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THE DEVELOPMENT OF PRESERVICE TEACHERS' TOPIC SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE USING SELECTED COMPONENTS OF THE CONSTRUCT

Thandiwe Lerato Sekhibane

A research report submitted to the faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfillment of the requirements for the degree of Masters of Science by combination of coursework and research.

Johannesburg, 2018

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Abstract

This study was concerned with assisting pre service teachers who were in the beginning stages of their Bachelor of Education (B. Ed) programme. This development was focused on content knowledge (CK) on the topic of chemical bonding making use of the Topic Specific Pedagogical Content Knowledge model which enables transformation of science CK using five components. These are learner prior knowledge, representations, curricular saliency, what makes the topic easy or difficult to teach and conceptual teaching strategies. The students referred were a sample of 30 early pre service teachers (EPT) registered in the second year Natural Sciences Methodology II course. CK and TSPCK development was fostered through the use of three components during a 6-week intervention. I adopted a Mixed Methods research design (MM) and gathered both qualitative (written tasks and semi structured interviews) and quantitative (CK and TSPCK tests) data. The results in the study show: (1) that there was general improvement in CK in pre and post-tests (2) that there was evidence of general improvement in TSPCK components used in the intervention; (3) that there was evidence of general improvement across the three components; (4) that there was interaction of TSPCK components observed, including those in those components that were not covered in the course; (5) that pre service teachers were observed to be using their knowledge of the topic of chemical bonding to draw on similarities and differences between the concepts imbedded in the topic of intervention, (6) that pre service teachers at their beginning stages of teacher training display, in planning, that they 'miss' the important aspects of teaching chemical bonding and (7) pre service teachers in their beginning stages of their teacher education programme developed explicit ways of thinking about their teacher knowledge. It was recommended that further research is needed regarding the nature and development of the interaction among preservice teachers' PCK components, and regarding how various contexts can stimulate the development and strengthen the interaction of these components. Furthermore, it has been suggested that more focus should be on the four aspects highlighted as the core problems in the learning of chemical bonding. The four problems were (1) EPT's showed no mention of the electrostatic nature of chemical bonding, (2) EPT's used macroscopic levels of representations to explain and describe bonding (3) EPT's in the study over emphasized the rule of the octet to explain chemical bonds (4) EPT's struggle with the idea of delocalized electrons in metals and since EPTs have shown that

they prefer the macroscopic representations, rather teacher educators focus on developing this preference to enhance their learning.

Key words

Topic specific pedagogical content knowledge, content knowledge, early pre service teachers, chemical bonding, transformation

Declaration

I declare that this dissertation is my own unaided work. It is being submitted for the degree of Masters in Science (Education) at the University of the Witwatersrand, Johannesburg

Thandiwe Sekhibane



February, 2018

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CHAPTER I: INTRODUCTION

1. Background and Context of the study

What knowledge must pre service teachers have as a determinant of their readiness to embark in classroom teaching? What knowledge must pre service teachers have to become qualified and competent science teachers? Is there a way of measuring the knowledge of teachers and so measuring how much knowledge a student teacher must have at varying stages of their teacher education programme? Perhaps the best response to these questions would be acknowledging that becoming a teacher is a complex process (Ruszynyak, 2008). Much of what the teacher learns and knows is embedded in their thoughts and what can be seen, heard and experienced are those aspects of what the teacher chooses to teach. That is, what the teacher teaches is not necessarily everything they know about the content they are teaching and so a teacher will, through experience, be able to select appropriate knowledge for a particular group of learners, and have thus have knowledge of what to emphasize and what to leave out for instance. The process of becoming a teacher requires a combination of skills, knowledge and experience. These skills and knowledge need to be learned and mastered by pre service teachers in order to create meaningful teaching and learning environments for learners (Mavhunga, 2012).

Pre service teachers do not have the same expertise as experienced teachers do but their knowledge bases for teaching may be developed before they assume their roles as full-time teachers. Shulman (2004) provides aspects about what considerations to take in the discourse about teaching. The key features of teaching are according to Shulman (2004), content knowledge being taught, the classroom context, physical and psychological characteristics of the pre service teachers. Of all these important features, it can be agreed that content knowledge understanding is the most critical in the process of teaching (Shulman, 2004).

During teacher training, one of the constituents of knowledge taught is the idea that that teaching requires the transformation of content knowledge (CK) to be taught. How pre service teachers adopt into such a practice remained unclear. The study focused on developing PCK in chemical bonding. PCK in a specified topic is defined as the knowledge that enables pedagogical transformation at a topic level (Mavhunga & Rollnick, 2013). It is regarded as a PCK construct localized at a topic level called Topic Specific Pedagogical Content Knowledge (TSPCK). The primary focus of the study was to investigate how the

exposure to an intervention impacted on the development in CK and TSPCK of pre-service teachers in their early years (second year) of study in the topic of chemical bonding. These pre-service teachers have been referred to as early pre-service teachers (EPT) in the study. The choice of chemical bonding as a topic of intervention was influenced by the understanding that it is perceived as an abstract and difficult topic to teach and yet critical in the understanding of Chemistry as a subject. Also, focus on the topic of chemical bonding is essential for the reason that researches on students' ideas of chemical bonding have revealed prevalent and consistent alternative conceptions across a range of ages and cultural settings (e. g. Boo, 1998; Taber, 1995; Taber, 2000) however, the conceptions that university students have about chemical bonding have been seen to be researched infrequently (Col & Taylor, 2001, p. 173).

1.1Problem statement

The University of the Witwatersrand School of Education attracts most of its student teacher cohort from previously disadvantaged schools in rural and township areas of the country. These preservice teachers have been noted to not being prepared sufficiently in science CK. This stems from the understanding that some teachers in the schools have limited content in the subject and therefore are unable to clearly transform this knowledge in a way that can be understood by learners Nezvalova (2011). The problems in these schools are escalated by the lack of proper science resources and facilities. These pre service teachers bring into teacher training images about teaching that have been construed from these experiences (Cross and Ndoferipi, 2013). When the same learners enrol into teacher education to 'learn to teach' they are distinguished from others in other teaching disciplines by this science subject that they teach. This then implies that they are expected to display a certain amount of proficiency in their CK in science. Due to the effects of undesirable science schooling backgrounds, the students have just come out of high school, and can be compared to those who are EPT, have challenges with understanding CK have been observed to be experiencing difficulty with learning, understanding and teaching these concepts (Boo, 1998; Coll & Taylor, 2001). The study adopts the TSPCK framework because little is known about the possible development of the construct with pre-service teachers in the earlier years of their study. The construct of TSPCK has been used previously to investigate development of pre service teachers in their final year of teacher training. The study therefore addresses the research questions introduced below.

1.2Research Questions

The study advocates for *explicit* means for pre-service teachers to begin to think and reason about their teaching drawing from the components of TSPCK. This act was perceived as one that would enable the process of measuring the quality of TSPCK in teachers to be less complex. With references to this notion, the study intended to answer the following main question:

What is the impact of an intervention that targeted the development of TSPCK in chemical bonding in EPT through the explicit instruction of three selected TSPCK components?

The underlying premise to the selection of these components has been that the topic-specific nature of PCK emerges from components that are exclusively based on content knowledge. According to Aydin *et al.* (2014) PCK is a complex construct in the sense that it comprises the interplay of the different knowledge and belief components. What remained unclear to them was the degree to which these components themselves were topic-specific. The study highlights the complexity of understanding these PCK components and more so, whether selecting a few them would yield required outcomes in terms of pre service teachers' development. I have used a selection of TSPCK components based on the understanding pre service teachers have disjointed PCK (Lee, Brown, Luft, & Roehrig, 2007) therefore using selected components to develop their PCK is supported (Park & Chen, 2012).

Therefore, the study asked the following sub-questions:

(i) What is the impact of the intervention on EPT's in chemical bonding content knowledge?

(ii) What is the impact of the intervention on the quality of EPT's TSPCK in planning for teaching chemical bonding?

1.3 Rationale

The B. Ed programme is a four-year degree which entails mastering different forms of knowledge (background knowledge, subject knowledge and theoretical knowledge), pedagogy (knowledge of the methods of teaching and learning, pedagogical content knowledge and pedagogical reasoning and action), an understanding of the educational context (socio-economic context, policy and policy environment) and reflexive practice as well as suitable attitudes and values (Cross & Ndoferipi, 2013, p. 11). The model that the

WSE science and technology utilizes expects pre service teachers in their first and second year to embark in general education with their major; Natural Sciences. The Natural Sciences course is aimed at introducing these junior students to basic introductory science concepts in Life Sciences, Physics and Chemistry. Only in their third year will these pre service teachers be permitted to select an area of speciality in one (or two) domains of this science.

Although pre service teachers would have been provided the necessary foundation in their first and second year, in a study by (Qhobela *et al.* , 2013) it was found that even pre service teachers in their fourth year of study that specialize in Physical Sciences (Physics and Chemistry) did not display the necessarily proficiencies in the subjects that they teach. There were two reasons attached to these claims 1) is related to the fact that pre service teachers may have not come into teacher education with the necessary knowledge in that helps them assimilate the concepts that are been taught to them appropriately. 2) Some pre service teachers come in to teacher education with a set curricular plan that they will in fact specialise in either Life Sciences or Physical Sciences due to their backgrounds in these subjects.

In their first two years, pre service teachers who have interest in pursuing either Physical Science or Biological Sciences (or both) as a major are required to take Natural Sciences as a major. Natural Sciences include four science domains: Life and living, Energy and Change, Matter and materials and Planet earth and beyond. Despite them preferring to specialize in either Life Science and/ Physical Sciences, they need to learn *basic* knowledge about all four Natural Sciences knowledge areas in the first two years of the programme. Although they are re-learning the content knowledge of these disciplines as prospective teachers, it is important that they start to be exposed to the teacher knowledge that helps teachers to transform their content knowledge (Nilsson, 1998). Other studies have captured this development for Chemistry (Mavhunga, 2012; Mavhunga & Rollnick, 2013) and in Physics (Qhobela *et al*, 2013) in pre service teachers who were in their final years of study but none of the studies based on the construct were done with EPT in Natural science.

It was recognized in this study that training these pre service teachers should entail providing skills and knowledge forms such as content knowledge and the pedagogical expertise to teach this content. This understanding draws our attention to the Shulman's notion of PCK. This knowledge makes a conjunction between content knowledge content and pedagogy, with the suggestion that this amalgam represents the understanding necessary for transforming content

knowledge into forms that are more accessible to students (Shulman, 1986; 1987). The complexity of this theoretical position comes with the understanding that for a teacher to be considered to have good PCK, they should first have a good understanding of their content knowledge and then develop the pedagogical proficiency in teaching this content. The study is concerned with pre service teachers' development of content and TSPCK in the topic of chemical bonding.

Chemistry is the science of matter and the changes it undergoes (Taber & Coll, 2002). Chemical bonding is a topic in Chemistry that is abstract and most difficult to teach and learn. This topic embeds the most central concepts that define the nature of chemistry as a subject. It also attempts to explain chemical phenomena of everyday life. Because of this difficulty, it may be assumed that the development of pre service teachers' knowledge in the topic may be limited to what they know and understand, as well as what they perceive as manageable to comprehend and fully articulate for instruction. Using TSPCK may enhance the learning and understanding of chemical bonding and may to an extent, improve the practice associated with teaching such a topic.

1.4 Theoretical Framework

The view of how CK may be deconstructed, reconstructed, sequenced and represented in a manner that will make it accessible to the mind of the learner. The study advocates for knowledge transformation that is topic specific. TSPCK is the ability of the teacher to reason about a topic using the five components, providing a justification this is a framework of thinking about transformation of CK at topic level. The five components are learners' prior knowledge about a topic and includes (alternative conceptions about the topic and learning difficulties); representations refers to metaphors, analogies and models to help learners understand the topic; curricular saliency sequencing of concepts and highlighting big ideas within a topic; what makes the topic easy or difficult to understand relates to learning difficulties and challenges associated with the topic and conceptual teaching strategies which are teaching strategies relating to how to teach these concepts.

1.5Outline of the dissertation

This dissertation comprises of five chapters. The structure, content and organization of the chapters are given below:

Chapter I

This chapter introduces the study through a discussion of the research problem. The chapter outlines the research questions in light of the problem identified. It is in this chapter where I have provided in depth detail about the nature of the research and I have outlined the intentions of the study.

Chapter 2

In chapter 2, I have divided the chapter into three sections. In the introductory section, I have reviewed literature based on PCK as one of the knowledge bases for teaching. There after I reviewed PCK literature specifically in regard to training pre-service teachers in teacher education programmes. It is in this section that I discuss the possibility of developing, capturing and measuring pre service teachers' PCK. This discussion is followed by literature on the topic specific nature of PCK. At this point the TSPCK conceptual framework is discussed as one of the possible routes in developing pre service teachers' competence in teaching science topics. As the study is centred on the topic specificity of PCK, a discussion on learning difficulties in the selected topic (chemical bonding) is provided.

Chapter 3

This chapter provides an overview of the research design. The chapter outlines the following: the research design and justification of the design drawing on the purpose and rationale for the study; a detailed discussion of the instruments used in the study; the selection of study site; the participants; the treatment in a form of intervention; the data collection process; the analysis; issues of validity and trustworthiness; ethics and the limitations of the study.

Chapter 4

Chapter four provides findings from captured data according to the research questions.

Chapter 5

In chapter five, I discuss findings from the data and discuss them in terms of what the literature articulates about the issue of concern. I strengthen the discussion though highlighting what is confirmed or contradicted regarding the issue of investigation. This final chapter provides possible answers to research questions and provides a detailed view on their

implications for science education, teaching and teacher education and a discussion of these leads to an understanding of the implications of this study for future research.

Conclusion of chapter

This chapter has served as the introduction of the study and has provided the research problem, the background and context of this problem and research questions that guide the study. The following chapter will provide insights from literature on similar problem being investigated. The next chapter will also provide the theoretical basis on which the problem under study can be located.

CHAPTER 2: REVIEW OF LITERATURE

2. Introduction

In this chapter, I review literature that pertains to the use of PCK in Science Education by pointing out to the various studies that have adopted the construct in developing science teachers' expertise. Although other PCK models exist following the original postulation by Shulman (1986, 1987), I pay attention to the topic specific PCK model that has been developed to aid the transformation of CK using the five components of the construct. Of concern is how using a selection of components of this construct can be adopted in developing the teaching competence in pre service teachers in their early stages of their teacher training degree. The literature reviewed considers models of PCK, the importance of developed PCK in pre service teachers, how a selection of components may be used in developing the teaching expertise of pre service teachers, and how developing pre service teachers in chemical bonding may foster development of their CK and TSPCK in the topic. This is based on EPT, and here I provide details about their experienced difficulties in CK and some of the common issues related to their transition between high school and University. I allude to the theories responding to TSPCK development in pre service teachers and hence locate this study to a theoretical framework. I close the chapter by providing a section on the discussion of the topic of choice. In this section, I discuss of some of the teaching and learning difficulties associated with learning chemical bonding

2.1What is known about PCK?

Shulman (1987) described PCK as the knowledge that contains ''the special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding'' (p. 8). This knowledge base has been used over the years to investigate teachers' knowledge by many researchers. This combination of PK and CK identifies distinct bodies of knowledge for teaching (p. 10). According Shulman, CK refers to the amount and organization of knowledge per se in the mind of the teacher, hence, PCK is defined as that special knowledge that distinguishes teachers against content specialists (Aydin *et al*., 2015) and is that type of knowledge that helps better understand teachers' knowledge of teaching. Shulman (1986, 1987), regards PCK is "an understanding of how particular topics, problems, or issues are organized, presented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8). Thus,

the key aspect of PCK is this transformation of CK in a manner that can be both understood and accepted by learners.

What has been known in science education research is that PCK is tacit. It is developed over long periods of time through experience and expertise. This is the case in the situation where a teacher is faced with learners not understanding a particular concept and they resort to trial and error to test what works that given situation. Their teaching expertise and competence is developed based on what has worked before. Evidence of developed PCK in teachers is thus a resultant of this practice and therefore, is seen in the teaching of ideas in a more organised, accurate and in a language associated with the discipline (Mavhunga, 2012; Shulman, 1986) based on previous experience.

In recent studies, focus has been placed on capturing and portraying PCK. One of the prominent developments has been the use of Content Representation (CoRe) that provides an overview of the content taught when teaching a particular topic and Pedagogical and Professional-experience Repertoires, (PaP-eRs) that capture teaching practice. This method of capturing PCK has been observed as the most useful method for eliciting PCK that is centred in a teacher's knowledge and pedagogical skills (Kind, 2009). One of the key elements of attempting to measure PCK is that the tools used to capture the construct have been centred on important aspects of teaching and learning such CK, knowledge about learners' prior knowledge and experiences including misconceptions, teaching strategies and methods of ensuring learners understanding of the content.

Numerous studies have reported that strong CK fosters the development of PCK and so PCK is regarded as a tool or vehicle for teachers to deliver the CK in their mind to pupils in a comprehensive manner (Ding & He, 2014, p. 53). Studies such as these have reported on the necessity for teachers to possess strong CK for effective science teaching. When teachers do not sufficient CK they become unaware of learners' prior conceptions and misconceptions, (Taber & Tan, 2011).

2.2 PCK and Pre service teachers

Researchers have introduced ways of developing PCK in pre service teachers for example, researchers who have used practical exposure like (Betram and Loughran, 2010); those that have used the CoRes and PaPers (Nilsson and Loughran, 2011) and also those that have made contributions to developing pre service teachers' PCK through reflective practice (Nilsson,

2008). One approach of interest to this study is what was postulated by Mavhunga (2012) (see theoretical framework below) which has been adopted in other studies. In her approach to training pre service teachers, she used an explicit intervention on the transformation of knowledge. The strength of the model by Mavhunga (2012) is favourable in training pre service teachers who are coming from undesirable science knowledge backgrounds. This model of PCK demonstrates a topic by topic approach that allows pre service teachers to be able to learn their CK while at the same time learning how to teach topics by transformation. The ability to teach is tied to the capability to transform knowledge for teaching. This is in harmony with the original postulation in Shulman (1987). He too saw the benefit for teachers with PCK as their capacity to transform knowledge. In his description of transformation, he states that "the capacity of a teacher to transform the CK he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the learners." This competence can be advocated for in the pre service programmes to explicitly develop the view that teaching is about purposeful transformation of teacher knowledge for the benefit of learners (Geddis *et al.*, 1993).

