could be recognized such as; Step 1: determining knowledge to be taught, Step 4a: Determining the teaching goals, Step 4b: Staging a scientific story. However some crucial steps were missing from teachers planning.

Support for this outcome came from the analysis of interview data using learning demand designed by Leach and Scott (2002) who described it as "a tool to inform the design and evaluation of teaching sequences" (pp. 124-130). After the data were transcribed and read over and again categories emerged and the final analysis entailed looking for planning stages mentioned in the learning demand tool. The analysis proceeded as follows. Firstly, I read through the interview transcript for each teacher over and over again. Secondly, I looked for evidence though each teacher' transcript using the schedule in Table 5.5. The steps included in the schedule were those identified by Leach and Scott (2002). The results of what teachers said are reported in Table 5.6 and for details of the questions asked in the interview see part 2 and 3 of Appendix 3. Examples of the teachers' responses appear in Table 5.7.

Table 5.5 Analysis of interview responses using a learning demand tool model

Code	Description	Examples
Step1	School science knowledge to be taught	NCS documents; textbooks
Step 2	Student everyday views of science	Chemical bonding; bond polarity, equal sharing of the electron pair occurs in all covalent bonds, ionic charge determines the polarity of the bond (Ozmen, 2004)
Step 3	Identification of learning demand Comparing features of language of school science and everyday social language of students	Selection of appropriate language
Step 4a	Teaching goals	Development of ideas
Step 4b	Staging scientific story	Different approaches used by teachers to teach chemical bonding
Step 4c	Supporting student internalize the concept	Worksheets, exercises
Step 4d	Handing over responsibility to students	Assignments, tests

Table 5.6 Frequency of the use of the steps of the learning demand model

	Teachers										
Code	T1	T2.	T3	T4	T5	T6	T7	T8	T9	T10	T11
Step1											
Science knowledge	x	x	x	x	x	x	x	x	x	x	x
Step 2											
Students' everyday views	x	x									
Step3											
Social language of science											
Step 4a											
Teaching goals	x	x	x	x	x	x	x	x		x	x
Step 4b											
Scientific story	x	x	x	x	x	x	x	x	x	x	x
Step 4c											
Student internalization	x	x	x	x	x	x	x	x	x	x	x
Step 4d											
Handing over responsibilities				x				x	x		

In interviews, teachers were requested to talk about the steps they follow during the planning phase for general chemistry and how they taught chemical bonding to grade 10 to 12 learners. In order to present and group similar ideas, I colour coded teachers' responses in Table 5.7. As was shown in Table 5.7, the results indicated that there are certain steps of the learning demand tool (Leach & Scott, 2002) that are used by the physical science teachers during planning of teaching sequences, whereas others were not. The results for each step in the learning demand are discussed separately in the following sections.

Table 5. 7 Examples of teachers' responses to different steps used during planning for teaching chemical bonding

Code Teacher	Step 1	Step 2	Step 3	Step 4a	Step 4b	Step 4c	Step 4d	Prior content knowledge (step 4e) extension
T1	Curriculum documents textbooks	Put charges on covalent compounds	-	Look at my outcomes; make science easier	Start with ionic; show formation of ionic compounds; practical on burning of metals	quizzes		Find logical sense based on what they know
T2	Policy document textbooks	misconception	-	Get concept across to learners	Theory behind practical; simulations; Bohr diagrams	exercises	Online worksheets	Find practical way of introducing the topic
T3	DOE scope	-	-	Make learners understand	Give examples; Demonstrate; practical	Exercises; activities		Link everyday situations to what I want to teach
T4	Syllabus Prescribed textbooks	-	-	Check if they have understood	Start with ionic; Lewis dot method; ball and stick model	homework	Mark work; assignment ;tests	Relate information to the learners, everyday understanding
T5	Curriculum textbooks	-	-	Teach the lesson such that learners understand	Explain covalent and ionic; draw structures or use model to demonstrate bonding; analogy	Worksheets assist weak learners	Home work on past exam papers; mark work	
T6	DOE content breakdown textbooks	-	-	Recap get learners attention	Ball & stick model; Bohr model; chalkboard formation of bonds	Blank notes for learners to complete	Test	Everyday examples; write notes on the board in proper language
T7	Internet textbooks	-	-	Start from easier to difficult	Experimenting Investigative questions hypothesis	Multiple choice questions	Give a pretest before the examination	Look at things in the industry
T8	Work schedule from DOE	-	-	holistic way of making it simpler for learners to understand	Use model; Lewis dot; draw orbital on chalkboard; practical	exercises	assignments	Use the ideas that the learners already know like attraction
T9	textbooks	-	-		Experiment; introduce content; demonstrate; role play	worksheets	Research and presentations	Use real life situation like friends sharing lunch
T10	Guide from DOE	-	-	Simple things first and give less information	Use match and stick model; chalkboard		Test	It is difficult to concretize the topic to learners they get bored
T11	textbooks	-	-	Use a variety of teaching method	Chalk & talk; question & answer; show video clip; demonstrate; practical	Exercise or worksheets	NCS examination	

Step 1 School science knowledge to be taught

In the context of the National Curriculum Statement (NCS) South African science knowledge for chemical bonding should include types of chemical bonds, explanation of chemical bonds using Lewis theory and represent the bonds using Lewis diagrams or notation (Department of Education, 2006). In step 1 of the learning demand tool, the design of teaching sequences involved the analysis of the science knowledge as presented in the policy documents. The results indicate that the majority of the teachers used step 1, by consulting teaching documents such as textbooks or policy documents as a reference to establish the nature of the school science that needed to be taught. The following quote illustrates what teachers said about science knowledge during the planning stage of designing teaching sequences.

> Well, roughly I follow a lesson plan method to actually develop what I am going to teach. I use the syllabus document which has the scope or schemes of work as guideline to know exactly what content to teach the child. That is a guideline and I draw up my lesson plans based on those guidelines (John-interview).

> I think I have to start with the curriculum in order to establish what I have to get through with the students; I look at textbooks to see how they have approached the topic. I come up with some way in the middle of the two. The curriculum is the main focus of teaching ideas (Sihle-interview)

From this evidence, it can be seen that the interviewed teachers use step 1(source of school science knowledge).

Step 2 students' everyday views of chemical bonding

It is likely that learners in grades 10, 11 or 12, will arrive in class with a variety of everyday ideas about any topic in chemistry education. The teachers are expected to anticipate these everyday ideas during the planning phase. However, the results of this study showed that the majority of the teachers did not indicate how they address students' everyday views of science at the planning stage of teaching sequence. The following quote is an example of what one teacher said about the everyday learners' views science.

> What I did find interesting is when they drew diagrams showing Lewis notation they would be fond of putting charges on those even in covalent compounds (Sihle-interview)

This quote illustrates that Sihle had not anticipated his learners making such a mistake. These results imply that teachers are not teaching from a constructivist approach In the constructivist approach alternative conceptions and engaging students' thinking are viewed as a critical part of any science teaching (Driver, Squires, Rushworth, & Wood-Robinson, 1994).

Step 3 Identification of learning demands-social language of science

According to Leach and Scott, (2002), the learning demand "for a group of students studying a particular area of the curriculum is identified by comparing features of the social language of school science, and everyday language of the students, looking for commonalities and differences" (p. 132). This indicates that the social languages of learners should be considered during the planning and teaching of science. The interview analysis shown in 5.2 indicates that teachers did not mention step 3. These results might indicate that step 3 of the learning demand tool is not applicable to the South African context of teaching science in the FET Phase. It could indicate that the teachers in this study had not been made aware of importance of learners' views in the teaching and learning of science.

Step 4 Planning a teaching sequence.

This step for identifying a learning demand involves the selection of teaching approaches. The planning of teaching sequences happens in four different stages and for the purpose of this analysis I have decided to label the steps as 4a to 4d.

Step 4a Teaching goals.

At this stage conceptual teaching goals are considered, for example introducing and supporting the development of an idea, emphasis of the idea and differentiation between concepts. The results indicate that ten of the eleven teachers interviewed had a clear goal; they knew what they wanted learners to achieve at the end of a teaching sequence. The following quotes illustrate how teacher planning takes into account specific goals.

> The first thing I do is start with a recap of what they might have known before. I try to see what pre-knowledge they have. I then teach them the concepts as they are in a step-by-step method starting with the easiest and finishing off with the most difficult (Cindy-interview).
>
> As an introduction to a particular topic I give learners life related examples. I then move on to looking at the different concepts. In my initial organizing of the lesson, I draw up a concept map I need to teach and draw up the sets of notes I'd need to give to learners, exercises that would consolidate examples to be done in class in terms of the to be taught concept.(Simi-interview).

In both quotes teachers support the idea of introducing a concept and then developing it starting from learners' prior knowledge.

Step 4b Staging a scientific story

The underlining concern here is about how the topic is taught using different approaches. This step was mentioned by the majority of the teachers in the interviews. In my analysis I looked at the approaches used by teachers to teach chemical bonding in the FET Phase. I decided to use results obtained from the interviews to draw up a mind map representing all the teaching approaches mentioned by each teacher during the interviews. This is illustrated in Figure 5.3 below. In the figure, the direction of the arrows indicates the path of a teaching activity and the number in brackets indicates the number of teachers who used that particular approach.

From Figure 5.1, it can be seen that three teachers used a molecular approach to teach chemical bonding, indicated by their use of, a ball and stick model to illustrate the bonding concept. The decision to teach from a molecular representation was not based on the National Curriculum Statement grades 10 to 12 (Department of Education, 2006). The results also indicate another approach; starting the sequence by teaching ionic bonding first, followed by Lewis dot method and three teachers chose this route. This approach is similar to that described in the National Curriculum Statement grades 10 to 12 (Department of Education, 2006).

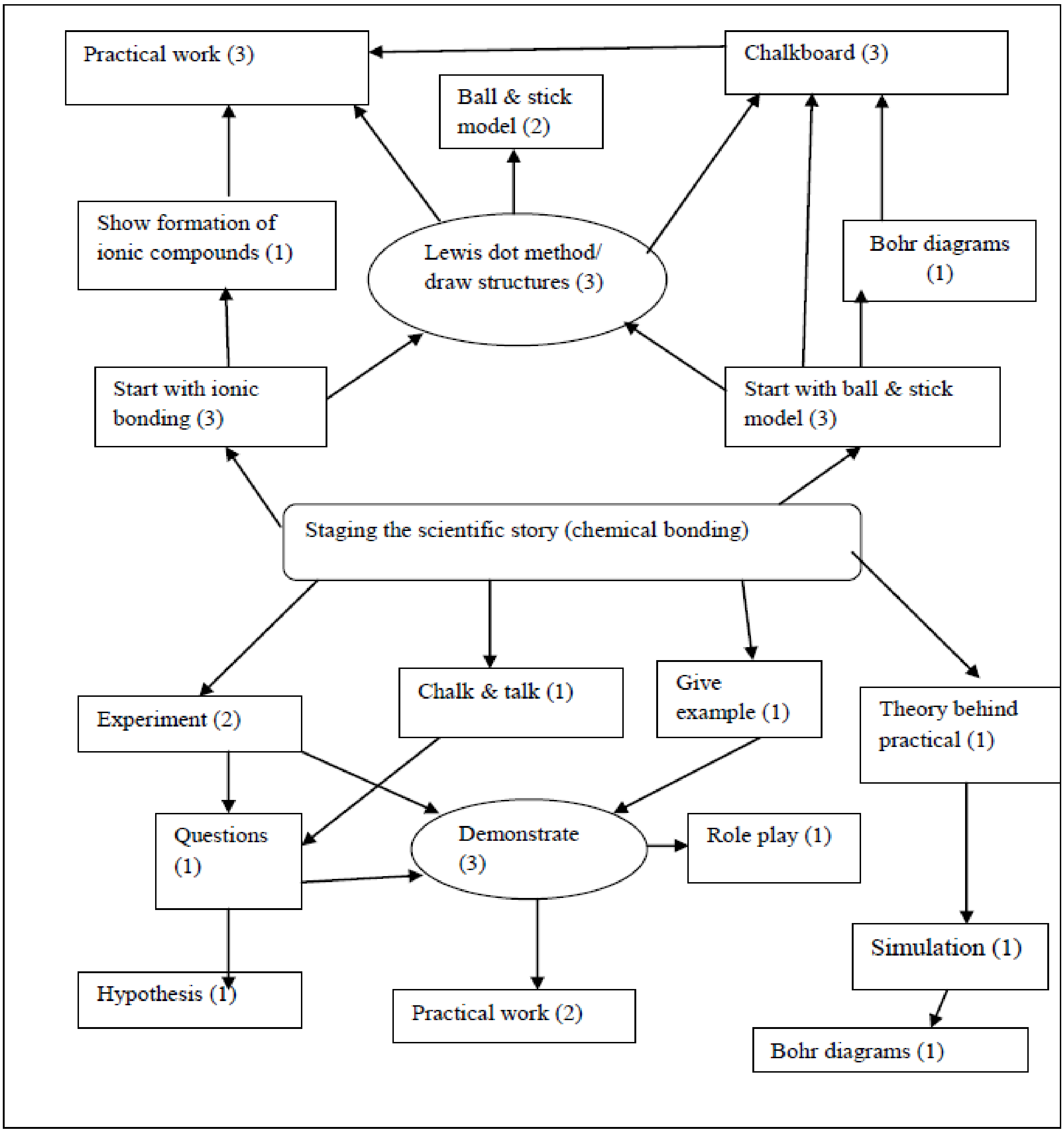

Figure 5. 1 Strategies used in staging a scientific story

The other five teachers started their teaching sequence by using methodological approaches. There is also evidence for teachers having selected a methodological approach; that is, a particular approach chosen according to availability of teaching facilities for teaching physical science at the school. This methodological approach is illustrated in the following two excerpts.

> We have got this package called multimedia package for teaching activity. The textbook does become very important, and the textbooks is basically a workbook that they can use and work through exercises, but after that, that would happen after a certain amount of teaching content, even our content teaching and the activities that we use is computer based well and getting to work through worksheets on line, so a lot of it is worksheet based (Peter-interview).

> I use the chalk board to explain the concepts, explain how hydrogen and hydrogen bond, use the textbook for electronegativity; I must use the periodic table with enough information, it means I must get a periodic table with enough information from somewhere else (Sabelo-interview).

It can be seen that Peter was teaching at a well-resourced school and had access to computers and his planning and teaching was based on the online teaching available. On the other hand, Sabelo is from a school where a chalkboard was still used as the most important resource. The other teachers had quotes similar to either Peter or Sabelo.

Step 4c Supporting student internalization.

There are different ways of supporting students' understanding of scientific knowledge, each teaching sequence should include a plan for monitoring students' understanding of science. This monitoring can take the form of whole class questioning, discussion or written activities (Leach & Scott, 2002). The results indicated that teachers had provided for some form of monitoring students' understanding during the planning phase. However, the monitoring was usually limited to written activities, such as tests, worksheets, exercises quizzes, and homework.

Step 4d Handing-over responsibility to the students

In planning the last stage, students are allowed opportunities to try out and practice how new information is created. This step involves the teacher providing some form of meditation at the beginning then, as time goes on, the responsibility is handed over to the students. The results from the interviews indicate that only three teachers were able to include this step in their planning when they provided for students to do assignments or research and present a topic.

At the analysis stage it became clear that teachers mentioned a step that was not clearly represented in learning demand as proposed by Leach and Scott (2002, p. 130); see table 5.7). I analysed for evidence from each teacher's interview schedule and found that nine interviewees indicated that learners' prior content knowledge should be considered during the design of teaching sequences in the FET Phase. The other two teachers did not mention this aspect during the interviews. I labeled this step as, prior content knowledge (see Table 5.7). The results imply that teachers are more concerned about learners' prior content knowledge than their everyday experiences or alternative conceptions of chemistry concepts at the planning phase of a teaching sequence.