In pre service programmes across the globe, the fundamental roles of such training to ensure those pre service teachers' pedagogical competencies which are needed to embark in the real life of teaching (Shulman, 2005). While it has been argued that PCK development is a result of trial and error teaching over long periods of time in practice, this study is concerned on whether it is feasible to FastTrack the development of PCK in science pre service teachers.

It has been noted in existing literature that pre service teachers enter pre service programmes with limited PCK and therefore also exhibit similar misconceptions as own learners. From this observation, Nilsson and Loughran (2012) noted that the situation could change if pre-service teachers were offered meaningful ways of defining, identifying, assessing and explicitly developing PCK. If pre service teachers are to be good teachers, they should be competent in their CK of their discipline.

Competence in PCK is seen to rely on competence in CK and therefore in order to develop a pre service teachers' PCK, it would be necessary that the student teacher be exposed to a learning sphere that provokes the learning of CK. Although Feiman-Neiser (2001) argues that the teacher training programme is not enough to produce teachers with desired qualities of teaching, exposing pre service teachers to programmes that explicitly teach them what to teach and how to teach it, may develop pre service teachers' content and relevant strategies

for instruction (Qhobela *et al.,* 2013). Although the development of a teacher is a lifelong process, I do acknowledge that the development of the pre service teacher is a lifelong learning process; however, teacher education programmes have the capacity to produce teachers that are knowledgeable in their CK and can be experts in transforming this knowledge in practice (Sekhibane, 2015). Consequently, PCK becomes a way in which we can measure developing teachers' competence (Abell, 2008). When the pre service teacher has developed PCK, evidence will be seen in the teaching of ideas in a more organized, accurate and in a language associated with the discipline (Mavhunga, 2012; Shulman, 1986). This entails the use of appropriate sequencing; relevant teaching strategies which include appropriate examples and relevant use of representations and analogies (Mavhunga 2012; Shulman, 1986). It is therefore imperative that we value PCK as a means to improve effective teaching (Rollnick, *et al.,* 2008).

Although pre service teachers cannot be compared with expert teachers in their thinking and reasoning about their teaching, transferring PCK reasoning to pre service teachers who are learning to teach, enables them to begin thinking about their CK against the ability of their teaching needs. Studying pre service teachers' ability to transfer knowledge into practice benefits both pre service teachers and teacher educators because it helps them reflect on "how science itself is done" (Nezvalova, 2011, p. 105). This in turn will enable pre service teachers to locate new ways of understanding science, particularly in the understanding of how science ideas relate to one another and how this science relates to other subjects. Kind (2009) also noted, that encouraging pre service teachers to understand PCK as knowledge they themselves are learning may assist them in their journey as developing science teachers as they will be more aware of their own learning. The benefits associated with PCK include enabled planning and enactment in ways that increase effective teaching.

2.3CK and PCK

CK, according to Shulman (1986), has three unique categories which are content knowledge (CK), pedagogical knowledge (PK) and curriculum knowledge (CuK). In his description of CK, he refers to 'going beyond knowledge of the facts or concepts of a domain'. For this discussion, I refer to CK as CK only and define it as knowledge and understanding of the central concepts, factual information and organizing principles that make up a discipline, an understanding of the big ideas (Grossman, Wilson, & Shulman, 1989). This body of knowledge and understanding was seen as the key in explaining science concepts more

clearly and resorting less to simplistic dialogue (Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008) leading to a more competent teacher with a strong professional knowledge base. Teachers' professional knowledge has been regarded as one important indicator of a teacher's competency and so, CK and PCK (dimensions of teacher professional knowledge) relate in ways that provoke great concern in professional teachers on how CK can be transformed to students in an appropriate and effective manner.

2.4What is known about the topic of choice

Studying pre service teachers' development of TSPCK relies on the topic of choice. The understanding is that pre service teachers ought to be competent in topics in a science domain such as (Physics, Life Science or Chemistry for instance) and that would ultimately result in their strength in PCK in that specific domain (Mavhunga, 2012; 2013). One such topic which is used in this study to foster pre service teachers' development of TSPCK is chemical bonding. Chemical structure and bonding is a topic in which understanding is developed through diverse models, which, in turn, are built upon a range of physical principles; students are expected to interpret a disparate range of symbolic representations standing for chemical bonds (Taber & Coll, 2002). Chemical bonding refers to a force that holds atoms together in a molecule or formula unit Silberberg (2015). This topic is one of the most complex topics to teach in chemistry. Like most topics in the domain, its difficulty is associated with it abstract nature, however, unlike other concepts in this domain, it serves as a basic chemical idea in understanding some other fundamental concepts such as the formation of compounds. This is especially problematic because the "overwhelming majority of elements occur in compounds combined with other elements (p. 61)". In addition, the concept of bonding is fundamental to molecular structure which provides details about the physical and chemical properties of a compound.

Because learners in high schools (and ETPs) have not developed a way of operating in the sub microscopic level, they experience difficulty in using abstract ideas to explain phenomena. For an example, pre service teachers can fail to describe the nature of the type of bonding between particles used to chemical and physical characteristics of the substances. Simply put, learners' basic schema cannot readily accept philosophies about particle ideas because their theories, knowledge and understanding of matter is based on what they can see, feel, touch. Chemical ideas, which are usually mental models used in chemical bonds are not consistent with learners' everyday experiences with matter. "[Learners] live and operate in

the macroscopic world of matter" (Nahum, *et al.*, 2004, p. 302). Therefore, these everyday experiences are what learners bring to the chemistry classroom, and they bring with them "ideas expectations and beliefs concerning natural phenomena which they have developed to make sense of their own past experiences" (Col & Taylor 2001, p. 172). While a greater part of their prior knowledge and experiences is based on the macroscopic level of representing phenomena, school learning introduces them to micro and sub microscopic ideas to similar contexts. In such situations, learners have been observed to battle with this new way of thinking as a result, have been reported to not finding it easy to follow shifts between the macroscopic and microscopic levels (Nahum *et al.*, 2004).

2.5Teaching and Learning aspects of chemical bonding

On the topic of chemical bonding, the learning difficulties of this topic can be contextualised. First and foremost, students do not grasp the underlying ideas about chemical bonding (Boo, 1998). The fundamental concept of chemical bonding is that it refers to electrostatic charge between particles (Silberberg, 2015) since after all, "electrostatic forces are the only important forces in chemistry" (p. 862). When teaching chemical bonding, emphasis is not always given to the underlying electrostatic nature of chemical bonding. The lack of understanding of this idea leads to consistent learning difficulties because students would not recognise when a chemical bond has occurred. According to Barker (1999) students experience difficulty in recognising when a chemical reaction occurs and notes that many students do not discriminate consistently between a chemical bonding and a change of state, which chemists call a physical change.

Most times the teaching of bonding is much aligned to identifying types of bonds as covalent, metallic or ionic. However, in most teachers tend to focus on these ideas as distinct entities so much that the intermediate state between covalent and ionic bonding is overlooked. According to Taber and Coll (2002), most materials have bonding that cannot be considered as "purely" covalent or ionic (or metallic). In most materials, the bonding may be more precisely described as intermediate, with varying degrees of covalent and ionic (and metallic) character. The notion of bond polarity indicates that the covalent-ionic dimension should be seen as a continuum, and not as a dichotomy. However, this being scientifically appropriate, students experience difficulty understanding what the differences are between the three different types of bonds. The learning difficulties for the individual types of bonding are discussed below.

2.5.1 Covalent bonding

Chemical bonds form in order to produce filled shells rather than filled shells being the consequence of the formation of many covalent bonds (Robinson, 1998). A covalent bond holds atoms together because the bond is sharing electrons (Robinson, 1998). Tan & Treagust, (1999) found that students in their sample were confused about the differences between covalent and ionic bonding. One of the prevailing misconceptions was that students thought that bonds are only formed between atoms that donate or accept electrons (Taber, 1994).

2.5.2 Chemical Bonding in metals

According to Taber (1995) students have poor understanding of bonding that takes place in metals. They view metallic bonding as "inferior to other forms of bonding". This finding may be linked to a reported finding by Robinson (1998), that students think that there are only two kinds of bonds: covalent bonds and ionic bonds. Anything else is just a force, "not a proper bond". The study also highlighted another area of student difficulty in relation to understanding bonding, that is, the concept of delocalisation of electrons and the electrical conductivity of graphite Tan & Treagust (1999). The students in the study seemed to experience difficulty in understanding the chemistry behind these situations.

2.5.3 Ionic bonding

According to Robinson (1998), students have a misconception that ionic bonds are the transfer of electrons, rather than the attractions of the ions that result from the transfer of electrons. Students also were observed to think that the reason electrons are transferred is to achieve a full shell. In a study by Butts and Smith (1987), most grade 12 chemistry students associated sodium chloride with ionic bonding and the transfer of electrons from sodium to chloride, but many did not understand the three dimensional nature of ionic bonding in solid sodium chloride. Peterson, Treagust and Garnett, (1989) found that students believed ionic substances such as sodium chloride possessed covalent bonds. This is consistent with the findings by Butts and Smith (1987) who reported that students were confused about covalent and ionic bonds. Some of the students they studied conceptualized the sodium and chlorine atoms as being held together by covalent bonds. In similar studies, it was found that a high percentage of the students believed that sodium chloride exists as molecules, and less percentage of students thought that one sodium ion and one chloride ion form an 'ion pair

molecule' (Taber, 1994; Tan & Treagust 1999). Taber (1997) has also investigated students' misconceptions dealing with ionic bonding. In the study, a small-scale survey was used to investigate how wide spread the misconceptions of the ionic bond were and he established that students had difficulty understanding ionic bonding. He stated that many chemistry students' understanding of ionic bonding: (i) overemphasizes the process of electron transfer, (ii) explicitly uses the notion of ion-pairs as molecules, (iii) is constrained by an appropriate consideration of valence, (iv) pays heed to an irrelevant electron history, (v) distinguishes between what are actually equivalent interactions between ions. Other studies show that students think that the atomic electronic configuration determines the number of ionic bonds formed (Taber, 1994). In the same study, it was observed that students thought that ions interact with the counter-ions around them, but for those not ionically bonded these interactions are just forces. The underlying idea of bonding is acknowledged, but the understanding of the chemical is vague.

2.5.4 The rule of the octet

In addition to finding that students had difficulties understanding bond polarity, shape of molecules, polarity of molecules, intermolecular forces, Peterson, (1986); Peterson and Treagust, (1989); Peterson *et al.*, (1989); and Goh et al., (1993) found that students also experienced problems with the octet rule. According to Tan & Treagust (1999) some students have the idea that when atoms of metals and non-metals combine, they form covalent bonds. They see that by sharing electrons, the non-metals complete their octet of outermost shell electrons, but they neglect the outermost shell of metal atoms. An identified misconception that stems from the octet is that atoms need filled shells as in group eight elements (Robinson, 1998); for instance, NaCl and other ions are stable because they have a filled outer shell. In some studies, it was showed that some students did not understand that every substance needs chemical bonds to maintain its structure that is either microscopic or macroscopic. In terms of polar and non-polar bonds, electronegativity was deemed to comprise attraction for a single electron rather than a greater attraction for the shared pair of electrons. This view was influenced by the octet rule, for students mentioned that fluorine is the most electronegative element because it has only one space left to fill to attain a stable filled valence orbital, and that iodine molecules (I_2) contain 1 minus ions because iodine element belongs to the halogen group (Coll & Taylor, 2001). There are significant problems associated with teaching the octet rule reported in literature. When teaching the topic of chemical bonding, too much emphasis is given to the octet rule as a principle of understanding chemical bonding (Coll &

Taber, 2001; Taber, 1995, 2000, 2003). First, the octet rule doesn't explain why bonding pairs of electrons don't repel each other despite the same charge and how moving electron can stay between two nuclei of atoms. Consequently, students cannot understand covalent bonding correctly, so just think that atoms share their valence electron to get an octet.

Second, the term 'sharing' often seems intended to reflect its social meaning and so imply 'equally. ' Students conceptualizing the bond in this way have difficulty making sense of polar bonds (Taber, 2003). Boo (1998) also reports that there were those who conceived of a covalent bond as the result of the sharing of 'one electron' between two atoms; i. e., one of the atoms donates an electron, which is then shared between the two atoms which are said to be held by the covalent bond. He explains that this appears to be extrapolated from the everyday meaning of sharing, such as the sharing of an apple between two friends. As such, there remain great differences between what is taught by science and what is learned by students (De Posada, 1997). Gilbert (1998) suggests that many of the ideas used to understand chemical bonds are not accessible at an introductory level. Instead, curricula models need to be used in order to simplify the topic. For an example, teachers choose to use ball and stick models to represent chemical bonds without making it explicit to learners the similarities, limitations and differences of these to actual bonding on the sub microscopic level avoiding the students thinking that the sticks represent the individual bonds. Students then develop their own "tool kit" of bonding concepts as part of their progression in learning about the subject (Taber, 1995a).

2.6 PCK defined from topic specific

One of the findings mentioned in the discussion made in 4. 1 about the value of PCK in science education is the realization that it is topic specific. There is more value in thinking about PCK in the context of a topic. While researchers agree about this, there has been no clear definition of what PCK in a topic looks like. One attempt is that postulated by Mavhunga (2012) who linked PCK in a topic to the idea of transformation of the content knowledge in a topic and she called her construct Topic Specific PCK. Details of this idea are discussed in the theoretical framework below:

2.7Theoretical Framework

Although the notion of PCK has been accepted, in this study, as necessary for the understanding of content may be transformed for teaching, Mavhunga (2012) critics this notion on the bases of its failure to make CK for teaching CK a component that could stand alone within the domains of teacher knowledge bases. She states that Shulman (1897) did not include this domain in the knowledge bases, and so did not define it as PCK but rather as knowledge reflecting knowledge linked to CK with respect to its teachability and so creating gap on what components may be classified as CK. This gap in Shulman's notion of PCK leads to an important dimension postulated by Mavhunga (2012). She adopted to this view of transforming CK for teaching providing, a justification that this framework of thinking about transformation highlights how CK may be deconstructed, reconstructed, sequenced and represented in a manner that will make it accessible to the mind of the learner. She further states that the process of deconstruction and reconstruction is necessary for each topic of the CK leading to the view of Topic Specific Knowledge for teaching. Mavhunga (2012) alluded to the view that sound understanding of CK is not enough for learners' understanding, nor is it enough for the development of PCK in pre service teachers. The importance of CK is, however acknowledged in the overall development of PCK (Kind, 2009a). With this understanding, Mavhunga (2012) identifies the knowledge components that enable transformation of knowledge suitable for teaching in a given topic. This idea refers to the capability needed to transform teachers' own comprehension of a given topic into formats that are suitable for teaching.

2.8The nature of TSPCK

According to the definition provided by Mavhunga & Rollnick (2014), TSPCK is the ability of the teacher to reason about a topic using the five components. This postulation guides and informs a more constructive and *explicit* means of transforming content for teaching. When we apply this theoretical construct to a topic, instruction tends to be specific to the topic which will then qualify it being different to other topics within the discipline (Rollnick & Mavhunga, 2014). Because PCK is viewed as teacher knowledge used in both reasoning and planning to teach particular topics, placing an emphasis on the topic specific nature of PCK is not farfetched. This knowledge is used to enhance student understanding in a particular topic such as Chemical Bonding. In transforming this topic for teaching, the uses of other forms of

knowledge which link closely to the postulation by Shulman (1986) are essential. The following components help describe PCK for a particular topic; learners' prior knowledge about a topic and includes (alternative conceptions about the topic and learning difficulties); representations refers to metaphors, analogies and models to help learners understand the topic; curricular saliency sequencing of concepts and highlighting big ideas within a topic; what makes the topic easy or difficult to understand relates to learning difficulties and challenges associated with the topic and conceptual teaching strategies which are teaching strategies relating to how to teach these concepts. These are not mere strategies for instruction but are strategies that may be used to enhance the conceptualization of the concepts taught to the learner. This is shown in figure A below:

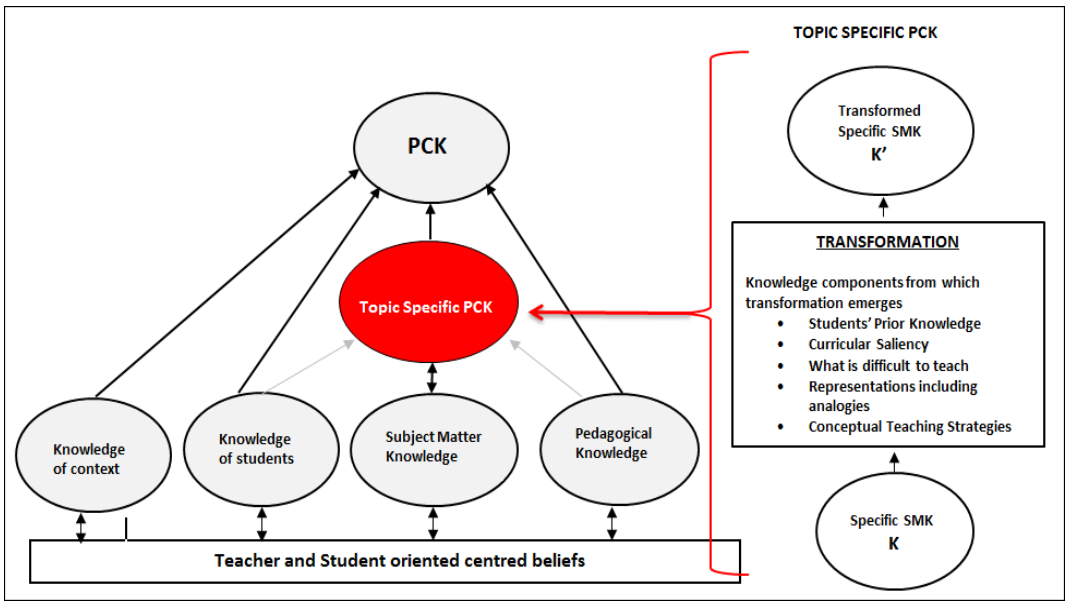


Figure A Topic Specific PCK model showing the 5 components of transforming CK.