The results indicate that the teachers routinely used steps 1, and 4a to 4c aspects of the learning demand tool during their planning of teaching sequences. It seems that teachers ignored steps 2 and 3 of the leaning demand tool during the planning phase of a teaching sequence. One can infer that these findings are linked to the way in which they teach science, using exposition/teacher talk. In general, teachers use policy documents to plan teaching sequences to teach chemical bonding at FET Phase. The survey and interview results both indicate that teachers plan teaching sequences from, either the Department of Education documents or textbooks. A summary of the teaching activities used by teachers in steps identified by Leach and Scott (2002) appears in Table 5.8.

Table 5.8 Summary of steps followed by teachers during planning

Aspects	References	Themes/Categories
Step 1	School science knowledge to be taught	Textbooks only (2) internet and textbook (1) Policy documents (3) textbook and policy documents (5)
Step 2	Students everyday views of chemical bonding	Identification of specific misconceptions (1) Thinking about misconceptions (1)
Step 3	Compare social language of science and everyday social language of students	teachers ignored this step
Step 4a	Teaching goals	Make science easier (4) Make learners understand (4) Use of different methods (2) No response (1)
Step 4b	Staging the scientific story Teaching a particular topic	Model (5) practical work (7) chalkboard (3) Simulations/DVD (2) Demonstration (5) Bohr/Lewis (4) Role play (1)
Step 4c	Supporting students internalisation	Exercise/ Quizzes/ (6) worksheet (4) Notes (1) Homework (10) Test (4) Examination (2)
Step 4d	Handing –over responsibility to the students	Assignments (2) and research and presentation (1)

*Number in bracket indicate the number of teachers

5.3 Teaching the topic of chemical bonding

There is ample evidence that most teachers teach from planned teaching sequences, as indicated in Section 5.1.1. The majority of the teachers indicated that they have developed a particular way of organizing and teaching chemical bonding. Some teachers indicated that they use the same teaching activities each year, while others indicated that they make changes to the order of the teaching activities, depending on whether the method had previously worked or not.

Sub-outcome 2c: Teachers indicated that their teaching is usually based on previous teaching sequences for chemical bonding and they make minor changes every year.

Support for this outcome came from the survey, Questions 3.2.1 through to question 3.2.6. These questions sought to establish how teachers sequence chemistry content in the FET Phase. In the survey teachers were requested to respond to statements using a seven point Likert type scale ranging between strongly agree (7) and strongly disagree (1). A response of 4 represented the midpoint or neutral views of the participants. Participants' responses with means less than 4 are thus referred to as negative or less supportive of the statements, while participants with responses greater than 4 are referred to as positive or more supportive of the statements. The analysis involved calculating percentages of teachers that selected each Likert response using SPSS computer software. The results shown in Table 5.9 were then interpreted using the MER (see Section 2.3.1).

Table 5. 9 Teachers' responses to statements on teaching chemical bonding

Statements	N	1	2	3	4	5	6	7	Mean	SD
I have developed my own way of sequencing and organizing teaching activities to teach chemical bonding	208	4.39	4.88	6.34	15.12	23.90	26.34	19.02	5.04	1,61
When teaching chemistry topics at FET Phase I use the same sequence of activities each year	196	13.78	12.76	13.78	18.37	19.90	14.80	6.63	3.89	1.81
I have not developed my own way of sequencing and organizing teaching activities to teach chemical bonding	196	34.69	14.29	9.69	15.18	10.71	6.63	8.16	3.06	2.01

From Table 5.9, it can be seen that the teachers gave positive responses concerning their having developed their own teaching activities to teach chemical bonding (*M* 5.04; *SD* 1.61). The third statement, which is almost the reverse of the first, results were largely (59%) negative; indicating agreement with first item that teachers had developed their own teaching sequence for teaching chemical bonding (*M* 3.06; *SD* 2.01). However, there were strong differences amongst teachers on the use of the same teaching activities each year. For example, 36% of the teachers responded positively whereas almost the same number (35%) responded negatively to the same question. The high value of standard deviation was apparently due to the fact that 35% of the teachers strongly disagree with the statement. The findings indicate that many teachers teach from planned sources of information, this is in contrast to what teachers said in the interviews discussed in section 5.3.2 below..

5.3.1 Do different groups of teachers plan differently?

The responses to the Likert statements in the survey were analysed for statistically significant differences between groups described in their profiles using ANOVA. Different statements on the use of teaching documents during the planning of a teaching sequence and four teacher's characteristics were compared and are presented in Table 5.10 and in 5.11. The results were colour coded where significance was found.

As an example consider the result in table 5.10 where the p value is reported as .012. This is the only analysis which showed a significant difference. This indicates that if in the population of all KZN teachers there were no differences between the three "facilities" groups, then the probability of getting this order of difference in the sample is only.012. In other words only about 1 sample in 100 would show this magnitude of difference. Hence it is more probable that these differences occur in the population i.e. that teacher who has few facilities will respond differently to the planning questions.

Table 5. 10 Statistical analyses of statements on teaching chemical bonding, qualification and experience

Characteristics		**Qualification**			**Experience**		
Statements		Unqualified	Under qualified	Qualified	1-6 years	7-12 years	More than 13 years
I have developed my own way of sequencing and organizing teaching activities to teach chemical bonding	N	8	68	126	80	57	62
	Mean	4.8	5.4	5.2	5.1	5.1	5.6
	SD	2.0	1.7	1.6	1.7	1.6	1.6
		F = 0.539 df (2; 199), p-value = .0.584			F = 2.196 df(2; 196), p-value = 0.090		
When teaching chemistry topics at FET Phase I use the same sequence of teaching activities each year	N	7	67	121	56	61	58
	Mean	3.1	4.1	3.8	3.9	3.8	4.0
	SD	1.6	1.9	1.8	1.8	1.9	1.7
		F = 0.898, df(2; 192), p-value = 0.409			F = 0.164, df(2; 192), p-value = 0.849		
I have not developed my own way of sequencing and organizing teaching activities to teach chemical bonding	N	8	66	122	77	56	61
	Mean	3.8	3.7	3.5	3.8	3.5	4.5
	SD	2.3	2.1	2.0	2.1	2.1	2.0
		F = 0.101, df(2; 193) p-value .= 0.904			F = 0.441, df(2; 191), p-value = 0.644		

Table 5. 11 Statistical analyses statements on teaching chemical bonding in relation to location and facilities

Characteristics		Location			Facilities		
		Township	Rural	Urban and small town	No facilities	Some facilities	Adequate facilities
I have developed my own way of sequencing and organizing teaching activities to teach chemical bonding	N	61	123	17	71	110	24
	Mean	5.4	5.2	5.1	5.7	5.0	5.0
	SD	1.8	1.6	1.9	1.5	1.7	1.6
		F = 0.342, df(2;198), p-value = .711			**F = 4.535, df(2;202) p-value = .012**		
When teaching chemistry topics at FET Phase I use the same sequence of activities each year	N	59	120	15	66	109	23
	Mean	4.0	3.8	4.1	4.2	3.7	3.7
	SD	1.9	1.8	1.9	1.9	1.9	1.6
		F = 0.368, df(2; 191), p-value = .693			F = 1.854, df(2;195), p-value = .159		
I have not developed my own way of sequencing and organizing teaching activities to teach chemical bonding	N	59	120	17	69	108	22
	Mean	3.8	3.5	2.7	3.9	3.3	3.6
	SD	2.1	2.1	1.9	2.0	2.0	2.4
		F = 2.025, df(2; 193), -value = .135			F = 1.876, df(2 ;196), p-value = .156		

The results indicate that teachers with no teaching facilities gave more positive responses about having developed their own sequence compared with teachers with only some teaching facilities. However, the survey results indicate that teachers' qualification, teachers' experience and location of school did not influence how teachers responded to questions associated with planning the teaching of chemical bonding.

5.3.2 Evidence from the interviews about how teachers plan

In order to understand the survey results, in the interviews teachers were requested to indicate if they used the same set of teaching activities as the last time they had taught the topic, and also to indicate when they make any changes. The interview results indicate that the majority of teachers use more or less the same teaching activities every year; only making changes when something had not worked previously. These results seem to contradict the survey findings, where only 35% of the teachers said they used the same teaching activities each year. The other survey group of teachers 36% said they used the same teaching activity each year. The following two quotes from the interviews illustrate what teachers said about using the same teaching activities as the last time.

> I would say 80% was the same as what I did last time, make some adjustment I mean small adjustment changes when the section did not work sometimes I would say that section did not work last year. I would make adjustment if the session did not work (Sihle-interview).

> Yes, I generally use the same method, but what I realised over the years is that I used the same method to teach the concept but use different examples from time to time. Teaching and learning is a process that is real and formed. Obviously there are areas where you would repeat things (Simi-interview)In the quotes there is an indication that the two teachers value the need to keep what works, while also modify things that are not enhancing learners' understanding of science. There was some level of agreement amongst the interviewed teachers, with teachers indicating that they made changes when a method had not worked.

5.4 **Analysing teacher planning using the model education reconstruction**

The interview data was further subjected to a theoretical analysis using the model of education reconstruction (see Section 2.3.1). In this study only two components of the model were used because the study did not directly involve learners during the data collection. The two components of the education reconstruction model relevant here involve content structure analysis and research on teaching and learning. The MER enabled the current study to establish, on a broad base, what teachers said about both the science content and learning experience of learners during the planning phase of a teaching sequence.

Sub-outcome 2d: Teachers design teaching sequences that are in line with the two components of the model of educational reconstruction. These components are analysis of content structure and research on teaching and learning.

Support for this outcome came from the teacher interview questions that asked how they re-organised the content for teaching chemical bonding, and how they addressed issues of learning and teaching bonding. The analysis involved reading through the eleven teachers' interview transcripts using a schedule, as presented in Table 5.12. I used the schedule in

Table 5.12, as a tool to look for evidence in the teachers' transcripts. A cross (x) on the schedule indicates that evidence was found for that aspect, with a blank indicating no evidence being found. The results of the evidence appear in Table 5.13. Examples of teacher responses appear in Table 5.14. In Table 5.14, I used colour coding to group similar ideas.

Table 5.12: The Analysis schedule using the model of educational reconstruction

Aspect Code	**Description**	**Examples from the interviews**
Science content (SC)	Sequence from the education point of view	Concepts from the NCS document
Science content structure (SCS)	Teachers Sequence Content Structure for instruction(constructions of knowledge)	Concept sequence for chemical bonding
	embed the abstract science knowledge in various context in order to address learning potentials and difficulties of learners	Examples used in the teaching sequence
Research on teaching and learning (RTL)	Teachers' views on teaching learning process	Teaching chemical bonding
	Teachers' views on learners conceptions	Learners' learning or understanding of chemical bonding

Table 5.13 Interview responses relating to science content and teaching learning-experiences

Code	Teachers										
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
SC	x	x	x	x	x	x	x	x	x	x	x
SCS	x	x	x	x	x	x	x	x	x	x	x
	x	x	x	x	x	x	x	x	x	x	x
RTL	x		x	x	x	x	x	x	x	x	x
	x	x		x			x	x		x	x

T represents teachers

Table 5. 14 Responses about planning a teaching sequence using two aspect of MER

Code	SC	SCS1	SCS2	RTL1	RTL2
T1	Forces; chemical bonds; Lewis; shapes	Forces; covalent; ionic; Lewis, Metallic, shapes	Practical activity burning properties; role play	Inter & intra molecular forces are confusing when taught at the same time	The topic is very abstract and not easy for learners to understand
T2	Forces; chemical bonds; Lewis; shapes	Covalent; ionic, Lewis, Metallic, shapes; Forces	Using different approach like seeing a video & simulations		It is difficult for learners to understand because it is not easy to visualize those things
T3	Forces; chemical bonds; Lewis; shapes	Forces; covalent; ionic; Lewis, Metallic, shapes	Use chalk board to explain the concepts, explain how hydrogen and hydrogen bond	If learners understand the periodic table they will have no problems understanding chemical bonding	
T4	Forces; chemical bonds; Lewis; shapes	Lewis; covalent; ionic; shapes; forces; metallic	I use illustration on board to make the concept more realistic for the learners using Lewis dot method	I have found that when learner sees things practical they can relate to it. The topic is difficult to teach	The relationship between forces, bonding, and shapes of molecules are problematic for learners
T5	Forces; chemical bonds; Lewis; shapes	Lewis; forces; covalent; shapes; ionic; metallic	I will show them how a metal loses electrons	I have noticed that learners understand better when I talk about 2 nonmetals and metal and non-metal	
T6	Forces; chemical bonds; Lewis; shapes	Forces; covalent; Lewis; shapes; ionic; metallic	I put a Bohr diagram on the chalkboard to show electron arrangement	It is abstract, but not difficult to teach	
T7	Forces; chemical bonds; Lewis; shapes	Forces; ionic; covalent; shapes; Lewis; metallic	I play a game	It is not difficult to teach, but difficult for learners to understand	Some learners find the concept of an atom too difficult to understand
T8	Forces; chemical bonds; Lewis; shapes	Forces; covalent; Lewis; ionic; metallic; shapes	I use ideas learners already know like attraction to explain forces	Anything that is abstract is difficult to teach	Learners find it difficult to understand because it is abstract
T9	Forces; chemical bonds; Lewis; shapes	Covalent; ionic; Lewis; metallic; forces; shapes	Use example of 2 friends sharing lunch	The topic is abstract; learners cannot see formation or breaking of bonds	
T10	Forces; chemical bonds; Lewis; shapes	Forces; covalent; Lewis; ionic; metallic; shapes	It's mostly chalk and talk.	It is abstract and difficult to concretize it to learners	It does not impact on our real lives directly
T11	Forces; chemical bonds; Lewis; shapes	Forces; covalent; ionic; Lewis; Metallic; shapes	Using the chalkboard, Get them to build the molecules, using molecule building kits,	It is not a concept that learners can easily grasps	Learners cannot visualize bond formation

T indicate interviewed teachers

The results indicated in Table 5.14 are discussed using two components of MER in separate paragraphs below.

Content structure

From Table 5.14 it can be seen that teachers reorganize content structure for instructional purposes. The results indicate that teachers T1 and T3 re-organised the content in a similar manner (shown brown), starting the sequence with: attraction forces, covalent bonding, ionic bonding, Lewis notation, metallic bonding and ending the sequence by placing molecular shapes. The results also indicate that T8 and T10 re-organised the concepts in a similar sequences (shown purple). To be specific, they both started the sequence with: attraction forces, covalent bonding, Lewis notation, ionic bonding, metallic bonding, and molecular shapes. The results also indicate that the remaining seven teachers reoganised the content for teaching chemical bonding in different individual patterns. The results indicate that eight teachers used visual teaching objects to remove the abstract nature of chemical bonding and make science accessible to learners. The two teachers, T3 and T10 mentioned using chalk and talk approach (shown green) and a further teacher focused on using prior knowledge to make science accessible to learners(shown grey).

Research on teaching and learning

Ten teachers spoke about the teaching and learning process that they engage in with learners during the teaching of chemical bonding. Eight teachers referred to chemical bonding as a problematic topic, because it is too abstract (shown in green) and difficult for learners to understand. Three teachers spoke about the importance of prior knowledge when teaching chemical bonding and how it facilitates learners' understanding of the topic.