The components of TSPCK within this model are based on the idea of the transformation of teachers' understanding of CK, into forms that are accessible to learners. Formal training programme may develop pre service teachers' PCK prior to practice (Mavhunga, 2014). Teaching CK is key in the understanding of learning how to teach, however it is understood that developing PCK can in essence stimulate the improvement of CK.

2.9 Benefits of developed TSPCK

There are a number of significant benefits of developed TSPCK in pre service teachers that have been reported in similar studies (Mavhunga, 2012). For instance, this postulation of PCK defined from topic specificity was based on the possibility of fast-tracking the development of PCK in pre service teachers before they embark on full time teaching. In the studies quoted, the role of experience was acknowledged as the key component of developing PCK in teachers, the TSPCK model lends itself an opportunity to fast-track their development of pre service teachers' PCK in planning before qualifying. This development has also been reported to be measurable. In previous studies on TSPCK (Mavhunga & Rollnick, 2011; Mavhunga, 2012; Mavhunga, 2014), the model has been proven to be construct that can be measured, advancing the idea that PCK is tacit. Quality could be improved in science pre service teachers from a perspective of thinking and planning (Mavhunga & Rollnick, 2013). Because pre service teachers are exposed to an intervention based on the topic of choice, pre service teachers' have been seen to develop explicit ways of thinking about their teacher knowledge. Developed TSPCK also enhances pre service teachers' ability to transform knowledge.

Mavhunga (2012) argues that the notion of considering PCK at a topic based level provides tools for knowledge transformation since TSPCK is explicitly linked to CK. The TSPCK construct enables this transformation within a particular topic using five components. In her study with fourth year pre service teachers, Mavhunga (2012) made use of all five components to develop TSPCK in the topic of Chemical Equilibrium. The pre service teachers under study were found to be able to transfer what they have learnt to other topics (Rollnick and Mavhunga, 2013). What pre-service teachers learn is a pedagogical competence to transform content knowledge, which they in-turn need to apply to develop TSPCK in the topic. Using TSPCK provides an interface where pre service teachers may be assisted in mastering core topics for teaching and therefore be able to transfer this knowledge in the teaching of other topics within their science domain or in their teaching in general. It is also understood that developing TSPCK can stimulate the improvement of content knowledge (Mavhunga, 2014) which then enhances the confidence of the student teacher in practice (Sekhibane, 2015; Rollnick *et al.*, 2008). In most previous studies, exposure to a TSPCK intervention in a given topic has resulted in pre service teachers developing the competence to teach at a topic level and therefore considering aspects of the topic to

transform unique knowledge that is linked to the topic. This is as opposed to the use of generic ways of thinking about the subject discipline. The value of PCK in teacher preparation programmes is said to lie in its usefulness in understanding teachers' knowledge (Abell, 2007).

2.10 The use of selected TSPCK components

In this study, focus is on using this approach for the development of TSPCK in Chemical Bonding but with selected components. Although there are different models of PCK in literature, the use of selected components is not a foreign idea. This idea is consistent with some studies investigating PCK where a limited number of components used were seen to be useful (Aydin *et al*., 2015). A study by Qhobela *et al.* (2013) that was carried out based on the same construct also found the use of few components useful. For this study, three components were considered: *learners' prior knowledge, representations and conceptual teaching strategies*.

The underlying premise to the selection of these components has been that the topic specific nature of PCK emerges from components that are exclusively based on content knowledge. PCK is a complex construct in the sense that it comprises the interplay of the different knowledge and belief components. I have used a selection of TSPCK components based on the understanding pre service teachers have disjointed PCK (Lee, Brown, Luft, & Roehrig, 2007) therefore using selected components to develop their PCK is supported (Park & Chen, 2012).

Conclusion of chapter

The TSPCK framework has been shown to be a possible way of capturing and measuring pre service teachers' PCK. This is done through focusing on a topic at a time and developing the CK and PK competencies to teach such a topic. The chapter has presented TSPCK as a conceptual framework for thinking about fast-tracking pre service teachers' process of 'learning to teach' and developing their PCK before actual full time classroom practice. It has been advocated that the use of selected components of the construct may foster development of pre service teachers' TSPCK and may still produce desired results. From the literature based on the teaching and learning of Chemical bonding, three key problems are highlighted as a basis for understanding the topic of chemical bonding; (1) Students fail to comprehend the sub microscopic level of representations and fully appreciate the macroscopic nature of

matter (2) In the teaching of chemical bonding emphasis is not always given to the underlying electrostatic nature of chemical bonding and (3) That when teaching the topic, too much emphasis is given to the octet rule as a principle of chemical bonding. The next chapter is the methodology of chapter. This is where the research journey is both conceptualized and theorized.

CHAPTER 3: METHODOLOGY

3. Introduction

In this chapter, I begin by discussing the overview of the research process. I provide the research design and justify the selection of such a design. I draw on the theoretical framework of this study and the research questions and justify how both relate to the research design. I further describe the components of the research design in the following order; the methods used in the study and the rationale for using such methods, the instruments used in the study, the selection of study site and participants, the intervention, the data collection process, the analysis, issues of validity and trustworthiness as well as ethics and limitations of the study. The goal of the overall process was to produce credible results on how EPT's TSPCK may be developed in their beginning stages of their teacher education programme. The following questions guided the inquiry:

(i) What is the impact of the intervention of the EPT's chemical bonding content knowledge?

(ii) What is the impact of the intervention on the quality of the TSPCK in planning for teaching chemical bonding?

3. Research Design

This study employed a mixed method approach (MM). The philosophical orientation associated with MM is the pragmatist paradigm. This means that it employs both qualitative quantitative approaches to answering research questions (Punch, 2005). This from of design gives rise to the methodological pragmatism in addressing the research questions. MM research combines both qualitative and quantitative data which therefore provides both subjective and objective forms of analysis. Studying EPT's development of TSPCK in the topic of chemical bonding required that both these approaches be utilized in the design. Thus, my selection of the MM approach was influenced by the following reasons: that integration of the two methods involved would give a better understanding of the research problem and complex phenomena than individual approach does alone, more so in a situation where the aim of the study is to capture the development of EPT's TSPCK in the topic of chemical bonding. This therefore implied that the selection of both research approaches was in support of the investigation of an issue from a holistic point of view, thus allowing the analysis to have access multiple perspectives of the development of a complex TSPCK construct in the

analysis of the same set of data. Overall, the MM approach was necessary to uncover information and perspective, increase corroboration of the data and render less bias and more accurate conclusions. The strength of making use of MM for this study was to enable the process of measuring the strength and quality of TSPCK for an individual student teacher primarily due to the tacit nature of this construct.

3.2 Research Strategy: Case Study

A case study provides a unique example of real people in real situations, what Stake (1995) refers to as 'the study of an instance in action'. This served as a basis for the selection of the strategy because capturing EPT's TSPCK required that they were studied in an authentic context that allowed for such a construct to be measured. Case studies recognize the multiplicity of variables operating in the same case, hence requiring more than one tool for data collection and multiple sources of evidence (Cohen, Manion, Morrison, 2011). From the previous discussion on research strategy, it follows that case studies can combine both numerical and qualitative data and therefore explains, illustrate and describe phenomenon (Yin, 1994). According to Merriam (2002, p. 8) a case study is "an intensive description and analysis of a social unit". The 'social unit' in this study is a class of second year EPT's. These are EPT's in their second year of study towards a teacher qualification known as the Bachelor of Education degree (B. Ed), with Natural Sciences as their major subject. Natural Sciences is a subject that is taken by EPT's in their first two years of training in preparation for a full major in Physics and Chemistry and/ Life Sciences. This course is made of sections of Physical, Life and Earth Sciences. Students that are admitted in the course are largely Science majors however; high school background in this subject is not a pre requisite, necessarily. In the B Ed programme, Natural Science is taught as a course in the first two years of the degree, after which EPT's are allowed to select their majors in two main streams, namely, Physical Science (a combination of Chemistry and Physics) and Life Sciences. These majors would be school subjects they qualify to teach at High School level on completion of the requirements for the degree. It has been observed over the years that EPT's in the early stages of teacher development generally have no TSPCK. This is primarily due to poor (or absence in) CK.

3.3 Sample

Following from the previous section of this chapter on the description of research strategy as a case study, the study was located in a curriculum methodology course of a class of 140 second year EPT's. These are EPT's were in their second year of study towards a teacher qualification B.Ed. degree. The EPT's were chosen because as beginner pre service teachers, they are assumed to be in the very early stages of their development as future teachers, hence it can be concluded that they have no TSPCK and poor CK. This is particularly problematic because one of the key features of a teacher education programme is to ensure that EPT's are developed such that, they have sound understanding and perception about teaching as a career. Although these EPT's are in the foundation phase of their training, they are still expected to go on teaching practice and teach, and so second year EPT's complete their teaching practice component in high schools for the first time (in their first year of training they are all in primary schools and mainly participate in micro teaching). In these teaching practice sessions they are expected to teach foundational topics of chemistry such as chemical change. Hence this study focus on the improvement of CK is based on developing the EPT's level of their CK and how to transform into teaching. It is assumed that teaching them the CK aspect in chemical bonding in the methodology course will improve both their CK and TSPCK in this topic and allow them to be able to teach this topic with *reasonable expected* competence for their level of study.

The teaching methodology class is essentially concerned with the teaching methodologies of science content, and therefore most suitable for the explicit discussions on transformation of CK in chemistry topics. Large proportions of these B.Ed. EPT's are from previously disadvantaged communities, and have come from a background of various curriculum changes in their twelve-year apprenticeship as learners. The B.Ed. programme with special reference to the Natural Sciences Methodology course exclusively, is specially designed to accommodate this profile of students. Although the whole class was exposed to the intervention, the sample size of N=30 was considered for the present study. The thirty EPT's were based on the criteria that they were the best performing students in the whole class of 140. From the 30 EPT's, 5 were selected for individual interviews.

3.4 Treatment

The treatment consisted of an intervention where the idea of transformation of CK was introduced to the EPT's. The intervention took place in the first semester of the academic calendar in the NS II methodology classes. The intervention was strategically placed in time prior teaching practice in secondary schools. In the methodology classes, the intervention was run on a weekly basis for 6 weeks, 3 sessions per week. The sessions were organized into 18 sessions of 50 minute each, 2.5 hours per week. In each week, the sessions ran on a Tuesday afternoon for three sessions where one third of the session was dedicated for lectures and the other two thirds, for tutorial periods. The lecture period was largely a single period which was used to introduce a single component of TSPCK. The double period was used to illustrate how the component could be used in the topic of chemical bonding. Naturally, while the focus was on the demonstration of one component of TSPCK at a time, the spontaneous emergence of other components in the explanations was pointed out. In such moments, an accompanying comment was made whether the emerging component(s) were yet to be discussed in full (in upcoming sessions) or a reminder of its discussion in the previous sessions.

Typically, sessions that introduced a particular TSPCK component would have a blend of teacher and learner centered discussions. For example, in the sessions introducing misconceptions, the EPT's were divided into groups of 4 members each. Each group was provided an activity that asked them to identify various learners' misconceptions in chemical bonding. The group discussions typically lasted for 20 minutes. The class would have a discussion based on the responses that were provided from the individual group discussions. The lecturer's role in the process was to facilitate and consolidate the EPT's ideas. The contribution of the lecturer in the consolidation was a crucial part of the treatment. This was due to the fact the details provided would be focused on how consideration of the discussed TSPCK component had influenced explanations of a concept in question.

The CK concepts used across the explicit discussion of the respective components of TSPCK were: atoms, elements, molecules, compounds, chemical bonds, types of chemical bonds, and balancing of chemical equations. It was however, noted that the listed concepts were sometimes repeated when introducing and discussing the next TSPCK component. Such moments, in my view, showed different aspects of the concept could be discussed for the benefit of the EPT's. The table below presents the sequence in which the components were

introduced and the CK components discussed under each. The table below presents the sequence in which the components were introduced and the CK components discussed

Table 3.1 Components and CK aspects discussed

WEEK NO.	NO. OF PERIODS	EQUIVALENT HOURS	TREATMENT
1	3	2.5	Introduction: Administer diagnostic test
1	3	2.5	Chemistry aspects of CAPS
2	3	2.5	Introduction to concept maps
2	3	2.5	Concept maps: Using Chemical Bonding
3	3	2.5	Introduction to representations
3	3	2.5	Using representations in Chemical Bonding
4	3	2.5	Content consolidation: valence electrons
4	3	2.5	Concepts, concept maps and representations
5	3	2.5	Misconceptions, analogies and metaphors
5	3	2.5	Conceptual teaching strategies
6	3	2.5	Consolidation of three components
6	3	2.5	Pulling together

As shown in the Table above, the selected components of TSPCK was used to introduce the construct in chemical bonding. The intervention explained each of the three components of TSPCK using the knowledge concepts of chemical bonding. Although some concepts were not tested ion the diagnostic test, they were related concepts that EPT's needed knowledge of to understand the concepts in the topic. In the sessions, EPT's were expected to interrogate the content of the topic from the perspective of each of the selected TSPCK components.

In the first two weeks of the treatment, the main focus of the sessions was based on the introducing EPT's to 'Learner Prior Knowledge (LPK)' the first component of TSPCK. Having answered and submitted responses to the diagnostic test, a discussion of LPK was held, first and fore most. This entailed a detailed discussion of what is entailed in the CAPS document and some knowledge of what the EPT's thought was important for discussion. All this information was written on the board. EPT's were asked to write down all the discussed terms and concepts in the topic in preparation for the next week. In the second week, EPT's

were introduced to the idea of concept mapping. The terms and concepts jotted down in the previous week were used for EPT's to design their own concept maps. In weeks three and four focus was on 'Representations' (RP), however, in the treatment, the lecturer used some of the common misconceptions in the topic to teach about this second component. For instance, in one question the lecturer asked EPT's to identify the misconception in the activity and offer an alternative explanation. EPT's responses in such a question demanded for them to use specific representations to explain the concept. This was especially important because in Chemistry topics such a chemical bonding, there are numerous abstract ideas that seek models in order to be conceptualized. Careful detail was put on students' understanding the use of symbols, chemical formula, chemical equations, demonstrations and experimentation. In week five, EPT's were introduced to the last components of the three selected components. 'Conceptual Teaching Strategies' (CTS) was the last component and distinguishes conceptual strategies from general pedagogy and logistics. This component required EPT's to draw knowledge and competencies leant from the other two components. EPT's here were encouraged to look back at their activities that required explanations use these to come up with strong, logical and coherent conceptual strategies.

3.5 Data Collection

Methods that were selected for collecting data were aligned to the research questions. Because the study investigated how exposing EPT's to an intervention develops their content and pedagogical knowledge, data for this study was collected at varying stages before, during and after the intervention. EPT's were required to provide responses to content tests and the TSPCK tool, to submit their weekly tasks during intervention and to also complete a number of pencil and paper instruments. Data was triangulated through the use of the following methods of data collection: pencil and paper Instruments, EPT's written tasks and interviews. Collection of data took place in 4 stages namely, pre testing, intervention, post testing and interviews.

3.5.1 Pre and Post testing

Data related to the level of achievement of CK in chemical bonding and the quality of TSPCK in the topic was collected prior to the treatment. The reason was to create a baseline from which future *shifts* or *lack of* could be calculated (Mavhunga, 2014). For measurement of the level of understanding of CK in Chemical Bonding, a CK test was used. It was necessary to have a process of post testing. To capture the shifts in both the CK and TSPCK

development, data related to the level of achievement of CK in chemical bonding and the quality of TSPCK in the topic was collected after the treatment. The reason was to compare EPT's performance in both tests and to their initial responses in the pre-test. For measurement of the level of understanding of CK in Chemical Bonding, a similar CK test was used in the post testing process. For the TSPCK tool, the same procedure was followed where EPT's were allowed to take the same test so that results of the pre and post-test could be compared and subject to analysis. The post-test took place thus: first EPT's were provided their results of the weekly activities and this work was extensively consolidated. Thereafter, EPT's were given their CK post-test. In this session it was explained to them that they each would be expected to answer questions in the test in order that their development is captured and documented. EPT's who gave consent to do so were allowed time to make a decision whether or not to continue with the research study. At the end of the test, the TSPCK tool was then issued out as a major assignment of the course and the EPT's were allowed a week to complete the tool). The post test results provided information on the degree of effectiveness of the intervention.

3.5.2 The CK test

The CK test (see Appendix I) was aimed to measure EPT's development of CK in the topic of Chemical Bonding so it was appropriate to make use of categories such elements and compounds, molecules, chemical bonding and chemical equations in the topic. In terms of the actual questions in the test, they are in a form of multiple choice questions as well as long questions. Different measures have been taken to scale the difficulty of the questions. The test has been designed in such way that participants were able to answer the test though it was unlikely that some would be able to answer all of them. This was because some of the EPT's had not had a good foundation of science in school, while some have not learnt science for conceptual growth. Although this may be regarded as major disadvantage, the results in the test were aimed at aiding the development of EPT's CK, TSPCK and to improve their practice for conceptual understanding. The distractors made use of in the test have been found to be common misconceptions in the topic of chemical bonding by teachers, teacher educators and researchers.

The major concern with this research tool is on the level of the questions, that because this is for research purposes and it is recommended that the test questions be broader (Bertram Christiansen, 1999). This concern was not prominent in my study because the test was integrated into what the EPT's course content entailed. Therefore, much of what was tested was what they are learning in their content courses. Another criticized aspect of this method of data collection was that if the test that only shows how well or how bad the students are, it conveys less of the participants' knowledge and ability (Cohen, Minion 1994; Bertram Christiansen, 1999; Creswell, 2007, 2009). In addressing this aspect, the test was designed in such a way that the test provided results that could be used to establish a point where the intervention could commence in preparation for the post test. The combination of the pre-test and the post-test provides data that can be used to measure EPT's CK.

3.5.3 The TSPCK tool

With the TSPCK tool (Appendix 2), I measured EPT's development of TSPCK in the topic of Chemical Bonding so it is appropriate to make use of categories such as CK, PK, PCK and some other knowledge forms associated with learners' difficulties in the topic. The questions in the study followed some list of intentions which are content and topic specific so as to gather evidence of consideration of the knowledge forms that aid the transformation of knowledge. For the TSPCK Chemical bonding tool, the participant EPT's spent 40 minutes answering the questions. The structure of the tool was thus: the tool had a total of three sections based on the three selected components of the study. The first section was based on LPK and questions relating to this component followed. The 'distractors' in this tool have been carefully selected to make up the MCQ based on common mistakes and misconceptions. The structure was not the same for all sections. Questions have been designed to suit the uniqueness of the respective TSPCK component hence based on ensuring that the questions capture what is intended to be measured in the study.

3.5.4 Interviews

Interviews in the study were used to consolidate and enhance data collected from the CK and TSPCK tool. Interviews were semi structured (see Appendix 3) to grant the participants an opportunity to elaborate on views highlighted on a particular aspect being probed based on the CK and TSPCK tool. The semi structured interviews in the schedule had pre-determined questions, which were grounded on the performance scores of the EPT's as well as any point of interest that emerged in any point of the treatment. For the interviews, the following

criterion was used, that EPT's who would be interviewed would be amongst the best performing EPT's in the sample of 30. The EPT's been invited to participate in the interview process and were told that they any views shared in the interviews would be used for the present study and to enhance future research. Therefore, no part of the interview would disadvantage them in any way in the course. They were assured of their rights to anonymity. This was ensured through the use of codes and synonyms. The EPT's were asked to give consent to the interviews first and foremost, but were also asked to give consent on whether or not they like to be audiotaped. In the interview process, the interviews took place in an isolated area where only the researcher and the interviewee were present. They were informed that the interviews would take a maximum of 15 minutes and they had a right to discontinue at any time during the interview.

3. 6 Data Analysis

3.6.1 Analysis of CK

Upon collection of scripts from the EPT's, the CK test were marked using a memorandum of correct responses. The memorandum was designed by four raters who were familiar with the concepts in chemical bonding. The test was marked using scores such that each item on the test would be analysed separately.

Question 1: For each of the questions below, choose an option from A or B, and a reason for your choice from 1, 2, 3 or 4. Circle your answ

A	B	1	2	3	4

e.g.

1.1 Sodium chloride exists as a molecule.

A TRUE

B FALSE

My reason for choosing A or B is:

1. The sodium atom shares a pair of electrons with the chlorine atom to form a simple molecule.
2. After donating its valence electron to the chlorine atom, the sodium ion forms a molecule with the chlorine ion.
3. Sodium chloride exists as a lattice consisting of sodium ions and chloride ions.
4. Sodium chloride exists as a lattice consisting of covalently bonded sodium and chlorine atoms.

My answer is:

A	B	1	2	3	4

In question one above, selecting the answers A or B would be one score. Selecting the reason would be another score. In total, there were fourteen items on the CK test and these were

tabulated as raw data and the mean score calculated (see Appendix 1). Thereafter, the results were subject to statistical analysis using Rasch. The statistical analyses of these numerical scores were used to determine the validity of the instrument and the correlation between teachers' CK.

3.6.2 Analysis of TSPCK

The TSPCK tool was collected from the EPT's and was marked by two raters who were familiar with the topic in the present study. A TSPCK rubric was used to analyse EPT's responses (see Appendix 2). These responses were analysed to find examples of limited, basic, developing, and exemplary TSPCK. In the rubric, scores were used thus: for limited TSPCK, a student teacher was scored (1), (2) for basic, (3) for developing and (4) for exemplary. These are tabulated as raw scores from which the mean scores of the pre and post-test are calculated.

3.6.3 Statistical analysis of CK and TSPCK scores

The Rasch statistical software works thus; it transforms the raw scores obtained from the rubric as ordinal data, into statistical measures that are located on a linear scale with equal intervals. For the analysis to be reliable, the item difficulty and person ability measures have to fall within the statistic range of -2 to +2. These reliability measures are considered to be acceptable. The reliability scores reveal an indication that the items and the person measures coherently work together to measure a single construct.

3.6.4 Qualitative and Quantitative aspects of data analysis

The selected data collection tools focus on both quantitative and qualitative aspects of the research question. In the case of quantitative data, the raw scores that were tabulated were subject to statistical analysis. For the qualitative data, the responses collected from the responses in the TSPCK tool, the weekly tutorial activities and the interview data were considered. The qualitative responses from the TSPCK tool were first subjected to thematic analysis for identification of TSPCK, then using the rubric discussed above; the responses were transformed for quantitative analysis to establish the quality of the observed TSPCK.

Data collected from the interviews was also subject to thematic analysis. All audiotaped data were transcribed, broken down and re-arranged (Lincoln and Guba 1985). In this process, there was repetitive coding and arranging of data in terms of themes. The themes that emerged were compared and analysed against the quantitative data from the statistical analysis tool to draw conclusions about observed phenomena. These themes were also used in reporting the findings (see chapter 4). The services of other researchers in the team were utilized for co-scoring and rescoring in order that the validity of the scores were enhanced.

The benefit of using the MM research method was explored fully in these analyses, as each different set of analysis provides unique revelations and understandings about the research questions.

3.7 Validity and Reliability

As a mixed method study, the establishment of the quality of the study relied on methods of assessing credibility in both quantitative and qualitative research methods. Reliability refers to the sound evidence to demonstrate that the intended test interpretation matches the proposed quantitative research, validity refers to whether the research actually measures that which it was planned to measure or the truthfulness of the results obtained from the research. In terms of the accuracy of the data collected through the instruments used; and evidence that the instruments used, measured what they have been designed to measure. With this, the generated item and person statistical fit index within the acceptable range of +2 and -2 indicates construct validity of the instruments. This concept of trustworthiness entails credibility, dependability, of the data analyzed and discussed. Through triangulation I have advanced the trustworthiness of the qualitative data collected.

3.8 Ethical Consideration

All the processes of data collection began with ethical consideration. Creswell (2012) points out that empirical research in education inevitably carries ethical issues, because it involves collecting data from people, and about people. Hence, this started with obtaining ethics approval from the Wits University Ethics Committee. Thereafter, consent forms were given to the pre-service teachers who indicated their willingness to voluntarily participate in this study. The form explained purpose of the research study, its benefits, the confidentiality and anonymity of the data collected. It was indicated in the consent form that the participant pre-service teachers were free to withdraw at any stage without any negative effect on them.

Conclusion of chapter

In this chapter I have provided the methodology which I followed in investigating the problem and attempting to answer research questions. The methodology was discerned carefully to ensure that the selected design and approach pursued to measure what was intended in the study. My research methods were designed to capture the following aspects; EPT's prior knowledge about the topic of chemical bonding covered in the CK test, their development of this knowledge during the explicit instruction of TSPCK intervention, and their thoughts and responses upon the nature of the course upon completion of the treatment. In the chapter that follows, I provide data gathered from the instruments used.

CHAPTER 4: RESULTS

4. Introduction

This study was concerned with the development of EPT's TSPCK using selected components of the construct. From the five components of TSPCK (learner prior knowledge, representations, curricular saliency, what makes the topic easy and/ or difficult and conceptual teaching strategies), three components of this construct were used in the 6-week intervention where CK aspects of the topic of chemical bonding were covered. The chapter unpacks a) EPT's responses to the CK pre and post-test, b) their TSPCK development, and c) responses to this CK in relation to their TSPCK development. The chapter is organised according to key findings which were the consequential of both qualitative and quantitative data and these are presented as themes below.

4. 1 Evidence of improved CK

(i) EPT's showed significant improvement in their CK test results

The EPT's CK tests were collected and marked using a memorandum of correct responses. In total, there were three sections of the paper (see Appendix 1). In section one, there was a total of three multiple choice questions which required EPT's to select their correct response (either being true or false) and select a reason for their choice in a list of possible answers. This means in the first section, there is a total of 6 items for analysis (two items per question).

The second section of the paper consisted of four long questions which required EPT's to define, explain, illustrate or discuss content aspects covered in the questions. These four questions were considered four individual items for analysis. The last part of the paper, which had three questions, asked the students to explain about properties of aluminium. These too were considered three individual items. In total, the CK test had thirteen items for analysis. The scores of the EPT's were tabulated (TABLE 4.1) and the improvement of the scores is observable. The EPT's responses were scored out of thirteen and the marks converted into a percentage. The EPT's responses were scored thus: 0 if the student teacher answered incorrectly, 1 if the response provided was correct (or partially correct) and N if the student teacher left the question unanswered. On average, the EPT's had from poor to good marks for their pre-test. However, the marks generally improved significantly for the whole sample in post-test. A score of 50% was considered to indicate good CK, therefore any mark below this

threshold was considered to be poor CK. The scores were subject to the Rasch model to confirm these observed trends.

Table 4.1 Pre Service teachers' pre and (post) results in CK test

CODE	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Mark Scored / 13	% score /100
RAM	0(1)	0(1)	1(1)	0(0)	1(1)	0(1)	0(1)	1(1)	0(1)	0(1)	1(1)	1(1)	0(0)	5(11)	40.71(78.35)
ROB	0(1)	0(1)	1(1)	0(1)	1(0)	1(1)	0(1)	0(1)	1(1)	0(1)	1(1)	0(1)	0(0)	5(11)	40.71(78.35)
SEK	1(1)	0(1)	1(1)	0(1)	1(1)	0(1)	0(1)	1(1)	0(1)	1(1)	0(1)	0(1)	1(0)	6(12)	46.32(88.04)
VOA	1(1)	0(1)	1(1)	0(0)	1(1)	0(0)	0(1)	1(1)	0(1)	0(1)	1(1)	0(1)	0(1)	5(11)	40.71(78.35)
AKA	1(1)	1(1)	1(1)	1(0)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	0(1)	11(12)	78.35(88.04)
SAM	1(1)	0(1)	1(1)	0(0)	1(1)	1(0)	1(1)	0(1)	1(1)	0(1)	1(1)	0(1)	0(1)	7(11)	52.15(78.35)
NAI	1(1)	0(1)	1(1)	0(1)	1(1)	1(0)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	0(1)	9(12)	64.58(88.04)
GOM	1(1)	0(1)	1(1)	0(0)	1(1)	0(0)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	0(0)	8(10)	58.26(71.12)
TOK	1(1)	1(1)	1(1)	1(0)	0(1)	1(0)	1(1)	1(1)	1(1)	1(0)	1(1)	0(1)	0(0)	10(9)	71.12(64.58)
MOF	1(1)	0(1)	1(1)	0(0)	1(1)	0(0)	1(1)	0(1)	0(1)	1(0)	0(1)	1(1)	1(0)	7(9)	52.15(64.58)
MOK	1(1)	0(1)	1(1)	0(0)	1(1)	0(0)	1(1)	0(1)	1(1)	0(0)	1(1)	1(1)	1(0)	8(9)	58.26(64.58)
UOM	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	11(13)	78.35(100.0)
MAD	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	11(13)	78.35(100.0)
SEF	1(1)	1(1)	1(1)	1(0)	1(1)	0(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	12(12)	88.04(88.04)
SON	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	12(13)	88.04(100.0)
MAT	1(1)	0(1)	1(1)	0(1)	1(1)	0(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	9(13)	64.58(100.0)

(For full table see Appendix 4)

The statistical analysis summary confirms that four out of the sample in the study were in fact lacking competence to answer the questions in the items selected in the instrument. Consideration is given to the 'model….' where the person reliability is given from Rasch based on person ability to be 0. 51 and 0. 50 in the pre and post-test respectively. The observed results were highly logical and consistent with what has been discussed in Chapter 1 of this study. The profile of these EPT's confirms that they have come to teacher education from undesirable school systems where they have not been sufficiently trained to cope with CK, two of the four EPT's have confirmed that they had never studied Chemistry prior

teacher training. From the item measure, the questions are rated in levels of difficulty. When the raw scores were put into Rasch, the reliability values were as follows.

Table 4.2 Summary statistics for validity and reliability of CK pre and (post) test tool

Reliability		Validity
Person	. 51(. 50)	Most Rasch measures in pre and post-tests fell within +2;-2
Item	. 89 (. 82)	

Most of the Rasch measures fell within the +2 and -2 range of Infit and Outfit statistics. This indicates that the scores are valid. For reliability scores to be considered reliable and trustworthy, they are to be on 0. 5 or more as is the case in the table above. These numbers indicate that if the same test items are given to other similar sample it would yield the similar results. It is critical to note that high person and item reliability values imply wide ability range among persons and wide item difficulty range respectively (Boone *et al.*, 2014). This implies that increase in the number of people to complete an item enhances the item reliability. Likewise, the higher the number of items completed by an individual who participated in the study the higher the person reliability. As a result, low person reliability indicates more persons of better ability are needed to complete the items while low item reliability implies that the sample is not big enough to precisely locate the items on the latent variable (Linacre, 2012, p. 644). As suggested by literature, most concepts in the topic of chemical bonding are difficult for EPT's, including aspects of what chemical bonding actually is. Out of the thirteen items, I had anticipated questions 2,4,10 and 13 to be amongst the most difficult questions for EPT's to provide responses for. This expectation was much influenced by what has been reported in literature. There are consistencies in international literature that students generally experience difficulty in ionic compounds and their structures, properties of metals and metallic bonding, covalent and ionic character of substances. The results of this study confirmed this hypothesis. Below is a table (TABLE 4.3) that shows item measures for the thirteen completed items in the pre-test.

Table 4.3 Item measure for pre test

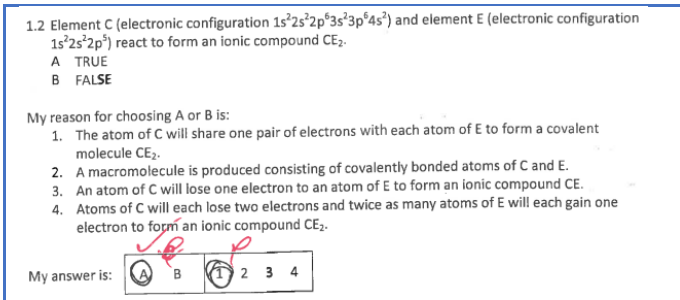
Person: REAL SEP.: 1.02 REL.: .51 ... Item: REAL SEP.: 2.83 REL.: .89

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
4	9	35	80.22	4.38	.81	-.8	.58	-.9	.59	.44	80.0	78.5	Q4
13	11	35	76.58	4.17	1.03	.2	1.57	1.4	.38	.47	80.0	76.0	Q13
10	14	35	71.63	3.99	1.23	1.3	1.41	1.3	.33	.49	65.7	73.3	Q10
6	16	35	68.51	3.94	1.39	2.1	1.77	2.4	.22	.50	60.0	72.2	Q6
2	17	35	66.97	3.93	.68	-2.1	.58	-1.8	.71	.50	85.7	71.6	Q2
12	27	35	50.04	4.58	.97	.0	.93	.0	.46	.46	82.9	81.2	Q12
7	29	35	45.46	5.02	.69	-1.1	.50	-.7	.60	.42	91.4	84.7	Q7
9	30	35	42.77	5.35	.79	-.6	.54	-.5	.53	.40	88.6	86.4	Q9
8	31	35	39.66	5.80	1.00	.1	.54	-.3	.41	.37	88.6	88.4	Q8
1	33	35	30.96	7.63	.71	-.4	.20	-.4	.47	.28	94.3	94.2	Q1
11	33	35	30.96	7.63	1.02	.2	.43	.0	.31	.28	94.3	94.2	Q11
3	34	35	23.13	10.35	1.13	.4	1.84	1.0	.02	.20	97.1	97.1	Q3
5	34	35	23.13	10.35	1.15	.5	3.50	1.6	-.07	.20	97.1	97.1	Q5
MEAN	24.5	35.0	50.00	5.93	.97	.0	1.11	.2			85.1	84.2	
P.SD	9.1	.0	19.74	2.24	.21	1.0	.87	1.1			11.0	9.1	

From the table, all items fall within +2; -2 excerpt for question 6 with zstd of 2. 1 *and* 2. 4. Question four was, according to the statistical analysis the most difficult question in the CK test. A few student teacher samples are given below:

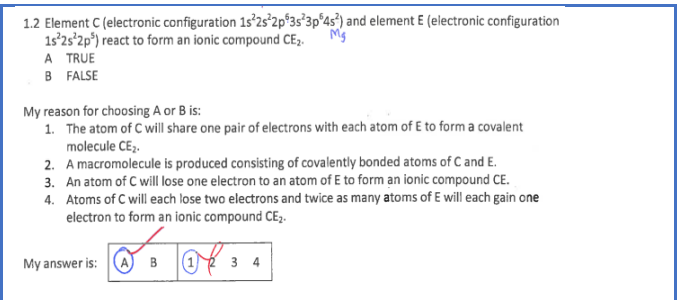
Table 4.4 Sample answers to question 4, the most difficult item in the CK pre test


1.2 Element C (electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$) and element E (electronic configuration $1s^2 2s^2 2p^5$) react to form an ionic compound CE_2.
A TRUE
B FALSE

My reason for choosing A or B is:
1. The atom of C will share one pair of electrons with each atom of E to form a covalent molecule CE_2.
2. A macromolecule is produced consisting of covalently bonded atoms of C and E.
3. An atom of C will lose one electron to an atom of E to form an ionic compound CE.
4. Atoms of C will each lose two electrons and twice as many atoms of E will each gain one electron to form an ionic compound CE_2.