5.5 Discussion of outcome two

The third research question sought to understand how teachers construct a teaching-learning sequence for teaching chemical bonding in the FET Phase. This discussion seeks to address that question. The answer is framed by two categories, namely, (**1)** teacher's use a variety of resources to plan for teaching, **(2)** teachers followed certain steps suggested by Leach and Scott (2002) as a guide for designing and evaluating teaching sequences. This question was quantified using Likert type items from the survey; the teacher responses being analysed using analysis of variance (ANOVA). Theoretical frameworks (Section 2.3.) were then used to interpret the data. The survey data, supported by interview findings, showed that teachers consistently used certain steps during the planning of a teaching sequence. To be specific, the results indicated that teachers used some steps in the learning demand tool suggested by Leach and Scott (2002). Unexpectedly, teachers used another step not identified in the learning demand tool (Leach & Scott, 2002) this step was labeled as “prior content knowledge”. These results could indicate that not all steps of the learning demand may be appropriate in the South African context.

In terms of use of teaching documents, textbooks were identified as the most commonly used sources of information for teaching in the FET Phase (see Section 5.2 concerning the survey data). This implies that teachers are teaching mostly from textbooks instead of curriculum documents. This poses some problems because topic sequences in some textbooks were not well organised. For example, Yoblinski’s (2003) study claims that some of the textbooks are written by people whose knowledge does not focus on accessibility of content to the learners. Yoblinsk studied how topics were sequenced in textbooks by asking students to comments on the topic sequence found in them. The results of Yoblinsk study indicated that some topics were not linked to each other in the teaching. He then suggested that the topic on enthalpy should be taught in the same semester as thermodynamics. Yoblinski insisted that if teaching and learning activities are not properly sequenced in the course, students are left frustrated. The current study argued in Section 1.2 that sequencing of topics make science accessible to learners in the FET Phase.

The success of science teaching is determined by many factors, such as teaching facilities, school location, qualification of teachers and their experience. The findings indicate that the qualifications of teachers did not have an effect on how they used teaching facilities. However, the availability of teaching facilities seems to have influenced how the teachers answered the questions on teaching sequences (see Section 5.3). This result is expected since teaching approaches used by teachers depend largely on what teaching facilities are available to them. These observations are similar to that of Supovitz and Turner (2000) where they found that the school’s availability of resources had significant influence on teachers’ investigative practices, but had no influence on the classroom culture. They also found that the type of communities in which the schools were located had little influence on the teachers’ practices.

Based on the analysis of results using learning demand suggested by Leach and Scott (2002) the results indicate that teachers used steps 1 and 4 (4a to 4b) aspects of the learning demand during the planning of teaching sequences (see Section 5.2). The data in Section 5.2 indicate that the majority of the interviewees ignored step 3, integration of social language and school science language in the teaching of science during the planning. The results further indicate that only two of the eleven interviewed teachers mentioned that they have to take into account the learners' misconceptions in the planning phase. The failure by teachers to incorporate steps 2 and 3 during planning was unexpected because the South African curriculum is founded in constructivist perspectives. The body of research into the constructivist approach showed that students come to class with everyday concepts, which may be different to scientific ones. These misconceptions play an important role in learning and should be considered when planning teaching (Driver et al., 1994). These results indicate that teachers are teaching using traditional methods. This situation seems not unusual, for example, Taber (2011) lamented that teachers use old fashioned methods of teaching such as exposition without engaging students' ideas. These findings are further supported by, Hobden (2005) who found that teachers used particular methods of teaching such as , direct teaching and problem solving skills that did not include students' ideas.

Analysis of interview data indicates that only three teachers spoke about how they would incorporate activities to hand over responsibility of learning to the students during planning. This step of the learning demand tool is crucial in the sense that learners can be prepared for long life learning by having the teachers acting as mediators of learning. The literature indicated that this step in infrequently used in teaching-learning sequences (Viennot & Rainson, 1999). The role played by the teacher in the design and evaluation of teaching learning sequences was not clearly defined in studies carried out by Meheut (1997) or Komerek and Duit (2004). Nevertheless, Leach and Scott (2002) argued that a teaching sequence that is based on teaching activities, without mentioning how these activities were engaged with by both learners and teachers, was problematic. From the current study findings it can be inferred that teachers do not prepare high school students for lifelong learning and this problem is linked to their training for high school teaching. The teachers in the current study did not plan teaching activities that provide the kind of support require for learners to become responsible for their own learning (see Section 5.2, Table 5.7).

The teachers' failure to mention all the steps as indicated in the learning demand suggested by Leach and Scott, and the emergence of an extra step (4e), indicate that the teachers were not familiar with all the steps identified by Leach and Scott (2002).

The analysis of results using the model of educational reconstruction indicates that the majority of the interviewed teachers think broadly about science content to be taught and restructure the science content before planning a teaching sequence. The teachers also think about issues that might hinder learning of the topic by the learners. The educational reconstruction model emphasises a close link between the theoretical and practical components of designing teaching sequences (Duit, 2007). This indicates that teaching of science requires a close integration between theoretical and practical aspects of scientific knowledge development. Despite, the fact that the majority of the teachers planned teaching sequences that were in line with the educational reconstruction model, there were some teachers who failed to include the issues of learners' pre-conceptions about chemical bonding at the planning phase. Data analysis showed that two components of the educational reconstruction model were used by teachers; these components are elementarization and construction of content structure for instruction. The results indicate that the general idea for chemical bonding is first to teach, attraction force then types of bonding starting with covalent bonds then Lewis notation/theory and lastly molecular shapes. The findings of the study are represented in a similar manner to that which Nahum et al. (2008) term "bottom up frameworks" (see 2.3.2).

5.6 **Conclusion**

To conclude, the third research question seeks to understand how teachers construct a teaching sequence for chemical bonding in the FET Phase. The findings indicate that teachers report that they plan teaching sequences with reference to the policy documents. When planning they appear to follow some of the steps recommended by the learning demand model and the model of educational reconstruction.

Data in this chapter indicates that teachers refer to teaching documents during planning of teaching-learning sequences. Teaching experience, location of schools and availability of teaching facilities were shown to be significant factors in how teachers developed or chose the sequences they used. The findings indicated that, when planning teaching sequences, teachers included some of the steps suggested in the learning demand tool by Leach and Scott (2002). They also included an extra step which had not been included in the learning demand tool, namely "prior content knowledge". The findings related to the fourth research question "why do the teachers use these teaching-learning sequences to teach chemical bonding in the manner that they do?" are presented in Chapter 6

CHAPTER 6

FINDINGS: WHY TEACHERS PLAN IN THE WAY THEY DO.

One main objective of this research was to understand how teachers design teaching-learning sequences. To this end, results have been reported in three main sections: first, results on analysis of the survey, with supporting evidence from the interviews (research question 1) then on teacher' sequencing chemical bonding concepts (research question 2) and teacher's planning of teaching sequences (research question 3). What follows is the last research question.

Why do the teachers use these teaching-learning sequences to teach chemical bonding in the manner that they do?

6.1 Analysis of teachers' responses to survey questions about why they selected particular teaching sequence

The purpose of this section is to understand why teachers sequenced the topics in a particular manner. The following outcome statement has been constructed based on the analysis of the survey data. This outcome t provides a summary of findings to the fourth research question.

Outcome statement three:

There are various reasons why teachers use different teaching learning sequences. For example, sequencing to facilitate learning requires a logical order of topics and recognition of prior knowledge. Chemical bonding is particularly problematic and teachers' knowledge is a significant factor to the success of a teaching sequence.

This main outcome was constructed from three sub-outcomes, which are described in the following sections.

6.1.1. Relevance of teaching learning sequences

In this section it will be shown that teachers view the use of different teaching activities in one lesson as important in assisting learners to construct scientific knowledge. Teachers also suggested that the order in which teaching activities are presented to learners played a crucial role in the success of teaching. Teachers further indicated that learners' participation in the classroom was pivotal to the success of teaching sequences. The teachers indicated that they sequenced chemistry topics using learners' prior knowledge.

Sub-outcome 3a: Learners understand science better when the order of topics and learners' participation are considered.

Support for this outcome was derived from the analysis of data of the survey questions that asked teachers to explain why they sequence topics differently and use different teaching activities (see Appendix 2, Part 2). The analysis was supported by data from the interview questions. As described in Chapter 3 there were seven point Likert type items, with options ranging from 1 indicating strong disagreement and 7 indicating strong agreement with the statements. Mean values of 4 or greater were viewed as positive or supportive of the statements, while responses with means value less than 4 viewed as less positive or non-supportive of the statements. The teachers' responses appear in Table 6.1.

Table 6. 1   Reasons given by teachers for their choices of teaching activities

Statements	**1= strongly disagree**					**7= strongly agree**				
	N	1	2	3	4	5	6	7	Mean	SD
Using a variety of teaching activities in one lesson leads to better learning	204	2.94	2.94	6.37	10.29	11.76	17.65	48.04	5.70	2.19
The teaching activities help learners to construct relevant scientific knowledge	207	0.48	2.42	2.42	7.73	9.66	27.71	54.59	6.10	1.85
The success of a teaching activity depends on the ordered and how it is presented to learners	206	2.42	1.46	1.94	3.88	7.77	21.36	61.17	6.22	1.25
The success of a teaching activity depends on learners paying attention in the classroom	205	1.95	3.41	4.88	5.37	8.29	19.02	57.07	6.00	1.17
The success of a teaching activity depends on learners working hard to achieve the learning outcomes	203	3.45	2.94	2.94	7.88	12.32	16.26	54.19	5.88	0.89
In general, I try to link the teaching and learning activities of an each concept to previous work/tasks	206	2.43	0	2.43	6.80	13.11	26.21	49.03	6.03	1.31
Using the same sequence of activities most of the time makes learners confident in the subject; learners like the same pattern	199	12.56	11.56	13.57	18.60	15.58	15.08	13.07	4.11	1.92

Table 6.1 shows how teachers responded to the statements relating to the success of a teaching sequence. The teachers gave positive responses to statements about using a variety of teaching activities in one lesson (*M* 5.70; *SD* 2.19), using teaching activities to help learners to construct scientific knowledge in the FET Phase (*M* 6.10; *SD* 1.85), the success of teaching activities is dependent on the order and how it was presented to learners (*M* 6.22; *SD* 1.25), the

success teaching activities is dependent on learners paying attention in class (*M* 6.00; *SD* 1.17), and the success of teaching activities also depended on learners working hard to achieve learning outcomes (*M* 5.88; *SD* 0.89). The results indicate that teachers were positive about linking the teaching activities to previous tasks (*M* 6.03; *SD* 1.31) but that they were neutral about using the same sequence of activities most of the time as this makes learners confident in the subject; learners like the same pattern (*M* 4.11; *SD* 1.92).

The statements were further analysed for significant differences between groups using four teachers' characteristics. The four teachers' characteristics are teaching experience, teacher's qualification; location of school and availability of facilities. An analysis of variance (ANOVA) and post hoc-tukey testing were carried out to establish the significant of each characteristic in relation to each statement. This analysis was carried out in order to expand the results in Table 6.1. The results where there was a significant difference were colour coded. The results of this analysis appear in Table 6.2 and Table 6.3.

The value $p = .007$, in the analysis indicates that if in the population there were no differences between the three "experience" groups, then the probability of getting this order of difference in the sample is only.007. In other words only about 7 samples in 100 would show this magnitude of difference. Hence it is more probable that these differences occur in the population (see Section 3.2; 3.6).

The data indicate that teachers with less experience gave more positive responses about the success and importance of teaching sequences compared with teachers with more than 13 years' experience. In general, the survey results indicate that teachers' qualification did not influence how teachers taught chemical bonding, but experience did.

Table 6. 2 Statistical analyses of reasons given by teachers in relation to qualification and experience

Characteristics		Qualification			Experience		
Statements		**Un-qualified**	**Under-qualified**	**Qualified**	**1-6 years**	**7-12 years**	**>than 13 years**
Using a variety of teaching activities in one lesson leads to better learning and learners are more involved in their learning	N	8	68	125	77	58	63
	Mean	5.6	5.2	5.4	5.58	5.36	5.14
	SD	0.7	2.2	1.7	1.83	1.97	1.77
		F = 0.605, df(2;196), *p*-value = .547			F = 0.987, df(2; 195) , p-value = .375		
The teaching activities that I use are aimed at helping learners to construct relevant scientific knowledge	N	8	69	125	77	58	64
	Mean	4.8	5.1	4.9	5.39	5.10	4.33
	SD	2.6	2.1	2.3	2.0	2.2	2.4
		F = 0.164 df (2; 199), p-value = .849			**F = 4.298, df(2; 196), p-value = 0015**		
The success of teaching a particular teaching activity depends on; how the teaching activities are ordered and presented to learners	N	8	70	125	77	59	64
	Mean	6.0	5.6	5.6	5.94	5.80	5.05
	SD	1.4	1.8	1.8	1.6	1.6	1.9
		F = 0.211 df(2; 200), p-value = .811			**F = 5.132; df(2; 197), p-value = .007**		
Success of teaching activities depends on learners paying attention in class	N	8	69	125	79	57	63
	Mean	5.9	5.5	5.8	5.9	5.6	5.5
	SD	1.6	1.8	1.6	1.6	1.9	1.6
		F = 0..508, df(2; 199), p-value = 0.603			F = 0.687, df(2; 196), p-value = .504		
Success of a teaching activity depends on learners working hard to achieve the learning outcomes	N	8	70	124	81	57	62
	Mean	5.5	5.8	6.1	5.8	5.9	6.2
	SD	1.2	1.5	1.8	1.6	1.6	1.3
		F = 0.291, df(2; 189), p-value = .295			F = 1.113, df(2; 197) p-value = .331		
In general, I try to link the teaching and learning activities of an each concept to previous work/tasks	N	9	67	128	78	59	62
	Mean	5.0	4.7	4.7	5.4	5.0	3.6
	SD	.2.4	2.6	2.2	2.2	2.2	2.5
		F = 0.7830, df(2;199), *p*-value = .921			**F = 10.484, df(2;196), p-value = .000**		
Using the same sequence of activities most of the time makes learners confident in the subject; learners like the same pattern	N	8	66	121	77	57	59
	Mean	3.5	4.1	4.1	4.2	3.9	4.1
	SD	1.8	2.0	1.8	2.0	2.0	1.7
		F = 0.393, df(2; 192) p-value = .676			F = 0.394, (2 ;190), p-value = .674		

Table 6. 3 Statistical analysis of reasons given by teachers in relation to location and facilities

Characteristics		Location			Facilities		
		Township	Rural	Urban/ small town	No facilities	Some facilities	Adequate facilities
Using a variety of teaching activities in one lesson leads to better learning and learners are more involved in their learning	N	61	122	17	71	109	24
	Mean	5.1	5.4	5.4	5.1	5.4	5.6
	SD	1.8	1.6	1.9	1.9	1.8	1.8
		F = 0.002, df(2; 197) , p-value = .998			F = 1.015, df (2; 201), p-value = .364		
The teaching activities that I use are aimed at helping learners to construct relevant scientific knowledge	N	61	123	17	72	109	24
	Mean	4.3	5.1	6.3	4.5	5.2	5.8
	SD	2.5	2.1	1.1	2.4	2.1	1.5
		F = 5.717, df(2; 198), p-value = .693			F = 1.854, df(2; 195) p-value = .159		
The success of teaching a particular teaching activity depends on; how the teaching activities are ordered and presented to learners	N	61	124	17	72	110	24
	Mean	5.2	5.7	6.5	5.3	5.7	6.0
	SD	1.9	1.7	1.0	1.9	1.7	1.6
		F = 4.311, df(2; 199), p-value = .015			F = 3.386, df(2; 203), p-value = .192		
Success of teaching activities depends on learners paying attention in class	N	61	123	17	71	111	23
	Mean	5.6	5.7	6.3	5.8	5.7	6.6
	SD	1.8	1.7	1.2	1.5	1.7	2.0
		F = 1.568, df(2; 198), p-value = .211			F = 0.920, df(2; 202), p-value = .156		
Success of a teaching activity depends on learners working hard to achieve the learning outcomes	N	61	123	17	72	109	24
	Mean	5.8	6.0	6.1	6.2	5.8	5.6
	SD	1.5	1.6	1.4	1.2	1.6	1.9
		F = 0.533, df(2; 198) p-value = .588			F = 2.844, df(2 ; 202), p-value = .061		
In general, I try to link the teaching and learning activities of an each concept to previous work/tasks	N	61	123	17	71	110	24
	Mean	3.6	5.0	6.0	3.9	5.0	5.8
	SD	2.6	2.3	1.7	2.6	2.2	2.1
		F =10.536, df(2;198) , p-value = .000			**F =7.681, df (2;202), p-value = .00**1		
Using the same sequence of activities most of the time makes learners confident in the subject; learners like the same pattern	N	59	119	17	68	107	23
	Mean	4.2	3.9	4.5	3.9	3.9	3.5
	SD	1.8	2.0	1.6	1.7	1.9	2.1
		F = 1.255, df(2; 192) p-value = .288			F = 3.386df(2 ;195), p-value = .036		

The data indicate that teachers from urban and small town gave more positive responses about the success of teaching sequences and linking teaching activities compared with teachers from township school. In general, the data from Table 6.3 indicate that the location and facilities have an effect on their responses to any of the statements suggesting the success of teaching sequences and linking teaching activities.

6.1.2. Reasons for logical development of the order of topics

In this section it will be shown that according to the teachers, prior knowledge was important in promoting better understanding of scientific concepts. To elaborate, teachers placed topics in a particular position in a sequence based on the scientific knowledge base required by learners to understand the next topic in a teaching sequence. Thus, this section gives evidence to justify the following outcome.

Sub-outcome 3b: The teachers indicated that linking new topics and learners' prior knowledge are the key factors in sequencing.

Support for this outcome came from the survey question which asked teachers to explain why they ordered the topics in a particular sequence (see Appendix 2, Part 2). These comments were read through and certain themes emerged from the data. This was an open ended question and themes were produced through data analysis and coding. The themes were colour coded and analysed using Excel computer software. The teachers' responses appear in table 6.4.

Table 6.4 Reasons given by teachers for sequencing choices

Comments	**N**	**Percent (%)**
Linking topics	56	24.7
Prior knowledge	53	23.4
Particulate/ microscopic	20	8.8
Practical/ macroscopic	7	3.1
Logical understanding	6	2.6
Others	20	8.8
No responses	65	28.6
Total	227	100.0

There are different reasons suggested by teachers for ordering the topics in a particular sequence. From the analysis shown in Table 6.4 above, two main themes emerged which are linking topics and learners' prior knowledge. The results indicate that 25% of the teachers said that it is important to link topics in a manner that can promote learners' understanding of general chemistry in the FET Phase. The following data excerpts from the survey illustrate what teachers said about linking topics in teaching sequences for teaching chemistry in the FET Phase;

> It is because there is a link in these topics, for example, information in the first topic will help learners to understand easily the second topic and also to understand the third topic

Because of links that they have there are topics you cannot handle before going through others

Some teachers used different phrases to indicate the linking of topics, for example the following excerpts illustrate what teachers said in this regard;

> The topics that are coherent must come one after the other for continuity
>
> There is a logical development of concepts, knowledge learnt, used in the next topic

During the analysis, although teachers used different phrases to illustrate sequencing topics, quotes similar to these were coded under linking topics or sequencing topics.

Another group of teachers sequenced topics from easy/prior knowledge to complex topics. The following data excerpts from the survey illustrate what teachers said about sequencing topics from easy to complex.

> Starting with easier topics will help learners to understand chemistry and enjoy it than starting with complex ones
>
> Learners must know the basics before tackling more complex concepts of chemistry

For teachers who indicated that topics were sequenced based on learners' prior knowledge as a foundation for teaching chemistry concepts, the following data excerpts illustrate what teachers said.

> I think they link to each other in terms of moving from information to a more challenging concept and to build some prior knowledge to build on
>
> I try to start with the sections that will form a solid foundation and that will make it easier for them to understand as we proceed.

In these quotes teachers indicated that when teaching chemistry, prior knowledge should be considered the beginning of teaching sequences. Quotes similar to those above were coded as "teaching from easy to complex topics".

Some of the survey teachers sequenced topics based on understanding of the knowledge of atoms, as illustrated by the following data excerpt:

> The knowledge of atoms and the structure of atoms, the periodic table is what learners need to know before learning chemical bonding and balancing of equations
>
> The learners need to understand the atoms, their structure and the periodic table so as to understand the chemical bonding, balancing of equations and molecular forces

Another group of survey teachers differed, and indicated that they sequenced the topics based on the nature of the topics. The following two excerpts illustrate what the teachers said.

> I sequenced topics from microscopic representation to macroscopic properties and applications
>
> I sequence topics from microscopic to macroscopic, I start with basics.

The examples above from the two groups of teachers were coded under "particulate and microscopic", indicating an emphasis on teaching starting from small units of matter. By contrast, some of the teachers indicated that they sequenced the topics from a practical point of view in order to make learners understand science content. The following excerpts illustrate what teachers said;

> The topics were sequenced from macroscopic to microscopic, from the visible to the more challenging, to the more complex
>
> The properties of liquids and solids, mixtures are practical aspects while an atoms is an abstract concept the rest of the concepts can follow after mastering the atom concept

The quotes given above indicate that some teachers placed topics that were practically oriented at the beginning, with more abstract topics at the end of the teaching sequence.

There is a general indication that some of the teachers sequenced topics using logical understanding of concepts. The following data excerpts illustrate what the teachers said;

> The sequence makes logical understanding of concepts that would follow later
>
> There is more or less a logical flow that will facilitate understanding in subsequent sections/ content

A small group of teachers indicated that they sequenced topics based on availability of resources at school. The following quotes illustrate what the teachers said;

They are presented in the work schedule provided by subject advisors from the department

There is insufficient material, equipment's are needed and resources.

In general, the results indicate that there are various reasons why teachers sequenced topics in a particular order. The most common reasons suggested by the teachers was that topics were sequenced based on the learners' prior knowledge and linking topics to one another.

6.1.3. Supporting evidence from interviews

In attempting to develop an understanding of why teachers sequenced topics in a particular order, in the interviews, teachers were requested to comment on why they placed a particular topic at the beginning of a topic sequence. They were also asked to comment on why they placed molecular forces in a particular position within a teaching sequence on chemical bonding. The teachers' responses appear in Table 6.5.

Table 6.5 Reasons for ordering general chemistry topics

Starting topics	Comments made by teachers	No of teachers
Mixtures	Taught in lower grades/ prior knowledge	5
Periodic Table	Prior knowledge	2
Structure of atom	Know ledge of electron configuration	1
chemical bonding	Starting point	1
chemical systems	Overarching topic	2

From Table 6.5, it can be seen that five teachers placed mixtures at the beginning of a teaching sequence, based on learners' prior knowledge from previous grades. These interview results support the survey findings given in the previous section, where 23% of the teachers indicated that they placed topics within a teaching sequence using learners' prior knowledge (Table 6.4).

The following data excerpt illustrates what teachers said about using prior knowledge when teaching chemical bonding.

> I can see bonding as one of the topics where one can work with the learners, the right approach and enough information. Bonding depends on the understanding of

> electronegativity, if learners understand the periodic table; learners will not have a problem with the topic (Sabelo-interview).
>
> I think Chemical Bonding is an easy topic as long as you've got good chemistry background and can relate it to learners. I find Chemical Bonding to be the easiest in chemistry to teach, you need to have good understanding of it (Themba-interview).

The two quotes illustrate that understanding chemical bonding was dependent on understanding of other concepts such electronegativity. There is also an indication that good teacher's knowledge on the topic improves the way in which it is taught to learners. In a follow up question teachers were required to explain why they have placed intermolecular and intramolecular forces in a particular place in the topic sequences. Data indicate that teachers who placed intermolecular and intra-molecular forces away from chemical bonding said that there was need to link molecular forces with properties of liquids and solids. This implies that during the teaching of molecular forces the properties of liquids and solids are discussed in relation to the types of forces that exist between the structures. It is also interesting to note that the six teachers who placed molecular forces next to chemical bonding gave many different reasons.

In general linking of topics and learners' prior knowledge was viewed as necessary to the success of a teaching sequence.

6.2. Teaching chemical bonding

In this section it will be shown that teachers suggested that learners found chemical bonding difficult to understand and some teachers said that they also found chemical bonding difficult to teach and understand. The lack of training on teaching physical science was suggested as one reason for poor understanding of chemical bonding in the FET Phase. Teachers suggested the abstract nature of chemical bonding as a cause of some of the problems experienced by learners during the teaching and learning of the topic. This section provides evidence to support the following outcome.

Sub-outcome 3c: Teachers suggested that that chemical bonding was problematic to teach

Support for this outcome came from the survey questions where teachers were presented with a scenario that "research has shown that bonding was difficult to understand". Teachers were then requested to respond to the following questions using a yes or no. The questions asked in the survey are. Do you find it difficult to teach? Yes or no? Why do you think so? Do your learners find chemical bonding difficult to understand? Why do you think so? Do you find it difficult to understand yourself? (See Appendix 2, Part, 3). The teachers' responses appear in Table 6.6.

Table 6.6 Reasons given by teachers for teaching chemical boding-survey

Chemical bonding	Responses	N	%
Teachers find chemical bonding difficult to teach	Yes	76	36.89
	No	130	63.11
Teachers' perception on learner finding chemical bonding difficult to understand	Yes	124	59.90
	No	83	40.10
Teachers find chemical bonding difficult to understand	Yes	30	15.15
	No	168	84.85

From the survey teachers were asked to confirm the research that has shown that chemical bonding was difficult to teach. Data indicate that 60% of the teachers indicated that learners found chemical bonding difficult to understand. In a similar vein, 37% of the teachers indicated that they found chemical bonding difficult to teach and 15% of the teachers said they (the teachers) have experienced problems understanding chemical bonding. However, a high percentage (85%) of teachers reported that they did not find chemical bonding difficult to understand.

The results of cross tabulation analysis indicate that the majority of the teachers who thought that their learners found chemical bonding difficult to understand were from rural schools and most of these teachers were qualified. The results in Table 6.7 indicate that teachers who found chemical bonding difficult to teach and to understand were less experienced teachers with 1 to 6 years teaching experience, and furthermore most of them were from rural schools but had access to some teaching facilities at school. These results imply that teachers' qualifications were not related to how easy or hard teachers found the teaching of bonding. On the other hand experience in teaching chemical bonding seemed to have an effect on teachers' perceptions.

Table 6.7 Number of teachers based on experience, qualification, facilities, locations and chemical bonding

	Experience				Qualification			Facilities			Location		
	Total	1 to 6	7 to 12	More than 13	Qualified	Under qualified	Unqualified	No facilities	Some facilities	Adequate facilities	Township	Rural	Urban & small town
Do you find chemical bonding difficult to teach?													
Yes	69	35	15	19	39	25	5	20	40	9	17	45	7
No	115	36	41	38	77	35	3	40	62	13	37	70	8
Do your learners find chemical bonding difficult to understand?													
Yes	111	44	34	33	70	37	4	34	62	15	29	74	8
No	73	27	22	22	46	23	4	26	40	7	25	41	7
Do you find it difficult to understand yourself?													
Yes	29	19	6	4	16	12	1	5	19	5	7	20	2
No	155	52	50	53	100	48	7	55	83	17	47	95	13

6.2.1. Reasons given by teachers for why chemical bonding is difficult to teach

Survey Responses

The responses given by teachers to the three questions on teaching chemical bonding were analysed and are reported in Table 6.8. The analysis involved reading through comments for each teacher over and over again until certain categories emerged from the data. I used categories to generate themes. In this study the themes were regarded as reasons given by teachers. I color coded these themes in Excel. For this analysis, I only used the number of years teaching physical science; the reasons for focusing the analysis on only one characteristic are two-fold. Firstly, few teachers responded to these questions at the end of the questionnaire. Secondly, previous results (Section 6.1, Table 6.2, and Table 6.7) have shown that the number of years teaching physical science affected the manner in which teachers sequenced the topics. A summary of the analysis of teachers' comments appear in Table 6.8.

Table 6.8 Reasons given by teachers on chemical bonding being difficulty and experience

Reasons/Themes	1-6 years	7-12 years	>than 13	Total	Percent
Why bonding is difficult to teach?					
Lack of understanding	5	7	5	17	13.18
Learners not paying attention	7	3	3	13	10.08
Abstract	13	10	13	36	27.91
Lack of resources	9	4	0	13	10.08
Easy to understand	20	17	13	50	38.75
Total	**54**	**37**	**34**	**129**	**100**
Why teachers' perceive chemical bonding to be difficult for learners?					
Learners find it difficulty	20	16	5	41	29.50
Learners do not enjoy the topic	10	9	12	31	22.30
Not well taught	8	10	6	24	17.27
Abstract	12	6	15	33	23.74
Lack of resources	8	1	1	10	7.19
Total	**58**	**42**	**39**	**139**	**100**
Why teachers find bonding difficult to understand?					
No adequate training	14	5	2	21	21.43
Lack of Experience/ good training	24	29	24	77	78.57
Total	**38**	**34**	**26**	**98**	**100**

From the survey teachers were asked to comment on the teaching and learning of chemical bonding. When aggregating the results on the nature of chemical bonding being an abstract topic, 52% of the teachers indicated the nature of the topic as problematic. It is also interesting to note that 17% of the teachers indicated that learners experience problems with chemical bonding because they had not been properly taught by previous teachers. The majority of the teachers who indicated that chemical bonding was easy to teach also mentioned good training and experience in teaching the topic as key to their success. About 21% of the teachers who found chemical bonding difficult to teach also indicated lack of proper training on physical science teaching as a contributing factor to their lack of understanding of chemical bonding.

6.2.2. Reasons given by teachers in the interviews for why chemical bonding is difficult to teach

In the interview teachers were requested to comment on survey finding that 37% of the teachers indicated that chemical bonding was difficult to teach. The teachers' comments about learners experiencing problems with chemical bonding appear in Table 6.9.

Table 6.9 Reasons given by teachers on learners finding chemical bonding difficult

Reason why chemical bonding is difficult for learners	Number of teachers
Chemical bonding is abstract and difficult for learners to understand and visualize the concepts	7
The relationship between different concepts of chemical bonding provide a challenge for learners	2
Chemical bonding does not closely relate to our everyday lives	2

From Table 6.9, it can be seen that the majority of the interviewees indicated that chemical bonding was abstract and difficult for learners to understand in the FET Phase. The following excerpts from the interviews illustrate what teachers said about chemical bonding as being problematic to learn in the FET Phase.

> I would think it is difficult to teach chemical bonding. For me the most difficult part is when the child has to synthesize all the concepts together and then start linking it to forces and shapes. Then it becomes problematic for them as they progress from one process to another. The concept of ionic bonding is not so bad but when they have to differentiate between the concepts so that they can be able to know where this one and that one occurs. And how intermolecular forces relate to bonding and how they relate to shapes of molecules that are the problematic part (John-interview).

> It is not difficult to teach, but it is difficult for the learners to understand, another problem is that it does take time and I do not think that our teachers have lots of time, the pressure of getting through the syllabus and the work is quite enormous so you allocate a certain amount of time to get through that and often you tend to leave pupils behind that have not fully grasped the concepts, but it something that you need to revisit regularly, I can see that it is difficult for the pupils because it not easy to visualize those things and that is why I use a lot of software quite a bit to try and re-enforce those(Peter-interview).