My answer is: A B | 1 2 3 4

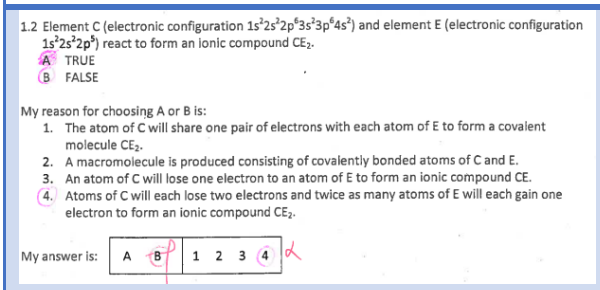
Extract from Sam


1.2 Element C (electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$) and element E (electronic configuration $1s^2 2s^2 2p^5$) react to form an ionic compound CE_2.
A TRUE
B FALSE

My reason for choosing A or B is:
1. The atom of C will share one pair of electrons with each atom of E to form a covalent molecule CE_2.
2. A macromolecule is produced consisting of covalently bonded atoms of C and E.
3. An atom of C will lose one electron to an atom of E to form an ionic compound CE.
4. Atoms of C will each lose two electrons and twice as many atoms of E will each gain one electron to form an ionic compound CE_2.

My answer is: A B | 1 2 3 4

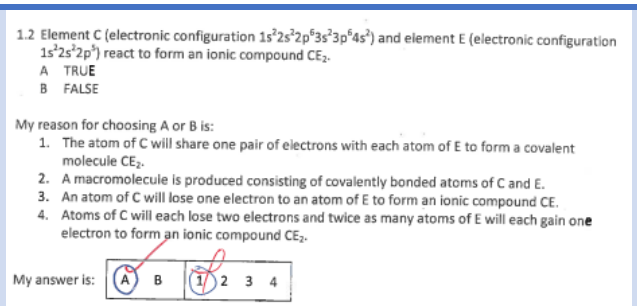
Extract from Lerato


1.2 Element C (electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$) and element E (electronic configuration $1s^2 2s^2 2p^5$) react to form an ionic compound CE_2.
A TRUE
B FALSE

My reason for choosing A or B is:
1. The atom of C will share one pair of electrons with each atom of E to form a covalent molecule CE_2.
2. A macromolecule is produced consisting of covalently bonded atoms of C and E.
3. An atom of C will lose one electron to an atom of E to form an ionic compound CE.
4. Atoms of C will each lose two electrons and twice as many atoms of E will each gain one electron to form an ionic compound CE_2.

My answer is: A B | 1 2 3 4

Extract from Nontuthuko


1.2 Element C (electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$) and element E (electronic configuration $1s^2 2s^2 2p^5$) react to form an ionic compound CE_2.
A TRUE
B FALSE

My reason for choosing A or B is:
1. The atom of C will share one pair of electrons with each atom of E to form a covalent molecule CE_2.
2. A macromolecule is produced consisting of covalently bonded atoms of C and E.
3. An atom of C will lose one electron to an atom of E to form an ionic compound CE.
4. Atoms of C will each lose two electrons and twice as many atoms of E will each gain one electron to form an ionic compound CE_2.

My answer is: A B | 1 2 3 4

Extract from Jerry

Note: The names used in this study are all pseudonyms

Question four (item 4) was an extension of question three (item 3). And according to TABLE 4.3 question three is one of the least difficult test items in tool. EPT's seemed to know from the given electronegativity values whether the elements given would yield an ionic bond, however, they were not so vested on why the two elements combined to form such a bond (the results of the post-test show otherwise). An interesting observation is the fact that three out of the four selected EPT's chose the correct response with incorrect reasons. Their selection of the atom of C sharing one pair of electrons with each atom of E showed that the EPT's were in fact confused about the terms covalent and ionic bonding. What is to be noted as well is the consistency in this thinking among the selected students, not only did they all select the incorrect reason, but their reasons were similar. A comparison of the same test item in the post test shows an interesting finding. In TABLE 4.5 test item four is still the most difficult question for EPT's. In the pre-test, only nine EPT's managed to score correct in the question. The post test results show that ten EPT's managed to get the correct responses. This shows that a majority of the EPT's in the sample held on to their initial ideas about the question and only one went through a conceptual change.

Table 4. 5 Item measure in the CK post test

Person: REAL SEP.: 1.00 REL.: .50 ... Item: REAL SEP.: 2.12 REL.: .82

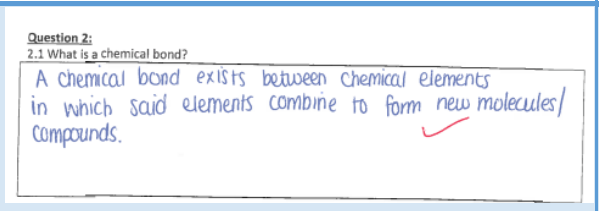
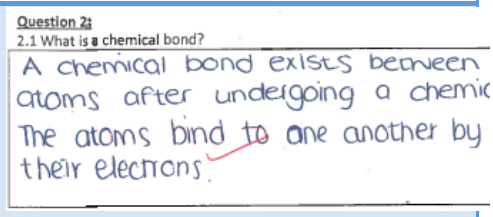
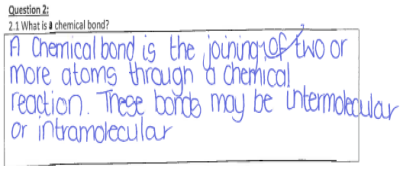
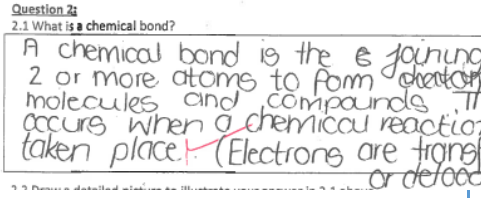
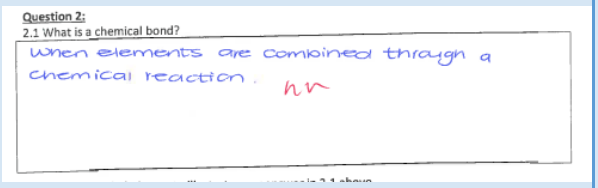
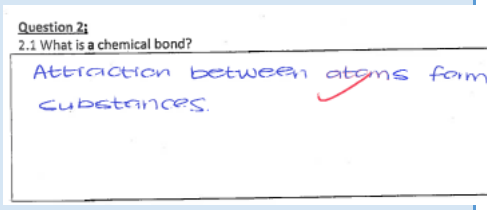
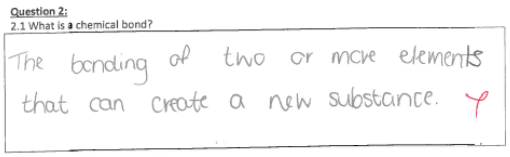
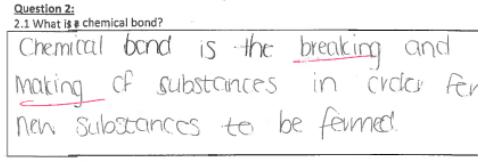
Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
4	10	35	94.69	5.90	1.09	.4	.96	.3	.68	.71	86.2	86.1	Q4
6	19	35	72.95	4.49	1.30	1.3	1.73	1.9	.52	.65	65.5	75.5	Q6
13	19	35	72.95	4.49	.97	-.1	.94	-.1	.65	.65	79.3	75.5	Q13
10	21	35	68.98	4.46	.67	-1.7	.56	-1.6	.74	.62	86.2	74.7	Q10
2	31	35	45.48	5.92	.94	.0	.66	-.1	.40	.38	86.2	86.8	Q2
3	33	35	36.48	7.72	.88	.0	.44	.0	.33	.28	93.1	92.9	Q3
9	33	35	36.48	7.72	1.17	.5	.69	.2	.23	.28	93.1	92.9	Q9
12	33	35	36.48	7.72	.88	.0	.44	.0	.33	.28	93.1	92.9	Q12
5	34	35	28.50	10.40	1.18	.5	4.73	1.9	-.01	.20	96.6	96.5	Q5
7	34	35	28.50	10.40	.78	.0	.18	-.4	.30	.20	96.6	96.5	Q7
8	34	35	28.50	10.40	.78	.0	.18	-.4	.30	.20	96.6	96.5	Q8
1	35	35	15.72	18.27	MINIMUM MEASURE				.00	.00	100.0	100.0	Q1
11	35	35	15.72	18.27	MINIMUM MEASURE				.00	.00	100.0	100.0	Q11
MEAN	28.5	35.0	44.73	8.93	.97	.1	1.05	.2			88.4	87.9	
P.SD	7.9	.0	23.78	4.50	.19	.7	1.24	1.0			9.0	8.4	

One critical observation following from the previous point about the resistance to conceptual change is seen in the comparison between the pre and post-test CK item measure. Looking at the pre-test, items (4), (13), (4), (10), (6), (2) are regarded the five most difficult questions in the test. In the post test, the same items remain areas of great difficulty. Item three proved to be one of the additional difficult questions in the post test. This observation is not surprising. As noted in the pre-test, it would follow that EPT's were not very sure what the ionic or covalent character of the elements really meant. Items (11) (12) and 12 were related questions on metals and metallic bonding. Amongst the three questions, question (11) was easier for

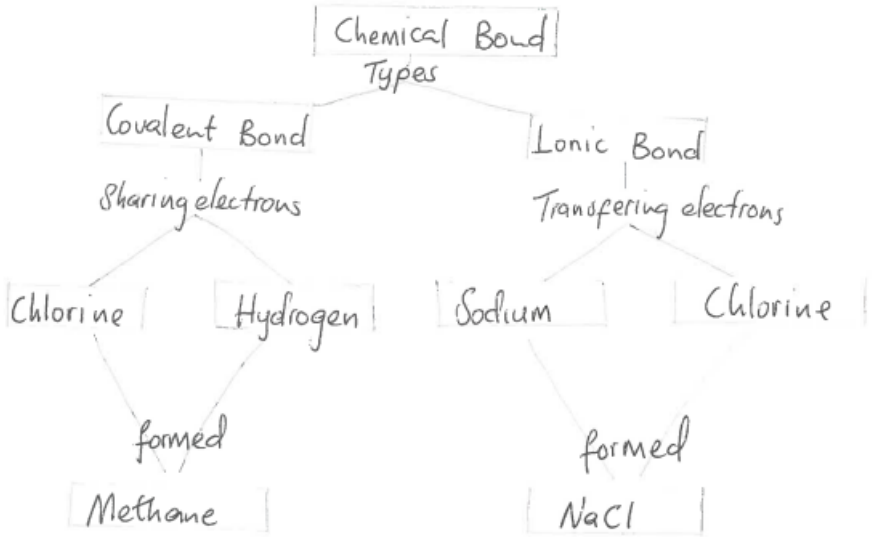
EPT's to answer and these results are consistent in the post test. In the CK test, EPT's also scored higher in questions requiring recall of facts such those of definitions. I have used responses of three EPT's and compared their pre and post test results.

Table 4.6 EPT's responses in the CK pre and post-test for item (7)

CODE	EPT's reponses in pre test	EPT's reponses in post test
KHOLEKA ABELO		
ROBIN		
UOMA		
NAIRO		

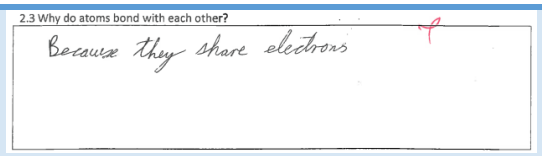
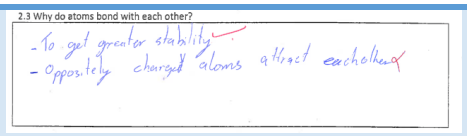
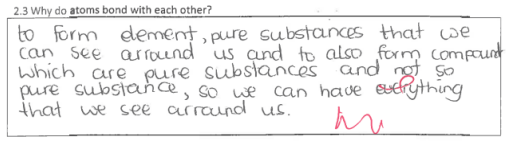
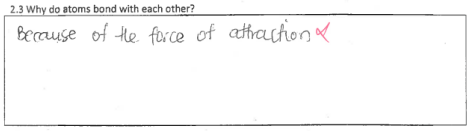
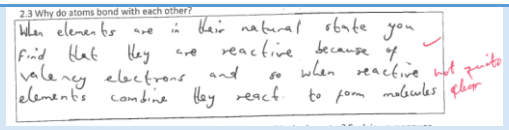
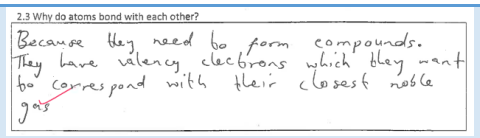
The definitions provided by the EPT's for what a chemical bond is improved with the post test results. In the pre-test, there was generally no mention of the role of electrons in a bond, and also no mention of the electrostatic charge that exists in bonded atoms. In the post test, although the answers remained superficial, there are details of the fundamental concepts of bonding, which given the quality of the responses in the pre-test tell a silent story about the ideas that EPT's learnt in the treatment. The EPT's understanding of this concept can be seen as improving because the responses given extend in detail. There is however room for improvement of these ideas because although the responses were correct, they are insufficient. One of the EPT's during the intervention provided the following diagram to define chemical bonding.

Figure 4A: Pre service teacher's concept map of chemical bonding



In his explanation, the pre service teacher Ndumiso, identifies the types of bonding and leaves out metallic bonding. However, the strength of his diagram is seen in the distinction of the behaviour of the electrons in each case. An extension of this question gives rise to an interesting observation. When probed on why they thing atoms bond, EPT's provided a variety of responses. Sample of these are given below:

Table 4.7 EPT's responses in the CK pre and post-test for item (9)

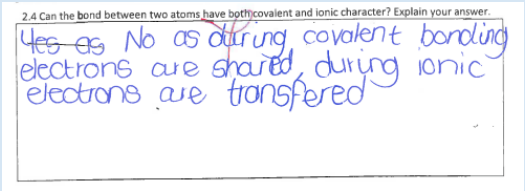
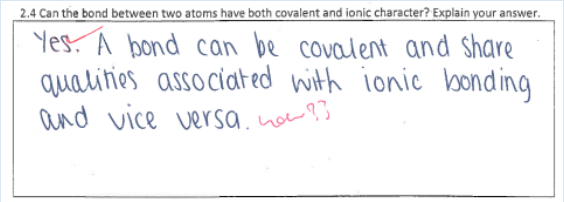
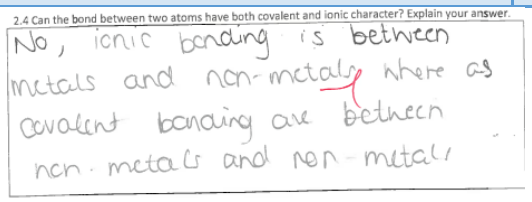
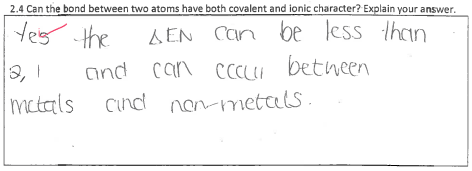
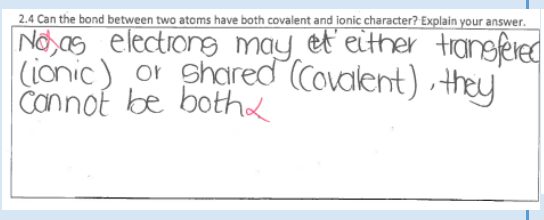
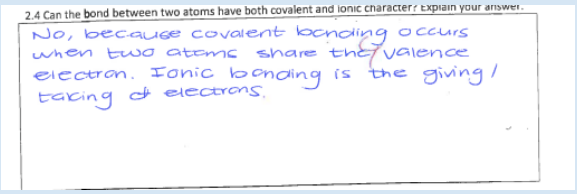
CODE	EPT's reponses in pre test	EPT's reponses in post test
AKANI		
MKHOLISI		
SIYANDA		

From the responses, one observable trend is that their understanding of chemical bonding, although fragmented, improves in the post test results. For instance, in Akani's response, the idea of stability came out but the pre service teacher remains unclear ad unsure about how this stability works in chemical bonding. Mkholisi mentioned the forces of attraction. This is a correct but incomplete response because the pre service teacher seems to want to mention the electrostatic force on chemical bonding. Siyanda's response uses the rule of the octet to provide his explanation. The use of human words in descriptions such as 'need' and 'want' is apparent. The pre service teacher has provided their understanding of why atoms bond within the context of atoms comparing themselves with noble gases as though atoms have in themselves ability to think reason and make decisions about their behaviour and characteristics.

In the both CK tests, EPT's were able to score in the items that required recall but the conceptual questions that followed the recall questions were seen to be harder for the EPT's. For an example, question 7 of the CK test required EPT's to recall what a chemical bond is for instance, but the follow up item 9 asks them why it is that atoms bond. The sample in the study managed to score relatively well in the question 7 (recall) but found it difficult to answer item (9) (conceptual).

The test item (10) yielded very interesting results from the EPT's. Besides it remaining as one of the most difficult questions for students, the actual responses of the EPT's are worth discussing.

Table 4.8 EPT's responses in the CK pre and post-test for item (10)

CODE	EPT's reponses in pre test	EPT's reponses in post test
KHOL EKA		
UOMA		
ROBIN		

The concept of covalent and ionic is highlighted again. The question in this item was probing whether EPT's saw that the best description of a chemical bond was through defining it in terms of electrostatic force. This definition is resultant of an idea that atoms could display both ionic and covalent character.

Overall, the significant improvement of the CK results is observable in the measurements provided below:

Table 4.9 EPT's responses in the CK pre and post-test for item (10)

Pre-test (thirteen items)	Post-test (thirteen items)
MEASURE 80.22 76.58 71.63 68.51 66.97 50.04 45.46 42.77 39.66 30.96 30.96 23.13 23.13 50.00	MEASURE 94.69 72.95 72.95 68.98 45.48 36.48 36.48 36.48 28.50 28.50 28.50 15.72 15.72 44.73

4.2 EPT's shifts in developed TSPCK were observed

The EPT's TSPCK tests were collected and marked. The responses given in the test were scored using a TSPCK rubric. The score system worked thus, (1) was given for limited (2) basic, (3) for developing and (4) for exemplary TSPCK. The tests were marked by me and two other peer raters. The raters were people very familiar with the TSPCK project, one being a senior lecturer and researcher in the field and the other, the lecturer in the NS II course. As explained in chapter 3, I made copies of a few scripts for marking and gave to each of the peer raters. I then marked the EPT's responses and gave it a score. The two raters followed a similar process and results were compared. Because we were all very familiar with the project, most of our ratings were very similar. In cases where there were irregularities, a discussion was held and a consensus pertaining what scores to allocate, reached. Table 4.11 shows the scores of the EPT's in their responses in the TSPCK test.