In the two quotes both teachers indicated that presentation of information on chemical bonding in textbook is problematic. In the second quote the teacher indicated that chemical bonding also required a lot of time to teach. From the two quotes there is an indication that it was not easy to link chemical bonding to learners' prior knowledge.

In attempting to understand why teachers indicated that chemical bonding was difficult to teach, teachers were requested to compare the teaching of chemical bonding to other topics. One teacher said that chemical bonding was difficult to teach because the topic was not well sequenced in the teaching documents. The following quote illustrate what the teachers said.

> When comparing chemical bonding to organic chemistry, organic chemistry is well structured and logical, you can teach a few rules and they can apply to a vast chain of

> work. The pupils seem to apply those rules to different situations. Chemical bonding seems to be so much in the air so difficult to visualize because they cannot see the atom and electron and orbital and things like that. In organic chemistry they can draw the structure, covalent bonds, you got your stem, your bonds, and they seem to grasp that easier (Saziso-interview).

In this quote the teacher indicated that, unlike with other topics, information presented on chemical bonding in teaching documents was unstructured and was not easy for teachers to follow.

6.3. Understanding Teachers' Knowledge

The purpose of this section was to establish a general picture of how teachers' knowledge may have influenced their decisions during the planning of teaching sequences. Data indicate that at the planning phase of a teaching sequence, issues such as learners' misconceptions and topics that may confuse learners were not mentioned by teachers. The main findings in this section are summarised in the following sub outcome.

Sub-outcome 3d: The manner in which teachers sequenced concepts for general chemistry and chemical bonding was influenced by their knowledge of chemistry

This outcome was derived from the analysis of teachers' responses to interview questions. The interview responses were read critically. Firstly they were asked about their own teaching and learning experiences and interest in science. Then they were asked for information about how they teach, and make decisions about teaching, particularly what strategies they use to make chemical bonding easier for learners to understand. They were also asked about specific sequences in these sections and to confirm the survey finding that learners find chemical bonding difficult to understand (see Appendix 3).

The analysis proceeded as follows: first I developed and adapted a rubric (Kind, 2009) to tabulate teachers' ideas about teaching chemistry in general and chemical bonding in particular. The rubric was developed using ideas from Padilla and Van Driel (2010) and the notion of Content Representations components proposed by Loughran et al. (2004) and incorporated the interview responses. Padilla and Van Driel (2010) used the Magnusson et al. (1999) model, which divides components into subcomponents and this structure was followed here. These subcomponents provided specific areas for data analysis (see Figure 6.1). Thus the main components for the analysis were drawn from teachers' knowledge of goals and objectives of the curriculum. For example, the teachers' knowledge the goals and objectives of the curriculum was divided into three subcomponents. These subcomponents allowed for the analysis of teachers' views on the abstract nature of science concepts, how they plan to teach chemistry, their understanding of learners' prior knowledge and their understanding of the curriculum (see Figure 6.1). Data analysis involved an interactive search for evidence from all the interviewees.

A summary of the teachers' profiles appear in Table 6.10 and the rubric for capturing teachers' profiles appears in Figure 6.1.

Table 6.10 Teachers' profile and science teaching characteristics

Teachers	Education	Number of years	Good science teacher	Interest in teaching science	Confidence	mentorship
Cindy	BSc/HDE	16 years	Know different ways to teach	Science is dynamic and not static like maths	Very confident	Senior teacher]at my school
John	BSc/HDE/B.Ed. Hon	14 years	good science teachers	Science, very interesting, and challenging	I know the content	Colleagues and subject advisors; experience you gain over the years
Lungelo	B Paed SC	24 years	Competent in my subject innovative	Look forward to the free periods.	In the content.	Through experience you find out what works and what doesn't; other people.
Peter	BSc/HDE/ MSc-phi	16 years	Feedback from students, colleagues and parents.	I cannot teach anything else	I do not shy away from difficult concepts	few people at my previous school
Sabelo	STD/ FDE/ B.Ed.-maths	14 years	Yes	Involved in a number of Science projects	One grows in the subject as individual.	as you teach your learners you develop new approaches
Saziso	BSc-phy/HDE	27 years	Reasonable [reasonably] good	I love teaching science	If I am not sure of something I go to the books	No one taught me how to teach science
Sihle	BSc/HDE/ MSc-chem.	20 years	My students perform well in science	I like making science easier for students to understand	I know my subject very well	very good mentor
Sima	STD/ACE-c	10 years	Yes, despite the challenges we face every day	Enjoying teaching the subject	Good at teaching the subject	department workshops
Simi	B Paed Sc/ B.Ed. Hon/ MED	23years	Assisting subject advisors teachers at workshops	I love teaching Science.	Extremely	I have learn from different people, reading, self-evaluation, learners' feedback
Themba	BSc/ studying PGCE	15 years	Teaching is not easy in South Africa, it is a challenging job	It is something I'll never walk away from	Confident teacher; very well prepared and I know what I'm doing	I actually taught myself.
Vusi	SED/FDE/ studying ACE	24 years	I'm fairly good	I enjoy teaching Science	There's very little that I don't know; My knowledge is very good	My lecturers.

- All teachers were teaching physical science grade to 10,11 and 12

Figure 6. 1 Aspects of Content Representations and subcomponent schedule

Aspect 1: An overview of the main ideas (curriculum)

Interview Focus	Code	Description	Example quotes from the interviews
Teacher' knowledge of goals and objectives Part 2	A1	Teacher's views about how learners learn science	How do you get the message across to the child, especially because of the nature of Physical Science is very often abstract and difficult for the child to relate to. For me the most possible challenge is to find best possible ways to relate the information to the child.
	A2	How teachers plan to teach the subject	I follow a lesson plan method to actually develop what I am going to do. I use the syllabus document which has the scope/ schemes of work as guideline to know exactly what content to teach the child. That is a guideline and I draw up my lesson plans based on those guidelines. I physically write out the content of what I want to teach (what I want to deliver) to the child in a classroom. I then come up with the best possible way that I could disseminate this information to the child.
	A3	Teachers' understanding of prior knowledge	In order for the learner to understand chemical bonding he needs this prior knowledge; Periodic Table – What is contained in the PT and how it is arranged; the detail structure of the atom. Names and Formulae of substances.
Teacher's knowledge of the curriculum Part 2	A4	Teacher' knowledge of the curriculum	A lot of it is from the textbooks and from my own innovative ideas, combining my ideas with those of the textbooks with my experience over the years to see what works. I found that if a child sees things practical and they can relate to something that is physical, tangible they learn better. I try to find tangible ways of explaining things to them. There are textbooks that tell you how to use models.

Aspect 2: Knowledge of alternative conceptions

Requirements for learning chemistry Part 3	B1	Teacher' beliefs about how learners learn chemistry	The learners can relate much easily when they use models and see the illustrations on the board. This takes away the abstract nature of the concept for the child.
	B2	Teacher's views on learners alternative conceptions	They draw diagrams showing Lewis Notation they are fond of putting charges on covalent compounds
Areas that are viewed as difficulty for learners Part 3/ Part 5	B3	Teacher' s views of chemistry topics or concepts that learners find difficult	The difficulty of chemical bonding lies in the synthesizing everything together, e.g. if you are given a structure and they ask you to talk about the shape of the molecules and they can't relate it to how the bond occurs between and type of bond that occurs. Grade 11 the concept of Covalent bonding is the one which more problematic because you talk of multiple covalent bonding, dative covalent bonding, hybridisation, that becomes problematic for them
Teacher' belief about what students should learn on the topic Part 3	B4	Teacher's beliefs about what learners should learn on a particular topic	I can demonstrate ways very often I like using analogy in my teaching to describe a particular concept or whatever I want to explain to a child. For example: I was just teaching reactions rates recently and I was trying to tell the children about the concept of surface area, and I used the example of a large log of wood. I asked them when they thought it would burn faster,

Aspect 3: Insightful ways for teaching for understanding

Assessment methods used	C1	Assessment strategies used by teachers to	I ask the students a lot of questions. That helps me to check whether they understand the concept being

by teachers Part 2/Part 3		assess learners' understanding science	presented or not. I would give the children questions in form of class work/ exercises to answer based on what I've been teaching them. I check by their responses to see how they've coped. If most of them are unable to answer the questions, than I would know that they did not understand the concept very well. That is my first way of determining whether the child understood the concept or not in the classroom. I give them a similar example to do it on their own; I will walk around the classroom to see if they are doing it properly; if students are doing it incorrectly I tell them what you are doing wrong. In the end I will discuss the whole question with the class
Aspect 4: Known points of confusion			
Known problems experienced by learners during the learning of chemistry Part 3/ part 4	D1	Topics or concepts that confuse learners during the leaning of chemistry	Have found that the inter and intra molecular forces are confusing
Aspect 5 Effective sequencing and important approaches to framing ideas			
General chemistry strategies Part 2/Part 3	E1	Strategies that apply to general chemistry teaching	I can demonstrate ways very often I like using analogy in my teaching to describe a particular concept or whatever I want to explain to a child.
Chemical bonding strategies Part 2/Part 3	E2	Specific representation of chemical bonding	I use the chalkboard; do discussions I use models and illustrations; Lewis dot method and get the learners to make models and compounds to show how bonding takes I also give them notes. I've started writing out the notes in my own writing, with more simple explanations. They take these down as part of the lesson and they do not take notes when I am teaching.
	E3	Teaching activities for chemical bonding	I want to use Lewis Dot to explain Ionic bonding. Firstly I would write down the symbol of a particular element that is involved. I take a simple one for starters, e.g. sodium chloride as a formula unit. To show how the bond forms between the Sodium and Chlorine atom – I write down the symbol on the board for sodium and I tell them that each side represents one orbital

(Adapted from Padilla and Van Dreil, (2011, p, 370) developed with my own examples)

To get a measure of the significance/ dominance of each of the views the interview results were coded and captured as free nodes on NVivo, computer software. These were then plotted as the frequency distribution shown in Figure 6.2.

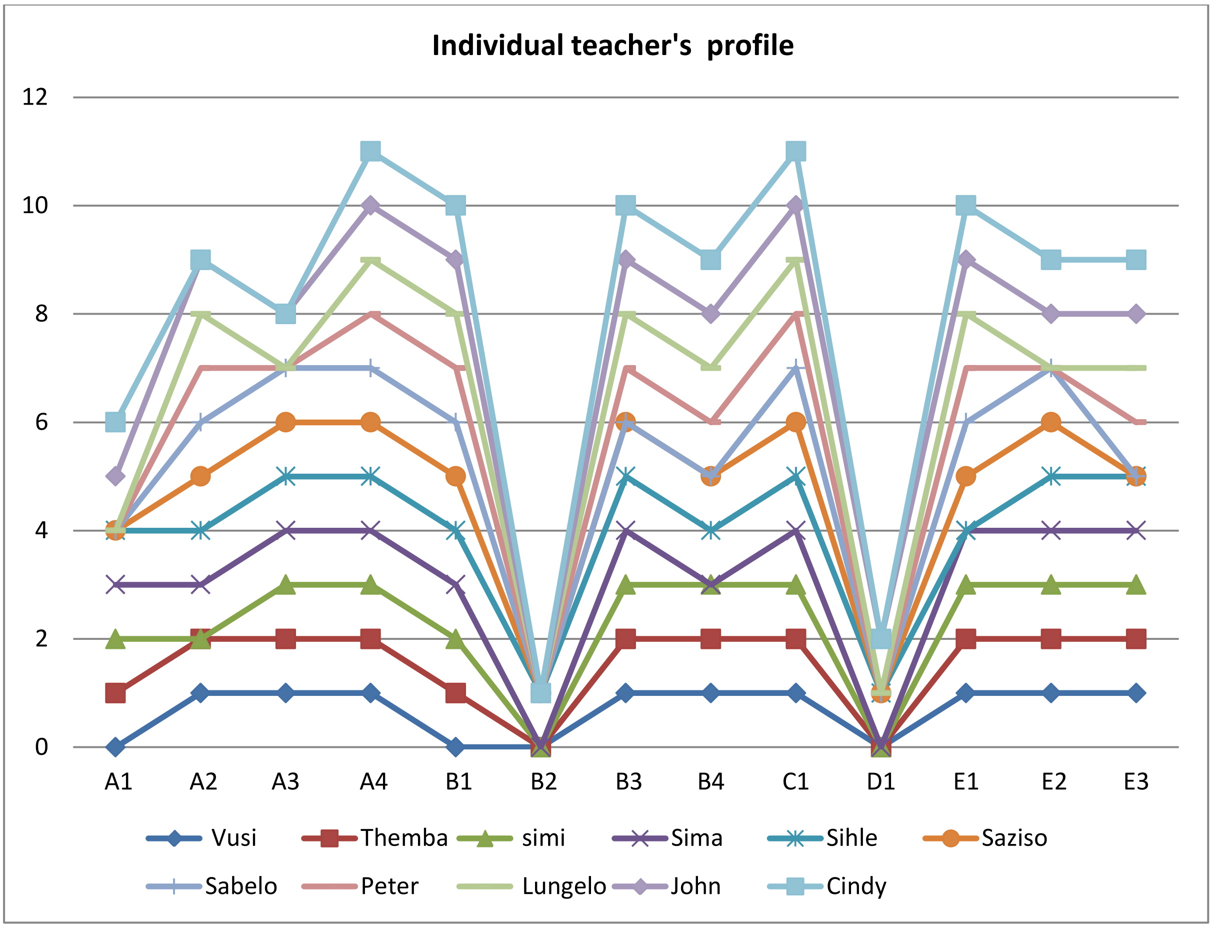

Figure 6. 2 Frequency with which teachers mentioned the Content Representation components

It is evident from Fig.6.2 that two particular components were not prominent among the interviewed teachers, namely B2, which refer to teachers' views on learners' alternative conceptions and component D1, which deals with topics or concepts that confuse learners during the leaning of chemistry. Qualitative and quantitative aspects of the analysis of the five Content Representations Components are discussed below,

An overview of the main idea (components A1, A2, A3, A4)

In general teachers seem to have a fairly good understanding of the curriculum. The results for component A1 indicate that six teachers articulated how learners learn chemical bonding. However, five teachers did not mention how learners learn chemical bonding. The results for component A2 showed that eight teachers indicated the importance of prior knowledge during the teaching of chemistry in the FET Phase.

Knowledge and beliefs about improving science teaching and learning (components B1, B2, B3, B4)

The analysis indicated that alternative conceptions learners held about chemical bonding (B2) were not commonly considered (only one teacher mentioned it). The results indicated that ten teachers ignored alternative conceptions during the planning of teaching sequences. The other components, beliefs about how learners learn (B1), teachers views of chemistry topic learners find difficult (B3) and teachers' beliefs about what learners should learn in a particular topic (B4) were mentioned by the majority of the teachers (see Figure 6.1

Insightful ways for teaching for understanding (C1)

Teachers spoke about how they assist learners' to understand chemical bonding and indicated that teaching chemical bonding required the use of different teaching approaches. The results indicated that written tasks were used as a form of assessment and teachers (11) indicated that there was need to monitor learners' understanding of chemistry in the FET Phase using assessment.

Known points of confusion (D1)

The analysis showed that only two respondents mentioned learners known points of confusion (D1) these results imply that teachers did not pay attention to parts of the concepts or topics that may confuse learners during their classroom practice.

Effective sequencing and important approaches to framing ideas (components E1, E2, E3)

The results indicated that teachers have developed broad ideas of how to teach chemical bonding and that the majority of them have developed particular representations appropriate for teaching chemical bonding during their practice. For example teachers spoke about how they use visual representations, such as models, to remove the abstract nature of the topic.