Table 4.11 The TSPCK rubric

TSPCK Component	Limited(1)	(2) Basic	(3) Developing	Exemplary (4)
Learner Prior Knowledge	No identification/No acknowledgement /No consideration of student prior knowledge or misconceptions	• Identifies misconception or prior knowledge • Provides standardized knowledge as definition • Repeats standard definition with no expansion	• Identifies misconception or prior knowledge • Provides standardized knowledge as definition • Expands and re-phrase explanation using at least one other component of TSPCK interactively	• Identifies misconception or prior knowledge • Provides standardized knowledge as definition • Expands and re-phrases explanation correctly • Confronts misconceptions/confirms accurate understanding drawing on two other component of TSPCK interactively

The rubric was adopted from similar studies studying the development of pre-service teachers (Mavhunga and Rollnick, 2013) TSPCK in other topics. The raw data from the TSPCK tests were subject to Rach statistical analysis. The scores range from (1) to (4), that is, when a student teacher displays competence that can be allocated to basic TSPCK for instance, they are scored a mark of (3). For the analysis of the TSPCK tool, thirty-five EPT's were selected for individual cases for in-depth analysis. These EPT's were followed from the beginning of the treatment in their lecture seminars, tutorial classes and their written work was submitted for analysis for the analysis. The selected students were showed great interest in this component of the course and were punctual and present for all the sessions.

In TABLE 4.12 results showing their performance in TSPCK is shown. The improvement in the pre and post-test scored is observed. EPT's showed significant improvement in performance across all three components. The TSPCK component of CTS was observed to be the most difficult for EPT's and this result is observable from the scores given in TABLE 4.11. Although generally, the EPT's scored between (2) and (3) for their responses, an overview of the CTS scores is between (1) and (2).

Table 4.12 Comparison of the TSPCK pre and (post) test raw scores (N=35)

CODE	LPK /4	RPS /4	CTS /4	Total /12	% scores /100
RAM	2(3)	2(3)	2(2)	6(8)	50.00(66.67)
ROB	2(2)	2(3)	2(2)	6(7)	50.00(58.33)
SEK	1(1)	2(2)	1(2)	4(5)	33.33(41.67)
VOA	3(3)	2(2)	2(2)	7(7)	58.33(58.33)
AKA	2(2)	2(3)	1(2)	5(6)	41.67(50.00)
SAM	3(3)	2(2)	2(2)	7(7)	58.33(58.33)
NAI	3(3)	2(3)	2(2)	7(8)	58.33(66.67)
GOM	2(2)	3(3)	1(2)	6(7)	50.00(58.33)
TOK	2(2)	2(2)	2(2)	6(6)	50.00(50.00)
MOF	2(2)	1(2)	2(2)	5(6)	41.67(50.00)
MOK	3(3)	2(3)	2(2)	7(8)	58.33(66.67)
UOM	4(4)	2(2)	2(2)	8(8)	66.67(66.67)
MAD	3(3)	2(2)	2(2)	7(7)	58.33(58.33)
SEF	3(3)	2(2)	1(1)	6(6)	50.00(50.00)

(For full table see Appendix 5)

A Rasch statistical analysis of the raw data confirms this finding. According to the model, the component that EPT's seemed to cope well with was LPK and with CTS, they experienced difficulty compared to the other two components. A detailed analysis of the TSPCK performance is given in the summary on Table 4.13 below:

Table 4.13 Summary of TSPCK pre-test performance

Person: REAL SEP.: 1.00 REL.: .50 ... Item: REAL SEP.: 5.57 REL.: .97

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
3	51	35	87.52	5.32	.93	-.1	.66	.1	.75	.74	85.7	86.5	CTS
2	69	35	39.05	4.52	1.09	.4	1.15	.5	.47	.70	80.0	80.9	RP
1	75	34	23.43	4.36	.99	.0	.74	-.4	.86	.68	76.5	78.7	LPK
MEAN	65.0	34.7	50.00	4.73	1.01	.1	.85	.1			80.7	82.0	
P.SD	10.2	.5	27.29	.42	.07	.2	.21	.3			3.8	3.3	

Although the three components retain their places in the rank order, the results improved across the three components in the TSPCK post-test. This is shown in table 4.14 below.

Table 4.14 Summary of TSPCK post-test performance

Person: REAL SEP.: .99 REL.: .50 ... Item: REAL SEP.: 5.34 REL.: .97

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
3	60	35	87.55	5.09	.90	-.2	.73	.0	.70	.71	85.7	85.7	CTS
2	81	35	34.56	4.57	.82	-.7	.62	-.8	.73	.75	82.9	79.1	RP
1	82	34	27.88	4.54	1.24	1.1	1.48	.9	.78	.73	73.5	79.0	LPK
MEAN	74.3	34.7	50.00	4.73	.99	.1	.94	.0			80.7	81.3	
P.SD	10.1	.5	26.69	.26	.18	.8	.39	.7			5.2	3.2	

The responses that the EPT's gave for their TSPCK test were consistent. Most EPT's gave similar responses with reasons for the various components. For instance, in the RP component, EPT's were asked which of the 6 representations given in the test would be their most preferred one. The responses which are given below show that EPT's preferred representations (1), (4) and (5) a detailed discussion of this observation is provided in section 4. 4 of this chapter.

Table 4.15 Pre service teachers' responses to the TSPCK component: RP

CODE	PREFFERRED REPRESENATTION
RAM	1
ROB	4
SEK	4
VOA	2
AKA	5
SAM	4
NAI	1
GOM	5
TOK	1
MOF	1
MOK	6
UOM	4
MAD	1
SEF	5
SON	1
MAT	4
SIT	5

(For full table see Appendix 7)

This may be primarily due to the familiarity. With the first representation, the use of one valence electron was fairly simplistic. Some of the reasons given for the chosen representation included simplicity, and that the representation showed valence electrons which will be shared in the bond. Examples of students' responses to what they like or did not like about the representations is given in TABLE 4.16 below for representation (1). The students selected below did not necessarily choose one as their most favourite strategy however; their discussion about representation (1) is critical at this point.

Table 4.16 Showing representation (1) as responded to by the selected EPT's

CODE	GCOBISA	MOFAMUTLI	SITHEMBILE
What I like	*It shows the electrons which atoms will share*	*It shows that two atoms come together to form a new substance*	*It shows clearly that there are electrons taking part in a bond*
What I don't like	*It does not help learners' prior knowledge. In teaching, it is easy to start from what learners know*	*It is difficult for learners whose ideas about atoms are not developed.*	*Learners who struggle with microscopic ideas will not be able to comprehend the concept.*

The CK responses provided in the CK discussion in this chapter can be seen as a possible factor in the quality of TSPCK responses. For instance, in a case where EPT's did not fully and conceptually comprehend a concept, their scores were low. The following samples confirm this premise.

Table 4. 17 Showing component of conceptual teaching strategies

CODE	AKYEMI	AVIOLA	MATHEW
Response given	*In teaching this lesson, I would start by identifying the type of bonding in graphite. Graphite consists of covalently bonded atoms.*	*I would start by telling learners that graphite consists of delocalized electrons. These are free electrons which are free to move anywhere. There are strong covalent*	*Graphite consists of layers of carbon atoms. Layers have the ability to slide over one another because of the existence of weak forces between them. This is why when you*

		bonds in graphite. At this point I would remind students about the forces that hold atoms together being van der Waal's forces	*sharpen a pencil, you observe such behaviour. It is this ability of the layers that can slide over each other.*

From the above responses, the common challenge is all three EPT's in the understanding of the chemical properties of graphite and how these affect the chemical bonds involved. The participant EPT's scored between 'basic' and 'limited' for this component. This was much lower in all components compared to LPK. EPT's chose responses A and E mostly as the most important when teaching about chemical bonding for the first time.

Table 4.18: Ideas pre service teachers consider important for teaching Chemical Bonding for the first time

CODE	SELECTION
ROBIN	**A**
SEKATA	**A**
VIOLA	**A**
AKANI	**E**
SAM	**B**
NAIROBI	**A**
GOMOTA	**A**
TOKYO	**A**
MOFAMUTLI	**C**
MOKHOLISI	**B**
UOMA	**B**
MADIBENG	**A**
SEFAKO	**A**
SONIA	**E**
MATTHEW	**E**

(For full table see Appendix 6)

The table shows a trend of what most of the EPT's consider most important for teaching.

Table 4.19 Showing the most important concepts to teach first in chemical bonding

CODE	THATANELO	SARAH	NOPI
Response given	*A, bonding takes place between metals and non-metals and non-metals and non-metals. Of learners don't understand how the periodic table is arranged, they can't identify the type of bond.*	*E. All atoms have the desire to be like group 8 elements. The octet rule says all atoms should have fill orbitals such as those in group 8.*	*E. the reason why we have bonding in the first place is because of the incomplete outer shells needed to be filled. Noble gases don't have this problem so they don't bond with other elements.*

Two of these EPT's (Thatanelo and Nopi) showed that they preferred choice E while the one preservice teacher (SAH) chose A. The interesting trend to note between Sarah and Nopi is that they consider the rule of the octet to be the primary aspects that learners need to understand in order to understand bonding.

4.3 Evidence of components covered in the course interacting with those not covered

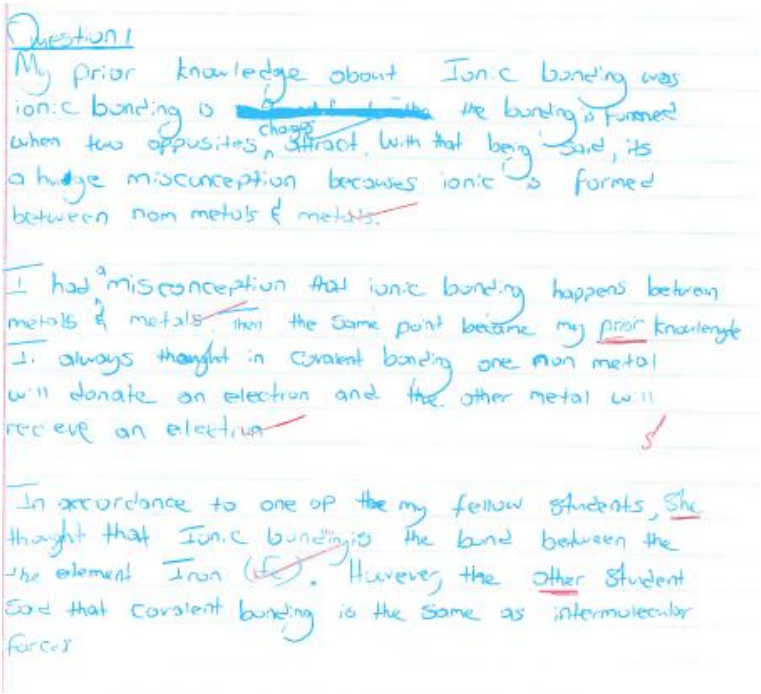
From table 4.15 what is notable is that all three EPT's make reference to the other TSPCK component of LPK in their justification of the chosen representation. In a case of Mofumatla, we see an interaction of LPK, RP and WMT. WMT is a third component that has not been taught explicitly in the course, however the student teacher is making reference to what makes the topic easy or difficult to understand for learners. This suggests that the five TSPCK components from the original postulation do not work in isolation but are have interactive ability. Revisiting table 4.19, this table not only provides information on what EPT's thought was most important as a starting in teaching chemical bonding. The data also shows the EPT's own ideas and set of views about chemical ideas. In their responses, EPT's mentioned aspects about teaching chemical bonding that are consistent with components that were not covered in the course. The justifications of their selected response teachers have in

fact, shown aspects of CS another component in the TSPCK conceptual framework. It is noted that EPT's in their responses used phrases such, "you *cannot expect learners to know x without first teaching them y; it is important that you explain noble gases first before you teach bonding*". Another aspect of this component was appreciated in one of the EPT's reasons for choosing A as a response, *"I think the big issue here is the knowledge of metals and non-metals, how do you teach bonding without making them aware of these?* "Although the phrasing of the statement may be modified, of crucial value is the understanding that the knowledge of metals and non-metals is a big idea. This is one of the strands of CS. The distractors are being compared by the student teacher and they are identifying metals and non-metals as a big idea. In the table below, I have provided evidence of what the common reasons for EPT's selecting A or E as the most important baseline for teaching chemical bonding.

4.4 EPT's drew on similarities and differences between the concepts of the topic discussed.

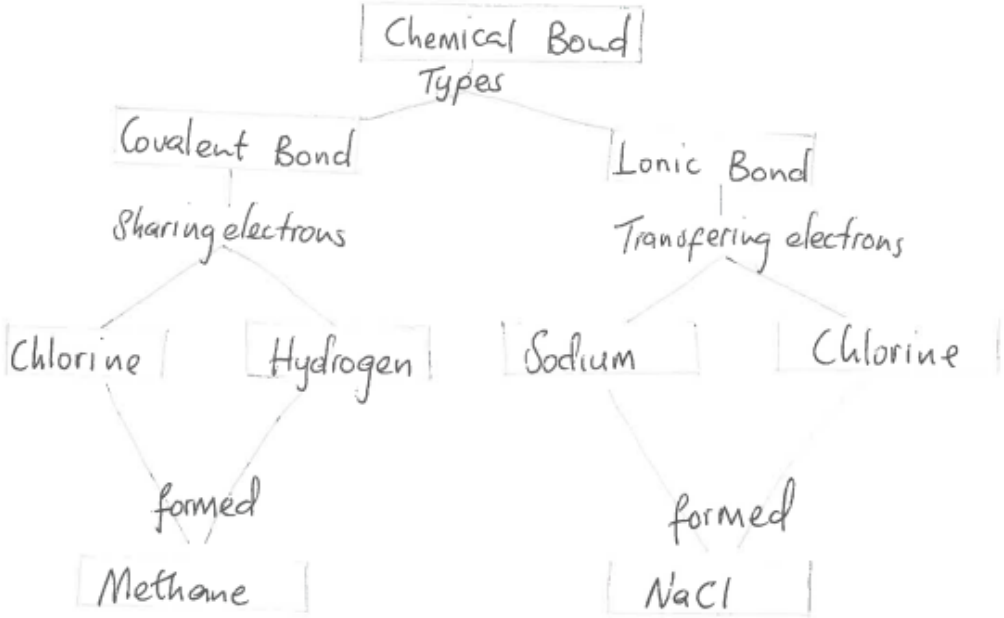
Some EPT's were seen to confuse the terms ionic and covalent bonding, but in the treatment, they make reference to this shift.

Figure C Pre service teacher's narrative about own misconceptions



This may be one of the possible reasons why the CK results based on ionic and covalent bonding were improved. The EPT's response to a question during the treatment shows that during this period, EPT's were already seeing where their misconceptions lied. Beyond this, EPT's in the sample like the student whose transcript is placed immediately above this discussion reflect and makes links between the concepts that are involved in chemical bonding. Most of such responses were evident in the class tutorial tasks which formed part of the treatment. The following diagram was note earlier in the definition of a chemical bond. Although the student teacher has only defined from the perspective of only two types of bonds, the similarities and differences between concepts and terminology involved. An ionic bond is similar to a covalent bond in the use of electrons in a bond, but it they are distinguished by the behaviour of these electrons in a bond.

Figure D Pre service teacher's concept map



Another instance where pre service teaches were observed to be making use of their knowledge of the topic to draw on similarities and differences between the concepts of the topic discussed is given:

> Thandiwe: *You were provided feedback on the CK test and immediately exposed to a 6-week intervention. How would you describe your experience in such an intervention*?

> Nondumiso: *... understand in high school, like you cannot talk about bonding without talking about electronegativity…. You know like what makes a bond ionic and covalent. We were never taught like those lattices…*

From the interview excerpt immediately above, the preservice teacher is observed to be comparing ionic and covalent bonding similarities drawn from the fact that they are bonds which take place between either metals and/or non-metals. The differences are highlighted in the state of electronegativity values. The following interview excerpt provides another example where a similar trend can be traced:

> Mofuoatla*: I find that understanding whether sodium chloride exists as a molecule very difficult to comprehend… In my head, molecules relate to compounds. I know all molecules are compounds but not all compounds are molecules…*

The student teacher's observation is not foreign to literature either.

4.5 EPT's preferred to use macroscopic descriptions to explain chemical bonding

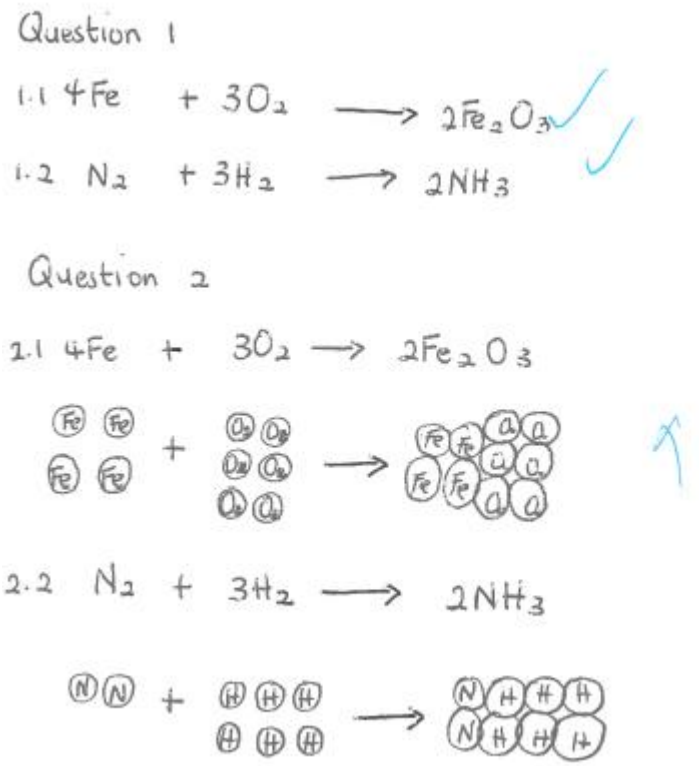
A crucial observation from the table is that EPT's, although much aware that chemical bonding is an abstract concept, tend to use macroscopic representations to explain a bond. This was also very evident in the intervention. When EPT's were given questions about representations, they provided responses such as the one in the excerpt below:

Figure E Preservice teacher's use of representations



In the representations provided as responses above, there were a lot of misconceptions captured and discussed. In the example above, the EPT's were struggling to show the arrangement of atoms in the formation of Iron Oxide. A similar finding was observed with the preservice teacher immediately below:

Figure F Showing challenges preservice teachers have with representations



EPT's seemed to cope well with symbolic representations more than they did with microscopic representations. This may be a reason for the observed trend in their most preferred representation. None of the sub microscopic (3) and (6) representations are selected as the best in teaching chemical bonding, only symbolic (1) and macroscopic (4) and (5).

In the discussions in the intervention, careful detail was observed in ensuring that EPT's ultimately were able to understand, explain and conceptualize chemical ideas in their abstract nature. In the same course, a lot of misconceptions were discussed however; EPT's in their TSPCK responses show that they held on to their original ideas about teaching chemical bonding. This is evident in the selection of representation (4) and (5) as their most preferred form of representation. Some of the reasons for choosing representation (4) and (5) are given below:

Table 4.20 Showing representation (4) as responded to by the selected EPT's

CODE	AKYEMI	AVIOLA	MATTHEW
What I like	This is a combination of everyday experiences with Chemistry. It makes learners understand better when they see they can relate with the idea.	This example will be good for learners who struggle with abstract concepts such as bonding between atoms and sharing of electrons	It shows that electros are shared between two atoms.
What I don't like	The long rope can be confusing for learners who have seen the rope. It must just show electrons.	May cause misconceptions. It looks like atoms fight over electrons.	I don't know understand how H atoms can be happy to share but also pull the rope as if they are competing for electrons

Here we see an interplay of LP and RP. The actuality of the interaction of the two components is notable. There are similarities in how the EPT's responded to representations (4) and (5) and these are related to the understanding of particulate nature of bonding substances.

Table 4.21 Showing representation (5) as responded to by the selected EPT's

CODE	MAVURU	NONDUMISO	SITHEMBILE
What I like	I like that learners are familiar with the idea of dating and love. If I say bonding is like dating, then they understand.	This is very handy because learners become the learning and teaching resource. This will be good for schools without resources.	The use of what learners can see is important. In this case, I can easily make learners do the same representation in class to show formation of bonds
What I don't like	If I use people, I cannot use I can't explain the chemical properties of matter	It can be difficult for learners to understand the concept. Because it can take them a while to start working with microscopic ideas.	Atoms do not behave like people do. It is difficult to explain something so small using people and big bodies.

In terms of these representations, they are similar in that they are both macroscopic. The EPT's preferences in these representations show that they believe the macroscopic representations worked best in the classroom as they give a practical approach to teaching chemical bonding. The selected representations were said that they were preferred because they could be used in class whether there are limited resources. The pre service teacher continued to advocate for the use of macro level representations because they saw these representations as those that worked well with learners' prior knowledge and experiences. Some of the reasons given for not preferring representation (3) and (6) for instance were that EPT's thought that leaners would not understand complex explanations (which they, themselves as teachers had limited knowledge in). However, in the statements about what they did not like about the macroscopic representations, EPT's seemed to understand the limitations of these representations as far as chemical bonding as an abstract concept was concerned. We see this when a pre service teacher states, "*If I use people, I can't explain the chemical properties of matter"*

4.6 EPT's developed explicit ways of thinking about their teacher knowledge.

This finding was extracted mostly in the interviews where EPT's were each provided an opportunity to discern their responses in either the CK, TSPCK tool and/or the intervention itself. The interview questions helped in that EPT's were seen to confirm or disconfirm the researcher's' thoughts about what made the two tests and the intervention easy or difficult. One such student teacher's excerpt is given below:

> *The issue with the chemical bonding test was that you don't know how much you know until you actually put yourself in the learners'' shoes.. . What I mean is that if I can't answer these basic questions about bonding as given in the test, then surely I must do more work to understand the work in order to teach it well.*

Learning to teach here has been extended to the understanding of concepts well enough to be able to transform them for teaching. The EPT's reflection about own content understanding draws our attention to the fact the student teacher is saying I didn't know how much I didn't know before this process. This could imply that as teachers we may not be aware of our own limitations in as far as our content is concerned until an opportunity comes to reflect about the depth of this content. A similar case is presented below. Unlike in the first, this student teacher draws links between the CK and TSPCK test;

> That thing [TSPCK tool] was much easier than the tests we had. I could focus on my teaching more and reflect on what I know against what I don't. It is important for a teacher to know learners' prior knowledge which they bring to the class… Like on TE I know most times I don't have the competence in my content to teach it in way that will make learners understand.

It would seem that the simultaneous process of dealing with CK and TSPCK at the same time helped the pre service teacher position themselves in terms of how much knowledge they had for teaching. The pre service teacher is observed to reflect on her own CK challenges and links this to how this limitation affects the transformation of CK on teaching practice.

Conclusion of chapter

The use of three components of the TSPCK construct in the 6-week intervention where CK and TSPCK aspects of the topic of chemical bonding were covered showed that EPT's could

be developed using a CK and TSPCK tool. The chapter has conveyed EPT's responses to the CK pre and post-test, their TSPCK development and their responses to this CK in relation to their TSPCK development. The key issues that have come out of the data were:

(a) That the EPT's at their beginning stages of their teacher training demonstrated improved knowledge of their CK as well as the knowledge of TSPCK.
(b) That there was evidence pointing that the three components covered in the intervention interact with those that were not explicitly taught in the course, thus implying improved TSPCK in the topic.
(c) That there was general improvement across the three components used in the intervention (a).
(d) That EPT's used their knowledge of the topic to draw on similarities and differences between the concepts of the topic discussed.
(e) That EPT's preferred to use macroscopic descriptions to explain chemical bonding.
(f) EPT's developed explicit ways of thinking about their teacher knowledge.

In the next chapter, I discuss the key findings which have been extracted from the central issues in this chapter. The key findings will be summarized and discussed in light of reviewed literature. The next chapter will also draw on the summarized findings to make conclusions and to provide implications of these findings for teaching and learning and science education.

CHAPTER 5: DISCUSSIONS, CONCLUSIONS AND IMPLICATIONS

5. Introduction

The study was concerned with EPT's TSPCK developed through an explicit inclusion of TSPCK intervention in the topic of chemical bonding. Most of these EPT's have been products of a system which has encouraged a narrow view of science subjects creating a problem of insufficient and undesirable levels of CK. The TSPCK construct was adopted to investigate the possibility of fast-tracking EPT's PCK in the earlier stages of their teacher education programme so that learnt competencies can be later used to transform CK in various other topics. Therefore, this chapter follows from the preceding chapter where findings were presented according to the research questions being asked. Data was collected, analysed and reported as six main themes. The chapter is also focused on providing conclusions and implications of the study. In so doing, chapter seeks to provide possible answers to research questions and provide a detailed analysis of these answers on their implications for science education, teaching and teacher education.

5.1 Key findings of the study

Based on the discussion of data in the preceding chapter, the key findings in regards to the beginning EPT's in this study were the following;

That:

(a) There was general improvement in CK in pre and post-tests.

(b)There was evidence of general improvement in TSPCK components used in the intervention.

(c) There was evidence of general improvement across the three components

(d) There was interaction of TSPCK components observed, including those in those components that were not covered in the course.

(e) EPT's were observed to be using their knowledge of the topic of chemical bonding to draw on similarities and differences between the concepts imbedded in the topic of intervention.

(f) EPT's at their beginning stages of teacher training display, in planning, that they 'miss' the important aspects of teaching chemical bonding and,

(g)EPT's in their beginning stages of their teacher education programme developed explicit ways of thinking about their teacher knowledge.

In the sections that follow, I discuss each one of the findings in detail.

5.2 General improvement in CK in pre and post-tests

The intervention emphasized the explicit discussion of the knowledge that effects pedagogical transformation of CK. The use of the limited components of the TSPCK construct provided EPT's ideas about teaching the concepts of chemical bonding. There was evidence that beginning pre-service teachers demonstrated transformation of CK of the topic of chemical bonding. The scores of the tests have shown that EPT's ability to answer questions that required more than factual recall were improved. This finding is consistent with what studies of the same kind reported (e. g. Mavhunga, 2012; Mavhunga & Rollnick, 2013).

The case of the TSPCK intervention shows that CK generally improves as a result of the explicit discussion about its transformation for teachability. Therefore, it can be asserted that sufficient understanding of chemical bonding concepts learnt in the context of pedagogical reasoning, has been found to improve with explicit instruction of the components of transformation. According to Mavhunga (2012), basing 'learning to teach' on each topic of CK needs the amalgam of knowledge talking specifically to it, and therefore transforming the topic pedagogically. The amalgam referred in this context was the use of TSPCK components directly in the intervention, ensuring that learnt competencies can be traced on the extent of the interaction of these components. EPT's improvement of CK is appreciated because in the study it has been consistently argued that CK is the central kind of knowledge to be mastered. This is especially the case for EPT's in the beginning stages of development because of their background in the subject may have been undesirable. This observed improvement in CK implies better understanding and reasoning about knowledge to be transformed for teaching. And because sound reasoning by teachers requires both a process of thinking about their actions and a sufficient range of content, this CK must be a strong base used to reason about teaching (Mavhunga, 2012). When this ability to reason about content is fostered, there will be evidence of the improvement if pedagogical expertise. In this case the pedagogical elements are aligned to the topic specificity of the content, hence the improvement in the

EPT's TSPCK. The discussion on the development of EPT's TSPCK improvement is discussed in the section that follows.

5.3 General improvement in TSPCK

There was evidence of improved TSPCK. This evidence showed that beginning pre-service teachers demonstrated transformation of CK of the topic of chemical bonding. This finding confirms that good CK results in the reciprocal development of TSPCK. The TSPCK framework is not only based on the sufficient understanding of CK by the EPT's, the model is however, anchored on reasoning through a topic using knowledge components that enable transformation of CK (Mavhunga, 2013).

It is a good model to emphasize and centralize the importance of CK in the development of TSPCK because at this stage, EPT's have not learnt enough and have not had sufficient practice to reflect upon in developing their practice as teachers. This can leave them feeling unprepared and can give rise to increasing levels of anxiety during practicum. The latter is based on the understanding that good CK gives a teacher a sense of security and confidence as they plan and teach the learners, which gives a firm foundation for a teacher to develop appropriate PCK (Kind, 2009). EPT's, much like novice teachers, need support and guidance for their professional and PCK development in the first few years of their careers, due to the complex nature of the teaching profession (Aydin *et al.*, 2015). Although much of what is reported in the development of EPTs' TSPCK is TSPCK in planning, the results contribute to the advocacy of including such interventions in teacher education programmes to fast rack EPTs' PCK before they embark in real classroom teaching. The study is not naïve to the fact that in depth, rich and sufficient pedagogical reasoning develops with time in a practice full of reflection in and on action (Nilsson & Loughran, 2012).

5.4 General improvements across the three components

The general improvement observed was consistent with findings from similar studies even though these studies made us of all five components of TSPCK (Mavhunga 2012, Mavhunga& Rollnick 2013, Ndlovu, 2014). It was also reported in these studies, the TSPCK component of (CTS) was observed to be the most difficult for EPT's. In great acknowledgment of the EPT's level of study in the teacher education programme, it is expected that EPT's at this stage lack the necessary foundation in CK. Therefore, this lack is expected in this particular component. However, the results show although CTS remained the

most difficult component compared to the other two, students' scores in the component improved significantly. Of all the five components, CTS encompasses the understanding of the other components (Mavhunga 2012) which draws to the fact that EPT's at this point are grappling with developing sufficient CK for themselves first, and later to test their understanding of this content its transformation.

During the intervention, the improvement and interplay of the selected TSPCK components happened simultaneously, more to the fact was improvement of other components that were not included in the TSPCK based intervention. While it was believed that transformation of CK emerges in the use of five TSPCK components (Mavhunga & Rollnick, 2013) the use of a selected number of components yielded similar results.

General PCK provides a basis for thinking about and positioning teacher knowledge. TSPCK provides teacher education framework that brings CK and the transformation of this for teaching purposes to the fore. The general improvement of TSPCK components gives hope because EPT's developing such knowledge is desirable to enable synthesis of knowledge and skills to develop pedagogical transformation. Their understanding and ability to score higher in the assessment and articulation of LPK and RP can be a driving force to develop a sense of how learners think and this can help them formulate effective teaching strategies.

It is the understanding of the knowledge components identified above, in relation to a given topic that enables its full transformation for learner understanding (Mavhunga, 2012). EPT's understanding of LPK was found to be the least difficult as compared to CTS (Mavhunga, 2012) this comparison does not suggest a hierarchal view of the TSPCK components. Components cannot be considered as separate knowledge bases because these components are so integrated and interrelated.

5.5 Improvement of TSPCK components including those not covered in the course

According to the original study based on TSPCK intervention, the quality of TSPCK can be improved in a chemistry topic by exposing pre service teachers explicitly to deliberations that require understanding a topic in terms of the five knowledge components of TSPCK interactively. The study reported on the success of the intervention based on a Chemistry Topic of Chemical Equilibria. The use of selected number of components from the TSPCK framework provides the possibility of developing EPT's at different levels of their teacher

education programme in unique approaches. In a case of the study by (Mavhunga, 2012), the sample was fourth year pre service teachers who were going to be qualified teachers in the same year. Investigating EPT's in their earlier years of development using a selected number of components in the framework outlines that EPT's contextual complexities associated with being a new student in the programme were fully considered.

The study analysed the EPTs' progress in the selected TSPCK components however, the development of the TSPCK emerging from the amalgam of all five knowledge components needed was portrayed. The EPTs' responses showed that although three components were used explicitly to develop them in the course, the EPT's knowledge improved even in the components that were not explicitly taught. This gives rise to an observation that EPTs' use of the components not covered in the course also showed the strength of the relationship between the components, that they are in interaction and cannot necessarily be separated and treated as separate entities.

This was not surprising considering that EPT's, like most pre service teachers have no prior PCK on which to draw from, hence they are more open to developing across components (Kind, 2009a). When they gave responses in the pre-test they often relied on what they have seen happen in their own years of schooling but in the post tests significant improvement showed how they their responses were becoming the result of their own thought processes. According to Aydin *et al*. (2015) teachers should have a firm understanding of all PCK components (e. g., knowledge of learner and instructional strategies). This interplay is important for PCK development; the components interact with each other in highly complex ways (Park & Oliver, 2008).

5.6 Using their knowledge of the topic to draw on similarities and differences between the concepts

When pre service teachers have sufficient content knowledge, they are able to explain the science concepts more fully and resorting less often too simplistic dialogue (Rollnick, *et al.*, 2008). This means, in their teaching, they are able to draw between concepts that make up a topic in a less superficial way. In the process of teaching, when EPT's had less confidence in their CK, they were forced to provide responses to the TSPCK tool using factual recall. When their CK and TSPCK improved, they could make links between ideas in the content as well as construct more appropriate analogies and metaphors for explaining concepts. This was

more so considering that EPT's at their earlier stages of training have not been in teacher training long enough to have knowledge that competes with their own existing conceptions of chemical ideas.

This finding is in harmony with Halim and Meerah (2002) where it was found that a majority of trainees held misconceptions similar to school learners. The intervention helped evoke their own learning and reflect on the legitimacy of the chemical ideas held prior training. And like the students in Halim *et al.* (2002, p. 223), trainees repeated their own misunderstandings; therefore, their ability to transform CK for learners was 'impeded' by their lack of knowledge. This capability was noted in Shulman, (1989, p. 15) that evidence of sound understanding of teachers' PCK increases "the capacity of a teacher to transform the CK he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by the learners.

More to the point that EPT's responses indicate that they could see variations and similarities between concepts and chemical ideas- their instructional strategies (in planning) revealed this. Although much of what has been found has been based on TSPCK in planning, the results are promising for teacher educators. This is so because EPT's ability to use their knowledge of the topic to draw on similarities and differences between the concepts provides insights into their perceptions on how they think their learners make sense of the chemical ideas and concepts. This is a good form of improvement following that teaching is a complex social activity, drawing on teachers' knowledge in ways that are not always well understood (NARST, 2009). The ability for EPT's to draw on different concepts within the topic of chemical bonding not only illustrates their development in content alone, but it also tells a silent story about their awareness of the nature of the complexity of teaching.

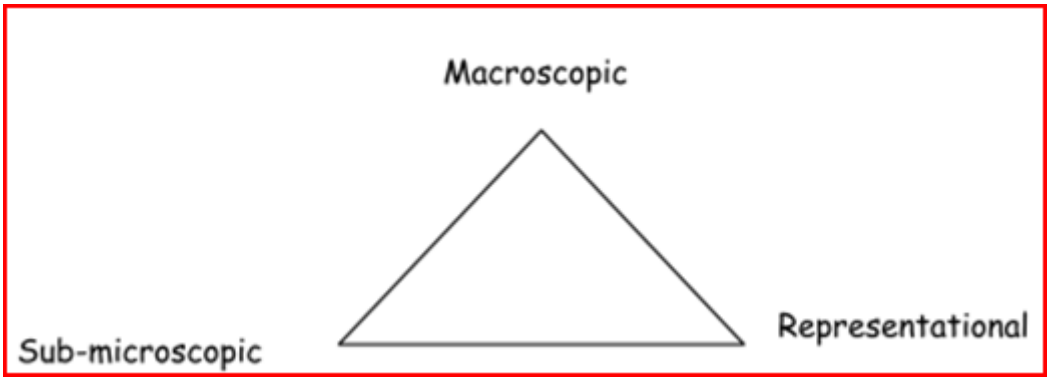
5.7 EPT's 'miss' the important aspects of teaching chemical bonding

Despite the promising results of both CK and TSPCK development in EPT's, an in depth analysis of EPT's responses both in the pre and post-tests suggests that EPT's seem to still 'miss' the critical aspects of teaching chemical bonding. From the responses obtained from their written work, the cohort displayed the following: (a) EPT's showed no mention of the electrostatic nature of chemical bonding, (b) EPT's used macroscopic levels of representations to explain and describe bonding (c) EPT's in the study over emphasized the

rule of the octet to explain chemical bonds (d) EPT's struggle with the idea of delocalised electrons in metals.