In summary the data indicated that there were prominent components such as understanding the curriculum and some components were not mentioned by most of the teachers. The non-prominent components included issues that focus on alternative conceptions and topics that confuse learners. The teachers' comments on how they make chemical bonding easy for learners to understand appear in Table 6.12.

Table 6.11 Summary of teachers' comments on making chemical bonding easier to understand

Teaching activity	Visual activities	Number of teachers
Use prior knowledge		1
Playing games	x	1
Role play	x	2
Simulation/ watching a video	x	1
Use of illustrations/ Bohr diagrams	x	3
Making models	x	1
Chalk and talk		2

Table 6.11 shows the range of strategies suggested and gives an indication of their popularity in the sample. These teaching activities included using illustrations/Bohr models (3): role playing (2), talk and chalk (2) and use of prior knowledge, playing games, simulations,) and making models, were each mentioned by one teacher. Aggregation based on the number of teachers using various forms of visualization to teach chemical bonding, showed that eight teachers used visual teaching activities to attempt to remove the abstract nature of chemical bonding and make science accessible to learners. The following interview extracts illustrate the point.

> The learners can relate much more easily when they use models and see illustrations on the board. This takes away the abstract nature of the concept for the child. It also depends on the types of learners you have. Sometimes different methods work well for different learners. So you also have to look at the caliber of learners you have and see what works better for them. Sometimes learners can understand a concept easily without having to see illustrations or anything tangible or physical. Others may take longer and may need additional aid for them to understand the concept (John-interview)

> I would have shown them formation of ionic compounds, practical on formation of compounds, making sodium chloride and looking at properties of ionic compounds. I would have used transparencies quite a lot, orbital boxes, where they got electrons they see how many electrons they can pair and they have got, you could physical take an electron from one and put it to the box to the other, make something where they actual make them overlap (Sihle-interview)

In these two quotes teachers indicated their awareness of the need to use visual teaching activities to present chemical bonding in a manner that is less abstract. In particular, in the first quote John indicated that the use of visual teaching activities is dictated by the cohort of learners because some learners do not understand the concept easily.

6.4. Discussion of outcome three

The fourth research question sought to understand reasons why teachers used a particular sequence to teach chemical bonding in the FET Phase. Data for this question were extracted from the survey and interviews. A rubric was used to analyse teachers' knowledge of chemical bonding and how it should be taught. Both the survey (Section 6.2, Table 6.6) and the interview (Section 6.2.2, Table 6.9) results showed that teachers viewed chemical bonding as problematic for learners to understand. The results also indicated that popular components of the CoRes suggested by Loughran et al., (2004) could be found among the responses (Figure 6.2)

In this discussion, I illustrate that there are various reasons why teachers use certain teaching sequences for teaching chemistry in the FET Phase. Analysis of data on the relevance of teaching sequences indicated that teachers use different teaching activities in a lesson in order to improve learners understanding of scientific concepts. Teachers indicated that the order in which teaching activities are presented to learners can enhance the success of teaching chemistry. This is a similar finding to that of Yuruk et al. (2000). Teachers indicated that the success of any teaching sequence also depends on learners paying attention and achieving outcomes in the classroom. In previous studies on teaching-learning sequences it was found that learners play a crucial role in allowing the researchers to evaluate the effectiveness of teaching sequences using pre and posttests (Meheut, 1997). Teachers in the current study indicated that the order in which learning materials were presented to learners was crucial to the success of teaching sequences. There were, however, areas of disagreement where some teachers indicated that there was no need to link teaching activities to previous tasks and that using the same pattern of activities did not necessary improve learners' confidence in science.

Statistical analysis indicated that the number of years of teaching physical science, location of schools and availability of teaching facilities influenced the manner in which teachers answered questions on the importance of teaching sequences. In particular, the findings indicated that teachers placed easy topics at the beginning and difficult topics at the end of teaching sequences. Teachers usually indicated that topics were sequenced based on learners' prior knowledge and logical sequencing of topics.

Analysis of the data on teaching of chemical bonding indicated that both the survey and the interviews findings support the outcome that teachers view chemical bonding as a problematic topic to teach and for learners to understand. To be specific, the survey findings showed that the majority of teachers (60%) indicated that chemical bonding was difficult for learners to understand and 37 % of the teachers indicated that chemical bonding was difficult to teach. The main reason suggested by teachers was that chemical bonding was abstract. The findings showed that a noteworthy percentage of teachers (15%) found chemical bonding difficult to understand. As explained in Section 3.2 the sample of teachers was drawn largely from those interested enough to attend in-service workshops or courses, so a more representative sample may have indicated a higher percentage of teachers experiencing problems with the teaching and understanding of chemical bonding. It is of great concern that these teachers are expected to teach chemistry concepts they are unfamiliar with in the FET Phase.

The opinions that chemical bonding is problematic to teach and understand are not new to this study. For example, Nahum et al. (2007) found that most scientists emphasized that chemical bonding was a complex concept. These authors also found that scientists made comments on the limited physical principles and models that they felt should be used to teach chemical bonding. The frameworks proposed by Nahum et al. (2008) and Taber (2001) indicated that there are different ways of teaching chemical bonding (see Section 2.3.2). The lack of clarity on how to teach chemical bonding seems to be a factor contributing to the problems teachers experience at high school. A review of literature on the teaching and learning of chemical bonding by Nahum et al. (2010) showed that the manner in which bonding was presented in textbooks worldwide was problematic at both high school and tertiary colleges. Thus, the literature suggested that traditional ways of teaching chemical bonding are contributing to learning difficulties experienced by the learners in the FET Phase.

Analysis of data on teachers' profiles indicated that interviewees were experienced, with an average of 17 years teaching experience, and were considered qualified to teach physical science in the FET Phase. The findings indicate that assessment was prominent amongst interviewees as a method for measuring learners' understanding of scientific knowledge at high school and teachers were able to articulate the strategies they use to teach chemistry and chemical bonding. These findings are in line with outcomes based education which focuses mainly on content, assessment and accountability (Berlach, 2004). However, these findings appear to contradict those of Padilla and Van Driel (2010), who found that assessment, was not given enough attention by the university teachers in their study.

Likewise, Sanchez and Valcarcel, (1999) found that teachers did not think about assessment during the planning of teaching sequences.

The findings of the current study indicated that teachers did not display skills and knowledge on two of the components of CoRes which had been highlighted by Loughran et al. (2004). These two components are teachers' knowledge of alternative conceptions (misconceptions) and known points of confusion for learners. The teachers in this study seem to have a limited knowledge on the effect of misconceptions as barriers to learning. This might imply that the problem of misconceptions has not been adequately taught during pre-service and teacher development courses. These findings are similar to those of Rollnick et al. (2008), where one of the participants failed to mention learners' misconception on chemical equilibrium that were informed by literature, which the authors ascribe to a lack of qualification in science education. The failure by the majority of the teachers in the current study to elicit learners' alternative conceptions during teaching and learning of chemistry indicated that teachers focus on learners learning the content and paying little attention to important factors that can contribute to meaningful learning. The South African curriculum is based on a constructivist approach (Department of Education, 2006). Nevertheless, the results of this study appear to show the converse; that teachers are not teaching from a constructivist approach.

6.5. Conclusion

This chapter has described data analysis that addresses the fourth research question of the study. This seeks to understand the reasons why teachers used a particular teaching-learning sequence to teach chemical bonding. This question was answered using comments made by teachers in the survey and interviews, measured against a rubric to elicit teachers' PCK on chemical bonding. The survey and interview results both showed that teachers view chemical bonding as problematic for learners to understand. The findings further indicated that teachers sequenced topics, starting with easy at the beginning and difficult topics at the end of teaching sequences. There was strong agreement among the teachers about using different teaching activities, the order of teaching activities influencing the success of teaching sequences and the role played by learners in the success of teaching sequences. Teachers disagreed on two issues, about linking previous tasks and using the same patterns of teaching activities as in previous tasks to promote learners' understanding of new ones.

There was a general pattern of teachers' PCK on chemical bonding. For example, components such as assessments, knowledge of the curriculum, and strategies for teaching chemistry were prominent among interviewed teachers. However, components required for learning, specifically learners' alternative conceptions, and concepts that confuse learners during the learning of chemistry, were not commonly acknowledged. The findings thus indicate that PCK might have influenced the manner in which teachers designed teaching sequences to teach chemical bonding. One can infer that sequencing of chemistry topics in the FET Phase was largely affected by the amount of teachers' experience and lack of accesses to teaching facilities.

In the concluding chapter the research process is summarized and conclusions are drawn based on the major findings of the study. The limitations and implications of the study are presented.

CHAPTER 7 CONCLUSION AND RECOMMENDATIONS

The purpose of this chapter is to provide a summary of the study. An overview of the methodology is given and the limitations of the study are outlined. The findings of the study are then discussed and conclusions drawn. Finally, the implications of the study are described.

The teaching of chemistry in schools continues to pose problems worldwide. Studies on teaching-learning sequences suggest that this is a possible way of improving learners' understanding of chemistry. The use of teaching-learning sequences has been shown to contribute to improving teaching in chemistry education (Leach & Scott, 2002). The purpose of this study was to understand the nature of teaching-learning sequences used by teachers in teaching chemistry, particularly in the topic of chemical bonding, and understand how and why teachers design and implement teaching learning sequences in the FET Phase in Kwazulu-Natal, South Africa.

This study demonstrates that it is possible to arrive at some understanding of the nature of teaching-learning sequences used by teachers to teach chemical bonding . For example, teachers suggest teaching-learning sequences which indicate that the positions of topics or concepts within a teaching sequence can be varied. The study also demonstrates that teachers follow steps in their planning but unfortunately are missing some important steps seen as essential by the model of educational reconstruction and the learning demand tool. For example, analysis of data involving the use of model of educational reconstruction, learning demand tool and pedagogical content knowledge, indicates that some teachers made absolutely no mention at all of the importance of learners' everyday experiences, or learners' possible misconceptions at the planning phase of a teaching sequence. This suggests that teachers are not guided by the learning theory of constructivism (or choose to ignore them?), despite all the guidance in the policy documents and contrary to Taber, (2011)'s claim "that constructivism has been widely adopted internationally within science education as a fundamental perspective on teaching and learning" (Taber, 2011, p. 257).

7.1 Summary of the methods used

The study was located within a pragmatic paradigm and a mixed methods research design was adopted. The mixed methods involved collecting both quantitative and qualitative data. The quantitative data were collected by means of a survey which was administered to 227 physical science teachers in KwaZulu-Natal. The survey questions consisted of both open ended and closed questions. The quantitative data were analyzed using SSPS computer software. Qualitative data were collected by means of open ended questions in the survey and semi-structured interviews administered to eleven selected physical science teachers. The audio tapes from the interviews were transcribed into text that was inductively analysed using NVivo software, and interpreted using the chosen theoretical frameworks. Overall the research design of mixed methods was shown to be useful in this particular study because it allowed the researcher to have access to rich data sources, which facilitated the interpretation of the findings. My recommendation is that this was a suitable approach yielding insights into teachers use of teaching-learning sequences and could be used profitably for research into other topic areas.

7.2 Limitations of the study

The methodology used for the study was considered relevant since the survey provided useful data which were supported by the interview data. The instruments used and the sample chosen contributed to the collection of relevant data (see Chapter 4, Sections 4.1; 4.2). By its very nature, that is involving people, research in science education has certain limitations. The first limitation of this study was the focus on a convenience sample based on geographical location of the participants and that they were attending in-service courses. It is not likely that the KZN physical science teachers who participated were completely representative of the whole province. While they might have the same characteristics such as qualification and experience, this group was different in subtle ways such as their willingness to participate. As noted by Kitchenham and Pfleeger (2002) “the main problem with this approach is that people who are willing to participate may differ in important ways from those who are not willing” (p. 19).

A second limitation, with regard to the research design, was relying on teachers’ self-reporting regarding claims to their practice in both the survey and the interviews. Classroom observation or learners’ book analysis could have been used to validate their claims.

However, it was not practical to observe a complete topic sequence, since the teaching of one topic may take several weeks and only one or two teachers could be observed at a time. However this approach would be worth considering if a large scale study was initiated involving more resources and researchers.

Another limitation is that some methodological alterations occurred at the analysis stage; some survey questions being left out in the final analysis because they were deemed not to be relevant to the main themes of this study. This was not problematic as the survey allowed for the use of different questions and also the use of semi-structured interview provided quality for the data. However it was felt that some teachers could have been confused by the different emphasis in questions between chemistry topic sequences and sequences of concepts. Future studies would need to make this even more explicit and perhaps provide examples from other topics. Having used the questionnaire with a large group of teachers, each part could be statistically analysed and refined for future use.

7.3 **Summary of findings**

In answering the research questions, outcomes were generated from both the survey and interview data (see Section 3.5.1). In this study outcomes represent the main findings of the study.

Research questions one: **"What teaching-learning sequences are used by teachers to teach general chemistry topics in the FET Phase?**

The first research question focused on understanding the patterns of teaching-learning sequences used by physical science teachers and data were provided by two open ended questions in the survey and more detailed information came from the interviews. The data indicated that the topic sequences suggested by teachers showed that the order of the topics taught before and after chemical bonding varied or were different among teachers. This implies that chemical bonding does not have a fixed position within the topic sequences used by the teachers in the FET Phase.

I found that teachers did not agree on a single topic sequence on the position of chemical bonding, although further analysis on topic sequences indicted that teachers were, nevertheless, still able to group topics into meaningful patterns of teaching sequences. To be specific, There were a variety of sequences, but most of them were meaningful (not arbitrary or random), and in fact there was consensus among most teachers on the following sequence: periodic table, structure of atom, atoms and molecules, atomic mass and diameter, mixtures, isotopes, properties of liquids and solids, names and formulae of substances, chemical bonding, molecular forces and balancing chemical equations. The current study has indicated that teachers had a preference for placing topics in a teaching-learning sequence starting with easy topics and ending the sequence with difficult topics. For example, topics such as chemical bonding were viewed as difficult and placed towards the end of the teaching sequence.

***Research questions two:* "What teaching-learning sequences are used by chemistry teachers to teach chemical bonding in FET Phase?"**

The second research question focused on understanding the sequencing of concepts within chemical bonding. Data indicate that the variation of sequences within the chemical bonding topic was less than that in the sequencing of general chemistry topics.

The teachers also indicated that they used different teaching approaches to explain abstract chemical bonding concepts. Some teachers, for example, indicated that when teaching chemical bonding the concepts could be placed in the following order: attraction forces, covalent bonding, ionic bonding, Lewis notation metallic bonding, and molecular shapes. Although individual sequences varied, in general, the findings indicated that the majority of teachers placed covalent bonding at the beginning and put molecular shapes at the end of a teaching sequence for chemical bonding. This result does not align with the sequence recommended by Taber and Coll (2002), which starts with metallic bonding (see Section 4.4.2). Data indicated that there was consensus among teachers regarding the programme guidelines they used most frequently during the planning of teaching sequences; these guides being official policy documents. However, teachers did not necessarily place topics in the prescribed order as in the policy documents. This correlates with earlier work by Donnelly (2007) and Berlach (2004) who found that if the curriculum was unstructured teachers easily got confused as to what to teach. Together, these findings suggest a need for the inclusion of clear guidelines in the policy documents on how teachers should design teaching sequences for chemical bonding in the FET Phase.

***Research question three:* "How do the teachers construct the teaching-learning sequences to teach chemical bonding?"**

Data indicate that teachers plan teaching sequences using information from programme guidelines and textbooks. The teachers used these sources of information to establish the chemistry content to be taught in the FET Phase. The findings indicate that teachers planning using some of the steps identified in the learning demand tool. Some steps in the tool could be recognized such as; Step 1: determining knowledge to be taught, Step 4a: Determining the teaching goals, Step 4b: Staging a scientific story. However some crucial steps were missing from teachers planning. Some of these steps are; Step 2, students' everyday views of science (chemical bonding), Step 3 identification of learning demands 9social language of science), and Step handing over responsibility to the students

The teaching-learning sequence suggested by teachers seem to be in line with some of the steps of the learning demand tool and teachers apply the two components of the educational reconstruction model (analysis of content structure and research on teaching and learning) during planning teaching sequences for teaching chemical bonding.

The survey data, supported by interview findings, indicate that teachers consistently used certain steps during the planning of teaching-learning sequences. To be specific, the results indicated that teachers used some steps in the learning demand tool suggested by Leach and Scott (2002). It is possible that this model is not appropriate in the South African context but I found some evidence that, teachers' teaching sequences were to some extent reflected theoretical underpinnings. For example, the teachers planned teaching activities in an organized manner, as shown by their use of some of the steps proposed by Leach and Scott (2002). With regard to the model of educational reconstruction (Duit, 2007) it was found that the steps included, were the teachers' own understanding of science content to be taught and the planning of teaching sequences. Consequently, rather than the model being inappropriate, it is more likely that these results imply that teachers are simply not aware of all steps of the learning demand tool. Moreover and unexpectedly, my findings confirmed that an additional step was advocated by the teachers, but this step had not previously been clearly identified in the four steps (1 to 4) mentioned by Leach and Scott (2002) (see Table 5.5). The additional step emerging from the data should be included as a fifth step in the learning demand tool. I labeled this previously unreported step as step 4e, "prior content knowledge".

***Research question four:* "Why do teachers use these teaching-learning sequences to teach chemical bonding in the manner that they do?"**

The fourth and last research question sought to understand reasons why teachers used a particular teaching-learning sequence to teach chemical bonding in the FET Phase. Data indicates that there are various reasons why teachers use different teaching-learning sequences. Teachers indicated that the order of teaching activities and learners' participation in class contributed to the success of teaching activities, teachers suggested that there are two common ways of sequencing topics, these are either linking related topics or sequencing topics using learners' prior knowledge.

Data also indicate that the interviewed teachers had an average of 17 years' experience, yet they did not mention all the aspects of the CoRes (Loughran, et. al., 2004) or PCK in the interviews. Those aspects mentioned were an overview of the main ideas, insightful way of teaching for understanding, effective sequencing and important approaches to framing ideas for (CoRes) and assessment (PCK) as an important aspect of teaching-learning sequences. However, teachers did not mention the inclusion of learners' alternative conceptions, nor did they, at the planning phase, identify ideas that could cause confusion for learners. The tendency of teachers to favour only some aspects of the PCK and neglect others is not new. Padilla and Van Driel (2011) found that professors did not consider assessment to be important compared to students' understanding of the curriculum. From my research, it appears that the South African teachers do not differ from those in other countries and tend to consider only parts of underlying theory in teaching-learning sequences.

Throughout the study I have highlighted the multifocal theoretical stance employed by the current study. For example, the model of education reconstruction offers a broad theoretical understanding of the design and evaluation of teaching-learning sequences. Only two aspects of this framework were used, namely, analysis of content structure and research on teaching and learning. Most of the teachers in this study seemed to apply the aspect that focused on content during the planning of teaching sequences (see Section 5.4) while some teachers ignored the aspect that focused on learners' conceptions of chemical bonding. On the other hand the learning demand tool offers guidelines on steps that should be followed during the planning of teaching sequences. The teachers in this study ignored one step completely, and barely mentioned the other two steps. The findings indicate that there were commonalities between the step ignored in the model of educational reconstruction and learning demand tool. The aspects that received least attention from the teachers dealt with learners' everyday experiences, and by contrast teachers indicated a strong focus on content related issues (see Table 5.5). Furthermore, the aspects of PCK to which teachers ascribed less importance were topics that confuse learners or the learners' everyday experiences of chemical bonding. The implication for these findings is that the teachers do not explicitly consider learners' everyday experience and possible confusion, as important at the planning phase of a teaching sequence. Bearing in mind the earlier finding concerning the acknowledgement by teachers of the importance of learners' prior knowledge but not their everyday experience, one may infer that this might indicate how teachers teach physical science in the FET Phase. In other words one may ask whether they recognise that physical science is in fact related to everyday experiences, or is it merely seen as academic knowledge?

7.4 Implication for educators

The findings of this study have implications for educators and should be distributed through different communications used by the Department of Education, presentations in conferences and journal publication as well as to publishers and text book authors. Data on planning teaching sequences show that teachers displayed limitations as classroom practitioners. For example, the findings indicate that they did not have the requisite skills for planning viable teaching sequences. The input of teachers in the design of teaching sequences should be explored further. Such studies might also be extended, for example by research on the inclusion of teaching sequences of topics in the policy documents or the design of relevant teaching activities for each topic sequence to support the teaching of chemistry in the FET Phase. Therefore in-service workshops need to be conducted regarding the importance of taking into account the learner's everyday experience and potential misconceptions in the planning stage of a teaching sequence. I recommend that teachers should be taught about and be involved in the development of teaching-learning sequences from an early stage of their education. Teaching documents, such as textbooks and curriculum support material should include and address common misconceptions held by learners on chemical bonding and other related chemistry topics. The teachers should also be encouraged to reflect on learners' problems and seek better ways of teaching chemical bonding in the FET Phase in a learner-centred manner.

More broad-based studies in relation to the location of schools, resource availability and teacher sample are needed to provide a broader picture of effective teaching-learning sequences used by teachers in KwaZulu-Natal, or elsewhere in South Africa. There is need to carry out a study to understand why teachers appear not to refer to learners' prior knowledge and misconceptions during the planning phase of a teaching sequence.

7.5 Implication for research

As discussed above, this study makes a useful contribution to the literature in chemistry education. It is one of the studies in chemistry education which seeks to understand how teachers design and implement teaching-learning sequences for chemical bonding in the FET Phase. In this connection, Meheut (2005) reports that there are not many research projects that "propose, and analyze, precisely, intervention of the teachers during a given teaching-learning sequences" (p. 199). The current study has discussed the limitations associated with involving teachers' ideas only in the design of teaching-learning sequences and in doing so it is hoped that this problem will be brought to the attention of other researchers in chemistry education and other fields. The current study has further demonstrated that within a teaching-learning sequence, the positions occupied by a topic or concept varied (see section 4.2.1; Table 4.4). In addition this study has offered other researchers an example of how to structure studies on teaching-learning sequences that do not involve pretests and posttests on learners' knowledge. Moreover, this study has made an important contribution on how to apply both MER and Learning demand tool to analyze data and frame teaching-learning sequences. In addition, the study has demonstrated that teachers pay attention to most aspects of both MER and Learning demand tool that deal with content, teaching, and assessment, but they did not mention the aspects that focus on the learners' everyday experiences, and supporting learners to take charge of their learning.

There are two main areas in which research at this level may contribute to existing knowledge base. Firstly, there is a theoretical contribution and secondly through the discovery of new facts. For example, data from the current study has indicated that teachers are not familiar with all the components of the MER and Learning demand tool. The MER has origins in the German Didaktik and has been adopted in some parts of Europe (Duit et al., 2012). The learning demand tool has origins in United Kingdom (Leach & Scott, 2002).

These models may not be universally applicable to developing countries, which may have the effect of limiting the theoretical contribution of this study. The main contribution of the study may therefore be uncovering new facts. The current study generated new ideas on teaching-learning sequences for chemical bonding in the FET Phase. These ideas may also find application in the sequencing of other physical science topics in the FET Phase.

Secondly, the current study has proposed a teaching-learning sequence on teaching chemical bonding in the FET Phase. This is important because there are few, if any; teaching-learning sequences on teaching chemical bond in the FET Phase. While the teaching-learning sequence and the findings upon which it is based do have some limitations, as discussed above, they are, nevertheless, of value in the teaching of chemical bonding in the FET Phase. The teaching-learning sequences provide an overview of how chemical bonding taught in the FET Phase. The teaching and learning sequence proposed in the current study is different from the teaching sequences described by Taber (2001) and Nahum et al. (2008). For example, a design of a teaching-learning sequence involves several 'components, in particular its structure" (Tiberghien, Vince & Gaidioz, 2009, p. 2296). According to Lijnse and Klaassen (2004) the structure of s is usually guided by, the design principles, pedagogical approach, methodological framework and students' assessment tools.

There is strong evidence from data that some teachers used similar ideas to design teaching activities on chemical bonding. For example, teachers engaged in elementarization of content, as illustrated in Figure 2.1 of the MER, and teachers applied step 1, step 2 and step 4 of the learning demand tool (see Section 2.3.1). Teachers were asked to discuss how they plan and teach teaching chemical bonding. Data obtained from planning for teaching (Section 5.2), show how teachers plan teaching sequences (Section 5.2.2) and the relevance of the local curriculum, context of schools, the relevant information on the design and implementation of teaching-learning sequences was used to model new facts and proposed the teaching- learning sequence for chemical bonding in the FET Phase described here. The ideas for the proposed teaching-learning sequence are reported in Table 7.1.

Table 7. 1 Proposed teaching-learning sequence for chemical bonding in FET Phase

Tasks	Description of teacher actions.
Pedagogical teaching approach	Guided Inquiry (not Direct Teaching) Identification of curriculum content Elementarization of science content/ making science content easy for learners Construct instruction content to create a logical TLS
Scientific content	Chemical bonding, attraction forces, covalent bonding, ionic bonding, Lewis notation, metallic bonding, molecular shapes. Teach metallic bonding at the beginning of the sequence (Taber & Coll, 2001) Construct concept sequences using learners' prior content knowledge
Modeling /Examples of teaching chemical bonding	Visualise the teaching of chemical bonding Provide learners with an opportunity to model chemical bonding structures Provide learners with opportunities to explain how the model works
Laboratory work	Use hands on experiments on formation of ionic compounds or burning experiments Use computer simulation do show formation of bonds,
Tasks	Give a project on building chemical bonding structures

The aim of the proposed teaching-learning sequence for chemical bonding is to support teachers in designing teaching and learning activities that emanate from research. The use of an appropriate teaching-learning sequence will lead to improved students' understanding of chemical bonding. The proposed teaching-learning sequence for chemical bonding, as identified in the current study, has been evaluated to some extent in terms of teachers' ways of teaching chemical bonding for several years (average 17 years) and needs to be implemented and evaluated in terms of students' learning (Ruthven, Laborde, Leach & Tiberghien, 2009). If the teaching and learning sequence is verified by researchers elsewhere, it can be a useful and effective teaching tool for chemical bonding and can be extended to other topics in the FET Phase. There is also a need to carry out a study that looks at the effectiveness and usefulness of the proposed teaching sequences for chemical bonding in the FET Phase, both in South Africa and other countries. The question that needs to be answered would be "what teaching sequences are effective for teaching chemical bonding?"

There is need to investigate further why teachers that did not mention learners' ideas during the design and evaluation of teaching sequences for chemical bonding. The research question that needs further study would be "why are teachers ignoring learners' ideas on concepts during the planning of teaching sequences for chemical bonding in the FET Phase?" In other words, what makes teachers use direct instruction instead of constructivist instruction?

To sum up, the findings of this study confirm, to a great extent, the amount of work already done internationally on the design and evaluation of teaching and learning sequence. I have identified possible topic sequences for general chemistry and concept sequences for chemical bonding in the FET Phase. I have identified possibilities that would help researchers involve teachers in the design and evaluation of teaching sequences. Having identified deficits in the official curriculum documents, the study design can be transferable to other concepts in science education to provide more helpful information for teachers in South Africa. It would also be useful in countries with similar context for teaching to that studied in KwaZulu-Natal, South Africa. The final words are based on my journey throughout this process.

> *My experience of this process can be summed up as; first, to be patient so that you avoid a breakdown, second, the learning process at this level is not straight forward and last supervision is part of this process.*
> *One step at a time, you will finally arrive at the finishing line. This is what keeps me alive and energetic.*

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APPENDIX 1

UNIVERSITY OF
KWAZULU-NATAL

University of KwaZulu-Natal
Research Office
Govan Mbeki Centre
Westville Campus
University Road
Westville
4000
South Africa
Tel No: +27 31 260 3587
Fax No: +27 31 260 4609
sshrec@ukzn.ac.za

24 FEBRUARY 2010

Mrs. D Sibanda
School of Science, Mathematics & Technology Education
EDGEWOOD CAMPUS

Dear Mrs. Sibanda

ETHICAL APPROVAL NUMBER: HSS/0098/10D
PROJECT TITLE: "How do teachers construct a Teaching-Learning Sequence (TLS) in chemistry education at FET Phase?"

In response to your application dated 18 February 2010, Student Number: **204518918** the Humanities & Social Sciences Ethics Committee has considered the abovementioned application and the protocol has been given **FULL APPROVAL.**

Any alterations to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study must be reviewed and approved through the amendment /modification prior to its implementation. Please quote the above reference number for all queries relating to this study.
PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

Professor Steve Collings (Chair)
HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS COMMITTEE

cc. Supervisor (Prof. Paul Hobden)
cc. Mrs. R Govender & Ms. T Khumalo

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

APPENDIX 2

Questionnaire

Dear Physical Science Teacher,

I am a lecturer and doing research in the School of Science Mathematics and Technology Education at the University of KwaZulu-Natal. I am pursuing a Doctoral degree entitled: How do teachers construct a Teaching-Learning Sequence (TLS) in chemistry education at the FET phase?

The aim of this study is to:

- Identify the different patterns of TLS used by experienced teachers to teach chemical bonding
- Describe how experienced physical science teachers order and organize teaching and learning activities.

Through your participation I hope to understand and describe how you oragnise and teach chemistry at FET phase.

Your participation in this study is voluntary. You may refuse to participate or withdraw from the project at any time with no negative consequence. There will be no monetary gain from participating in this survey. Confidentiality and anonymity of records identifying you as a participant will be maintained by the School of Science Mathematics and Technology Education, UKZN

If you have any questions or concerns about completing the questionnaire or about participating in this study, you may contact me or my academic promoter at the contact details listed above. The questionnaire should take you about 10-15 minutes to complete. I do hope you will take the time to complete this Questionnaire. Please sign below to show your willingness to participate in the study.

Thank You:

Researcher: Mrs. Doras Sibanda [033 260 6040]

Supervisor: Prof Paul Hobden [031-260 3447]

………………………………………………………………………………………………………

I (full name) ……………………..……………………………………………………hereby confirm that I understand the contents of this document and the nature of the study and I consent to participating in the study. I understand that participation is voluntary and that I may withdraw at any stage of the study.

----------------------------------- -----------------------------

Signature of Participant Date

1. **Part 1: Biographical Data**

Please could you provide us with the following information about yourself and the school you are currently teaching.

1.1. Personal information. Use a cross or tick to indicate what is appropriate to you.

Name (not compulsory)	
Number of years teaching	1-6 years ☐ 7-12 years ☐ more than 13 years ☐ other (specify)________________________
Number of years teaching physical sciences at grade 10,11,12 level	1-6 years ☐ 7- 12 years ☐ more than 13 years ☐ other (specify)________________________
What is your qualification?	B Paed ☐ BA ☐ BSc ☐ Matric ☐ STD ☐ other (specify) ________
Have you studied further in education?	Yes ☐ No ☐ Specify qualification obtained__________
What is the highest qualification completed in physics? (e.g. Physics I)	
What is the highest qualification completed in chemistry? (e.g. chemistry I)	

1.2. Current school information: write your answer in the space provided or tick the correct box below

Name of school	
Nearest town e.g. Kwamashu/Newcastle	
Approx Number of learners in grade 12 physical sciences class in 2010	less than 32 learners ☐ more than 32 learners ☐ other(specify) ________________
Where is your school situated?	township ☐ Rural ☐ urban 7 small town ☐

Which description best suit your school?	built after 1994 ☐ ex model C ☐ private school ☐ built before 1994 ☐ other (specify)________________________
Would you say that the facilities and resources at your school are suitable to deliver the physical sciences curricula to grade 10 to 12?	

1.3. This section is to find out about the resources you have at your school for helping you to teach science. Tick what is appropriate to your own teaching environment in boxes provided.

Do you have gas in the rooms you teach physical science at your school?	Yes ☐ No ☐
Do you have a laboratory at your school?	Yes ☐ No ☐
Do you teach in the laboratory the whole day?	Yes ☐ No ☐
Do you have a classroom set aside for teaching physical science?	Yes ☐ No ☐
Do you teach in different classrooms within a day?	Yes ☐ No ☐
Does your classroom/lab have enough space to do: demonstrations to grade 10-12 curricula?	Yes ☐ No ☐
Do you have enough chemicals to do demonstrations to grade 10-12 curricula?	two years ☐ one year ☐ a term ☐
Do you have glassware to do demonstrations to grade 10- 12 curricula?	Yes ☐ No ☐
Do you carry out demonstrations in the classroom/lab?	Yes ☐ No ☐
Do learners themselves carryout any investigations, experiments or practical?	Yes ☐ No ☐
On average how many demonstrations do you carry out per term	
How many physical sciences teachers are currently teaching at your school?(including yourself)	
Pleas could you list tow chemistry practical that you have carried out in grade 10 since the beginning of this year (2010): ____ Please could you list two chemistry practical that you have carried out in grade 11 since the beginning of this year (2010): ____	

1.4 This section seeks to understand how accessible the following physical science teaching documents are at your school are.

To what extent do you have access to a copy of the following documents at your school?	
Physical Sciences National Curriculum Statement document Grades 10- 12: (a) General………………………………	Personal copy ☐ school copy ☐ Other (specify) _________________
(b) Content……………………………	Personal copy ☐ school copy ☐ Other (specify) _________________
(c) Learning program guidelines……………	Personal copy ☐ school copy ☐ Other (specify) _________________
(d) Subject assessment guidelines……………	Personal copy ☐ school copy ☐ Other (specify) _________________

1.5 This section seeks to understand how you access some of the resources listed below. Please indicate if you have copies of the following resources:

Physical science workshop notes	Personal copy ☐ never seen it ☐ other(specify) __________________
Physics discipline textbook	General Physics ☐ Advanced level physics ☐ Other (specify) __________________________
Chemistry discipline textbook	General chemistry ☐ Advanced level chemistry ☐

	Other (specify) ______________________________
Guides to teaching physics (e.g. Mechanics & Waves)	Personal copy ☐ never seen it ☐ other(specify)__________________
Guides to teaching chemistry (e.g. Chemical equilibrium)	Personal copy ☐ never seen it ☐ Other (specify)_________________
Which text book do you use for the majority of your preparation?(Give name)	
Which textbook do the learners use? (Give name)	
Do the learners have their own personal copies?	
Are there any other resources that you use at your school apart from the ones mentioned above?	

2. Part 2: Sequencing some general chemistry topics

Chemistry has many different topics that depend on each other. The order in which you introduce the topics can make a difference. E.g. you need to deal with ionic and covalent bonding before dealing with acids and bases

2.1. Below is a list of topics taught in grade 10 to 12 physical science chemistry section.

- The periodic table
- Mixtures
- Properties of liquids and solids
- Atoms & Molecules
- Structure of atoms
- Atomic mass & diameter
- Isotopes
- Chemical bonding
- Intermolecular & intramolecular forces
- Names & formulae of substance
- Balanced chemical equations
- Chemical systems

Use the table below to indicate the most likely order you would introduce these topics when teaching chemistry.

1st	2nd	3rd
4th	5th	6th
7th	8th	9th
10th	11th	12th
Is there a special reason why you ordered the topics in this particular sequence?		

2.2. Suppose you are teaching chemical bonding at FET phase (grade 10or 11) and you are asked to teach the concepts listed below.

Please could you re-organize these concepts into a sequence that is suitable to your teaching and aims at improving the learners' understanding of bonding. Use a number to show the order of your sequence, for example number 1 will mean the first concept to be taught and number 6 would mean the last concept to be taught. Write the appropriate number next to each concept.

- Metallic bond ________
- Ionic bond _________
- Covalent bond _________
- intermolecular forces ________
- Lewis theory ________
- Molecular shapes ________

2.3 Explain why the sequence you have listed above is appropriate to teach bonding?

____

2.4 This section seeks to understand your own views on why you use different teaching activities in your teaching of physical science at FET phase, Use a scale of 1 to 7 to indicate your view/opinion on each of the statements below. Number 1 to indicate that you strongly disagree and number 7 to indicate that you strongly agree

	1	2	3	4	5	6	7
Using a variety of teaching activities in one lesson leads to better learning and learners are more involved in their learning							
The teaching activities that I use are aimed at helping learners to construct relevant scientific knowledge							
The success of teaching a particular teaching activity depends on: (a) how the teaching activities are ordered and presented to learners………………..							
(b) whether learners pay attention in the classroom….							
(c) whether learners working hard to achieve the learning outcomes………..							

3. **Part 3 Organising chemistry topics to teach physical science**

3.1 This section seeks to understand what informs your decision to organize topics in a particular way. Please can you indicate by ticking the responses that best describe the source of some of your topic sequence?

	Never	Almost never	Seldom	Some times	Often	Almost always	Always

Where do I get most of my ideas for sequencing topics when teaching chemistry at FET phase?							
I follow a topic sequence provided by: (a) the learning programme guidelines of the national curriculum statement …………………………………………...							
(b) the physical sciences content of the national curriculum statement document …………………………………………...							
(c) my head of science discipline or colleague (self)							
I sequence and organize teaching topics to cater for different abilities of learners at FET phase							
I sequence teaching topics in the same way I was taught at school/ university							
I use same topics sequence as the that provided by the textbook							
I don't have a topic sequence; I just see what happens during lessons and change to suit learners needs.							

3.1. Based on your experience, indicate whether you agree or disagree with the following statements about sequencing and organizing of teaching activities when teaching chemical bonding at FET phase. By teaching activities we mean tests, reading notes, demonstrations, teachers talk/lecture, practical, whole class discussions, completing a worksheet etc. Use a scale of 1 to 7 to indicate the level of your agreement. For example 1 would mean strongly disagree and 7 would mean strongly agree.

	1	2	3	4	5	6	7
In general, I try to link the teaching and learning activities of a each concept to previous work/tasks							
I have developed my own way of sequencing and organizing teaching activities to teach chemical bonding							
The sequence of activities that I use are the same as those used in textbooks and policy documents							
When teaching chemistry topics at FET phase I use the same sequence of activities each year							
Using the same sequence of activities most of the time makes learners confident in the subject; learners like the same pattern							
I have not developed my own way of sequencing and							

organizing teaching activities to teach chemical bonding							
How do you organize the concepts to teach the Periodic table at FET phase? ____							

3.3 Research has shown that bonding is difficult to understand.

(a) Do you find it difficult to teach? Yes □ ☐ ☐

Why do you think this is so? ____

(b) Do your learners find it difficult to understand? Yes □ No ☐ ☐

Why do you think this is so? ____

____

(c) Do you find it difficult to understand yourself? Yes □ No ☐ ☐

Why do you think this is so? ____

____

3.2. What tips or challenges with teaching bonding would like the researcher to be aware of?

____

Thank you very much for your time.

Would you please provide your telephone number if you would allow me to contact you? (not compulsory)
Telephone number: ______________________

Please could you assist by returning the questionnaire as you can to the researchers. My contact details are as follows:

Ms Doras Sibanda (033 260 6040)
School of Education & Development
Pietermaritzburg Campus
Private bag X01
Scottsville 3201

APPENDIX 3 Interviews

Dear Physical Science Teacher,

I am a lecturer and doing research in the School of Science Mathematics and Technology Education at the University of KwaZulu-Natal. I am pursuing a Doctoral degree entitled: How do teachers construct a Teaching-Learning Sequence (TLS) in chemistry education at the FET phase?

The aim of this study is to:

- Identify the different patterns of TLS used by experienced teachers to teach chemical bonding
- Describe how experienced physical science teachers order and organize teaching and learning activities.

Through your participation I hope to understand and describe how you oragnise and teach chemistry at FET phase.

Your participation in this study is voluntary. You may refuse to participate or withdraw from the project at any time with no negative consequence. There will be no monetary gain from participating in this study. Confidentiality and anonymity of records identifying you as a participant will be maintained by the School of Science Mathematics and Technology Education, UKZN

If you have any questions or concerns about interviews or about participating in this study, you may contact me or my academic promoter at the contact details listed above. The interviews should take about 30-60 minutes. Please sign below to show your willingness to participate in the interview.

Thank You:

Researcher: Mrs. Doras Sibanda [033 260 6040]

Supervisor: Prof Paul Hobden [031-260 3447]

…………………………………………………………………………………………………

I (full name) …………………….……………………………………………………hereby confirm that I understand the contents of this document and the nature of the study and I consent to participating in the study. I understand that participation is voluntary and that I may withdraw at any stage of the study.

---------------------------------- ----------------------------

Signature of Participant Date

Interview questions

Part 1: Questions concerning background information

Tell me about your science teaching history. / Where you are teaching? / What is your qualification? How long have you been teaching? / would you consider yourself a good science teacher? / do you enjoy teaching science? / Are you confident?

Who taught you to teach science?

What are the main resources that you use to teach science?

Do you get help from somewhere/someone concerning the teaching of science?

(Oh that is interesting; tell me about the most recent time you did this)

Part 2: Questions concerning teaching chemistry in general

Now let us talk about how you teach science.

If you are about to teach a section in chemistry how do you go about planning your teaching activities?

What steps do you normal follow? / Do you follow an order? / Why? / Do you think of any problems that might be experienced by learners when planning the teaching activities?

Do you generally do what you did last time?

When do you make changes?

How do test for learners' understanding of chemistry topics?

Part 3: Questions concerning teaching of chemical bonding

Now let us talk about how you teach chemical bonding?

You teach this topic in which grade?

Tell me how you have taught it in the past at school in grade 10-12?

Where did you get the ideas for teaching it this way? (Would you say that the source of your ideas is mentor, other teachers in school, subject advisors, textbook, or research articles?)

Do you think it is successful?

How do you know?

How do you decide what to teach first?

What teaching activities do you use when teaching bonding?

Describe some of your teaching activities/ describe your teaching style. /do you do a lot of chalk board work, talking, ohp, demonstrations/ practical work.

If I ask some of your students how you taught them, what do you think they will say?

Part4: questions concerning how teachers organize topics in general chemistry

Let us talk about how you would organize the following topics in relation to chemical bonding over three years in FET grades 10-12?

Here are some cards with general chemistry topics, use the cards to arrange these topics in an order that would help learners' better understand chemistry.

What make you put this first? Why did you put forces next/away to bonding?

In the questionnaire most teachers paired up topics what do you think could be the reason for this?

Part 5: Questions concerning specific subtopic of bonding

Let us talk about how you organize the concepts of chemical bonding?

The questionnaire responses show that three sequences listed below were common, what do you feel about these sequences?

A. Forces→Covalent → Ionic→Lewis → Metallic → Shapes
B. Lewis →Forces → Covalent→ Shapes → ionic → Metallic
C. Shapes→ Lewis → Forces → Covalent →Metallic →Ionic

From the questionnaire responses 33, 5% of the respondents find teaching bonding difficult.

Do you feel the same?

Do you feel that learners are finding bonding difficult to understand? / Have you noticed any components of chemical bonding that confuse learners?

Part: 6 Closing question

Can you mention any ideas about teaching chemical bonding that are important and have not been discussed during the interview?

Can you compare the teaching of bonding to other topics/is it more difficult to teach or harder for learners to understand?

APPENDIX 4

Textbooks references (see Figure 4.20)

Study and master

Van Zyl, E. J., Craul, V. Meyer, A., Muller, C., & Spies, L. (1999). Study and master physical science: grade 11&12. Cape Town, Cambridge university press

Oxford/success

Broster, P. Horn, W. James, H. & Solomon, n(2012). Oxford successful physical science grade 11 learner's book. Cape Town, Oxford University Press.

Mind in action

Mann. M (2010). Mind in action series; physical science textbook/workbook grade 11Cape town, Allcopy Publishers

Spot on

White, M. (2007) Spot on physical sciences (spot on series) grade 11, Johannesburg, Heinemann Publishers (Pty) Ltd

Focus

Gedule, E. (2007). Focus study guide: physical science: grade 10 -12, Cape Town, Maskew miller longman.

Oliver

Oliver, A. (2009). Physical science: theory & workbook grade 12. Cape town, Reivilo Publishers

APPENDIX 5 TURNITIN CERTIFICATE

turnitin

Your digital receipt

This receipt acknowledges that Turnitin received your paper. Below you will find the receipt information regarding your submission.

Paper ID	383278848
Paper title	Thesis on TLS
Assignment title	Literature review - Part 1 (Moodle 21026733)
Author	Doras Sibanda
E-mail	placeholder@placeholder
Submission time	12-Dec-2013 08:56PM
Total words	59153

First 100 words of your submission

How teachers construct teaching- learning sequences in chemistry education in the Further Education and Training phase Byby Doras Sibanda Submitted in fulfillment of the academic requirements for the degree of Doctor of Philosophy of Education in the School of Education College of Humanities University of KwaZulu-Natal i December 2013 PREFACE The work described in this thesis was carried out in school in Kwazulu-Natal from December, 2009 to November, 2013 under the supervision of Prof Paul Hobden This study represents original work by the author and has not been otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of...

Thesis on TLS

ORIGINALITY REPORT

7%	6%	3%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

APPENDIX 6 DEPARMENT OF EDUCATION PERMISSION

kzn education

Department:
Education
KWAZULU-NATAL

MRS S DORAS
141 GOLF ROAD
EPWORTH PIETERMARITZBURG
3200

Enquiries: Sibusiso Alwar
Date: 07/01/2010
Reference: 0002/2010

RESEARCH PROPOSAL: HOW DO TEACHERS CONSTRUCT A TEACHING- LEARNING SEQUENCE (TLS) IN CHEMISTRY EDUCATION AT THE FET PHASE?

Your application to conduct the above-mentioned research in schools in the attached list has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educator programmes are not to be interrupted.
5. The investigation is to be conducted from 07 January 2010 to 07 January 2011.
6. Should you wish to extend the period of your survey at the school(s) please contact Mr Sibusiso Alwar at the contact numbers above.
7. A photocopy of this letter is submitted to the principal of the school where the intended research is to be conducted.
8. Your research will be limited to the schools submitted.
9. A brief summary of the content, findings and recommendations is provided to the Director: Resource Planning.

...dedicated to service and performance
beyond the call of duty.

KWAZULU-NATAL DEPARTMENT OF EDUCATION
POSTAL Private Bag X9137, Pietermaritzburg, 3200, KwaZulu-Natal, Republic of South Africa
PHYSICAL Office G25, 188 Pietermaritz Street, Metropolitan Building, PIETERMARITZBURG 3201
TEL Tel +27 33 341 8610,8611 | Fax +27 33 341 8612 | E-mail

kzn education

Department:
Education
KWAZULU-NATAL

10. The Department receives a copy of the completed report/dissertation/thesis addressed to:

The Director: Resource Planning
Private Bag X9137
Pietermaritzburg
3200

We wish you success in your research.

Kind regards

R. Cassius Lubisi (PhD)
Superintendent-General