The four aspects highlighted are no foreign ideas to existing literature. In fact, literature suggests that the four points (with other notable problems such as bond energy, bond polarity, electronegativity) are the key areas of difficulty in the teaching and learning of chemical bonding. In terms of the definition of chemical bonding, EPT's seemed to be much concerned with describing the atoms in a bond, as opposed to recognising that what matters in a bond in fact, is the electrostatic attraction (Silberberg, 2015). The study lent EPT's a great opportunity to explore their use of representations for this topic. From the given representations, it became clear that EPT's preferred what was tangible to explain chemical concepts Gensler (1970). This problematizes the teaching of chemical bonding. In chapter 2, I argued that chemical bonding is one of the most important topics in chemistry and understanding this topic is also fundamental to other topics within the same discipline. The use of representations is very important in this topic, more so the use of analogies and metaphors creates room for students to understand the concepts better. However, EPT's use and preferences in representations suggested that their thinking was aligned to what can be seen or touched -operating in one level of representations. This was unlike the recommended use of three levels of representations (Johnstone, 2001):

Figure G Showing three levels of representation



From the figure, each form of representation is important, but the representations have limitations. EPT's responses seemed to suggest that using *only* macroscopic representations would be *enough* to develop learners' understanding of the ideas about bonding.

In terms of the octet rule, the findings were alarming. EPT's showed that they thought the octet rule was the *absolute* rule for bonding. This was observed in responses where they spoke of the idea that; 'ultimately what atoms need is to fill their outer shell, *as in group 8 elements'*. Although much of this was discussed in the intervention, EPT's held on to their original ideas that they came with into the programme. Glasersfeld (1989) attests to this finding. He says that sometimes students have such strong misconceptions that even after learning the correct concepts in the classrooms, they resist modifying their pre-existing ideas. Instead, they try to interpret the new acquired knowledge using their preconceptions.

EPT's prior conceptions seemed to have put them in a comfortable space to think and attempt some work on both covalent and ionic bonding. They seemed less accustomed to learning and discussing on metallic bonding. There were two issues with this type of bond: that EPT's thought metallic bonding was weaker bonding than the other two and they seemed to struggle with the concept of delocalisation of electrons in graphite Tan & Treagust (1999).

5.8 Developed explicit ways of thinking about their teacher knowledge

Good teaching is not only about knowledge but also the capability to reason soundly about teaching (Mavhunga, 2012). The seminal founder of the TSPCK construct saw potential in the construct in its early stages of inception. According to Shulman (1987), the benefit for teachers with PCK is their capacity to transform their comprehension, as they pedagogically reason about their teaching. This was evident in both the EPT's written work and the interviews.

Because PCK is hidden knowledge, the exposure to a TSPCK intervention was evident in the improvement of the construct itself on the student teacher as well as getting them to begin reasoning in some desired way about their teaching. Kind (2009) attests to the indefinable nature of PCK and draws on the fact that PCK is developed through teaching in practice. Although scholars have been of the view that PCK tacit- hidden knowledge trapped in the minds of the teacher, this intervention successfully drew on EPT's TSPCK in the topic of chemical bonding. It is however, accepted that pre-service teachers rarely demonstrate teaching that is evident of PCK by virtue of their lack of classroom practice experience (Mavhunga, 2012). Thus, at a pre-service teacher level, the likely PCK, and TSPCK, to be developed is in an espoused format which is at a level of planning and reasoning (Mavhunga 2012, 2014). According to Kind, (2009a) there are reported inadequacies in EPT's still in the

process of learning to teach. However, the TSPCK intervention based research that has been employed in this study indicates that it is now possible for teacher educators to produce highly knowledgeable teachers. TSPCK provides a useful conceptual framework for understanding and developing teachers' competence. The intervention provided one of the ways to get EPT's to gain knowledge about the nature of knowledge, and this is pointed out in acknowledgement that the development of knowledge is a complex process.

5. 9 Possible answers to the research questions

The study advocated for a more *explicit* means of thinking about teacher knowledge where teachers begin to think and reason about their teaching drawing from selected components of TSPCK. The underlying assumption was that this process was to enable the measuring of the quality of TSPCK in EPT's to be less complex. I have argued that shifting to this way of thinking about our instruction makes us opportune to capturing the knowledge that would have otherwise been abstract and embedded only in the minds of the teachers. Of interest to this study was the EPT's understanding of the central ideas of chemical bonding, measuring their ability or inability to connect and formulate relationships between big ideas and subordinate ideas and to capture whether they are in fact able to transform their knowledge of chemical bonding for thoughtful instruction. The main question was posed thus: What is the impact of an intervention that targeted the development of TSPCK in chemical bonding in EPT through the explicit instruction of three selected TSPCK components?

To make links and draw conclusions and provide possible answers to this question, the possible answers to the following sub questions were mandatory:

(i) What is the impact of the intervention on EPT's in chemical bonding content knowledge?

(ii) What is the impact of the intervention on the quality of EPT's TSPCK in planning for teaching chemical bonding?

What is the impact of the intervention of the EPT's chemical bonding content knowledge?

This first question aimed to investigate how EPT's content knowledge was developed through an exposure to the TSPCK intervention. The intervention covered both content and topic specific pedagogical knowledge aspects that relate to chemical bonding. In terms of the CK, EPT's development of this knowledge was observed. Evidence of this development was

captured in the quality of the responses. EPT's improved significantly in questions that required recall of facts about the topic. However, this being the case, evidence of notable conceptual understanding was captured in the CK tool analysis. When results of the CK tests were compared (that is, a comparison of the CK pre and post-test) it was evident that an exposure to the intervention fostered some development of chemical ideas in EPT's. EPT's were seen to be able to reflect on their knowledge about the topic and also reflected on the limitations of their own CK. The cohort also demonstrated sound understanding of concepts they had initially struggled with prior to the intervention. EPT's were seen to start articulating issues relating to content in terms of their own backgrounds- what content was taught to them in their high school experiences and also how this content knowledge relates to their current positionality.

What is the impact of the intervention on the quality of EPT's TSPCK in planning for teaching chemical bonding?

The question was centered on the understanding of how EPT's topic specific pedagogical expertise was shaped by the exposure to the TSPCK intervention. The study has shown that quality TSPCK development relies on the strength of CK. Evidence of significant shifts in EPT's TSPCK were observed, the development of CK and TSPCK were seen to happen simultaneously. EPT's reflected on the strengths of their CK understanding through engaging with the questions given in the TSPCK tool. The reflections that EPT's gave were an essence of their teacher efficacy, they could position themselves in terms of their own strength in teacher knowledge and how this knowledge can help them start deliberating their classroom practice as future teachers. EPT's also attested to this value of the intervention on their development as they saw the TSPCK model as a source of their realization of the importance of CK understanding, and more so on how this content could be transformed into its teachable means. The value of TSPCK being measurable also helped EPT's become aware of how their PCK can potentially be measured; advancing the idea that PCK is tacit and developed with years of expert teaching in the classroom practice. The EPT's TSPCK quality could be improved from a perspective of thinking and planning.

What is the impact of an intervention that targeted the development of TSPCK in chemical bonding in EPT through the explicit instruction of three selected TSPCK components?

In previous studies, the development of EPT's TSPCK was measured based on the explicit exposure to the five components of TSPCK, namely, learner prior knowledge, representations, curricular saliency, what makes the topic easy, what makes the topic difficult and conceptual teaching strategies. For this present study, EPT's were exposed to an explicit intervention consisting of three components. These components were learner prior knowledge, representations, and conceptual teaching strategies. The TSPCK intervention which entailed a limited number of components provided EPT's support the development of TSPCK components separately. This resulted in EPT's being able to connect TSPCK components with one another. The use of limited components also illustrated that the development of one component affects the whole improvement of TSPCK. This was evident in how EPT's could relate to TSPCK components that were not taught explicitly in the course. The three components selected for the intervention showed the relationship, in the nature of the interaction between the components. Their relationship also showed that TSPCK components cannot be considered as separate entities because these components interrelate. The integration of all these TSPCK components was what was captured in the observed TSPCK development in planning and reflection.

5.10 Reflections on rationale

The fore aim of this study was to investigate a way that EPT's development of teaching Chemical Bonding could be fast tracked before embarking in formal classroom teaching. Because EPT's in their beginning stages do not display the necessarily proficiencies in the subjects that they teach, exposing EPT's to a TSPCK intervention was recognised as one of the effective ways to develop their content and pedagogical expertise. The study helps to appreciate that training EPT's in their beginning stages of their teacher education programme can help foster the development skills and knowledge forms such as those related to CK and the pedagogical expertise to teach this content. EPT's in this study began reflecting on this amalgam of content and pedagogical knowledge as knowledge bases that represents the understanding necessary for transforming CK into forms that are more accessible to students (Shulman, 1986 ;1987). From the data collected and analysed, it became apparent that EPT's

in the sample grew appreciation that good understanding of their CK serves as primary basis for their development of pedagogical proficiency.

Running a TSPCK intervention on a topic such as chemical bonding was based on the understanding that it would be challenging would be for the inexperienced teacher to learn and understand it for teaching purposes. The study does not claim that EPT's have fully developed in their TSPCK in the topic however, without the intervention, EPT's knowledge in the topic may have continued to be limited to what they know and understand, as well as what they perceive as manageable to comprehend and fully articulate for instruction. Using TSPCK has, based on the reported result of this project, enhanced the learning and understanding of chemical bonding and may to an extent; improve the practice associated with teaching such a topic.

5. 11 Appropriateness of research design

The research design followed MM approach. The use of the approach was due to its strength in capturing both qualitative and quantitative data. In this reflection, I have considered four aspects of this approach: Its capacity to provide a broader perspective, its capacity to limit personal bias, provision of more data and the provision of different answers.

5. 11. 1 Capacity to provide a broader perspective

The use of qualitative and quantitative data implied that the strengths of both methodologies were acknowledged to provide a broader perspective on the data collected. This was so in the CK and the TSPCK tests that was collected for analysis. This qualitative data was subject to quantitative means and this provided a much broader perspective on the data. The multiplicity of the data perspective enabled the research to provide more comprehensive and reliable evidence. The research questions that were asked could not be answered by qualitative or quantitative approaches alone because capturing the strength of CK and TSPCK. In investigating the development of EPT's TSPCK in the topic, the CK and TSPCK data could be quantitatively analyzed however, there were underlying factors of experiences and also how EPT's made sense of these experiences. It is in this amalgam that the broad perspective of the data was most useful.

5. 11. 2 Capacity to limit personal bias

The MM research design follows a pragmatic perspective. This perspective has helped in the analysis and reporting of the findings. The data reported was based on the research questions asked and what has been highlighted as the answers to these questions has been regarded as what is fit and practical regarding the research questions under investigation. The findings are not interpreted based on the researchers' views but based on the problem under investigation. In chapter one, I provided the key questions that guided the study, and in designing the inquiry, the questions were the primary basis for the selection of analytic tools.

5. 11. 3 Provision of more data

The process of offering a statistical analysis from the quantitative data together with quantitative means of collecting EPT's written works made the research more comprehensive. In an attempt to answer the research questions, a consideration of multiple sources of data provided an opportunity to gather more information from which to draw conclusions. The CK and TSPCK tools provided both qualitative and qualitative data while the written work and the interviews helped to confirm and consolidate these data.

5. 11. 4 Provision of different answers

A statistical analysis, generated from quantitative means provided one answer, a percentage for instance, where EPT's scores were analyzed. Having these results with some evidence of written and spoken data from the paper pencil instruments as well as the made the research more comprehensive. The combination of the CK, TSPCK and interview data ensured that the provided a better understanding of research problems. The data collected each had a place in the key findings. Using MM revealed a variety of information that was different and served the same purpose. This gave multiple perspectives on the same data.

5.12 Implications for science education, teaching and learning and teacher education

There are number of implications that are underlying the present study:

(i) The data in this study provides a basis in terms of designing a model that suits EPT's content developmental needs at various stages of their 'learning to teach' process.

(ii) That the TSPCK model operates on a content specific base, therefore this enables teachers to adopt more specific instruction.

(iii) The TSPCK framework gives a model that allows the possibility for more topics to be covered especially those topics that are known to be problematic in NSC and those that are highlighted in literature. This will be helpful for beginner EPT's who are in need of this content for teaching practice.

5.13 Limitations of the study

The study acknowledges the following limitations to the data and findings reported:

(i) The study lacked a control group to help compare the strength and impact of the intervention.

(ii) Controlled sample size was one of the practical limitations of the study.

(iii) The study did not investigate the impact of their previous experiences on the amount of content captured, nor did the study acknowledge learnt competencies that may have come through socializing with peers, experts and other relevant individuals.

(iv) The study and data collection happened in a short period of time. The short period of time may have hindered the opportunity to capture significant improvement.

5.14 Recommendations for further study

From what has been discussed in the key findings of this study, it has become seeming that further research is needed regarding the nature and development of the interaction among preservice teachers' TSPCK components, and regarding how various contexts can stimulate the development and strengthen the interaction of these components. It is therefore recommended in the study that focus should be on the four aspects highlighted as the core problems in the learning of chemical bonding. The four problems are EPT's showed no mention of the electrostatic nature of chemical bonding, (b) EPT's used macroscopic levels of representations to explain and describe bonding (c) EPT's in the study over emphasized the rule of the octet to explain chemical bonds (d) EPT's struggle with the idea of delocalized electrons in metals Since EPTs have shown that they prefer the macroscopic representations, rather teacher educators focus on developing this preference to enhance their learning.

5. 15 Conclusion of chapter

This chapter has put together the key findings of the study and discussed these findings in light with existing literature. The TSPCK framework although having been the conceptual tool used to analyse the EPT's development, has given rise to the possibility of thinking about learning to teach in the perspective of EPT's in their beginning stages of development. This creates, in the scholarly community, hope for the development of EPT's pedagogical reasoning. Topic Specific PCK as measured in the context of pedagogical reasoning, specifically the transformation element, has been found to improve with explicit instruction. This suggests possibilities for accelerated preparation of teachers for practice in the realm of a construct which has previously been thought to be developed with extended and reflective experience only. These findings have immediate potential benefits for teacher preparation in the South African context.

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APPENDICES

Appendix 1

Chemical Bonding

Chemical Bonding Content Knowledge Tool

Question 1:

For each of the questions below, choose an option from A or B, and a reason for your choice from 1, 2, 3 or 4. Circle your answer in the space provided, e. g.

1.1 Sodium chloride exists as a molecule.

A TRUE

B FALSE

A	B	1	2	3	4
	○				○

My reason for choosing A or B is:

1. The sodium atom shares a pair of electrons with the chlorine atom to form a simple molecule.
2. After donating its valence electron to the chlorine atom, the sodium ion forms a molecule with the chlorine ion.
3. Sodium chloride exists as a lattice consisting of sodium ions and chloride ions.
4. Sodium chloride exists as a lattice consisting of covalently bonded sodium and chlorine atoms.

My answer is:

A	B	1	2	3	4

1.2 Element C (electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$) and element E (electronic configuration $1s^2 2s^2 2p^5$) react to form an ionic compound CE_2.

A TRUE

B FALSE

My reason for choosing A or B is:

1. The atom of C will share one pair of electrons with each atom of E to form a covalent molecule CE_2.
2. A macromolecule is produced consisting of covalently bonded atoms of C and E.
3. An atom of C will lose one electron to an atom of E to form an ionic compound CE.
4. Atoms of C will each lose two electrons and twice as many atoms of E will each gain one electron to form an ionic compound CE_2.

My answer is:	A B	1 2 3 4

1.3 Metals are hard and strong because the forces which keep the metal atoms together are strong.

A TRUE

B FALSE

My reason for choosing A or B is:

1. Metallic bonding in a metal is a sea of electrons in between positive nuclei and not a force.
2. Metal atoms are tightly packed which gives the metal properties such as hardness and strength.

3. Metals consist of overlapping orbitals with delocalised valence electrons which are attracted to positively charged nuclei in all directions.
4. The electrons in a metal are free to move and the layers of atoms can easily slide over each other.

My answer is:	A B	1 2 3 4

Question 2:

2. 1 What is a chemical bond?

2. 2 Draw a detailed picture to illustrate your answer in 2. 1 above.

2. 3 Why do atoms bond with each other?

2. 4 Can the bond between two atoms have both covalent and ionic character? Explain your answer.

Question 3

Aluminium is often used in foil in the catering industry.



3. 1 What is the name of the type of bonding between the atoms in a piece of aluminium?

3. 2 Describe how the bond mentioned in 4. 1 is formed.

3. 3 Aluminium is malleable, ductile and conducts electricity. Based on the type of bonding you described in 4. 2, explain one of these properties of aluminium.

THE END

Appendix 2

Chemical Bonding TSPCK Tool based on learner prior knowledge,

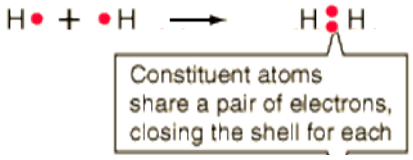
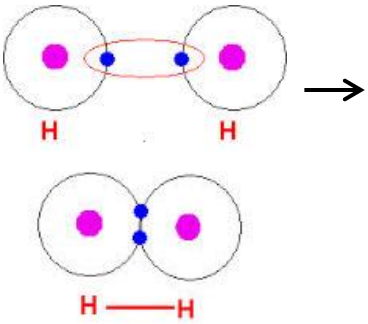
Representations and Conceptual Teaching strategies

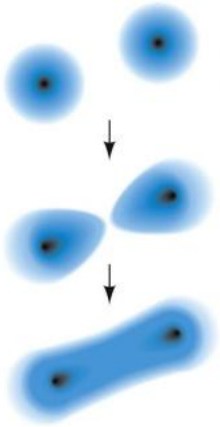
KNOWLEDGE FOR TEACHING CHEMICAL BONDING

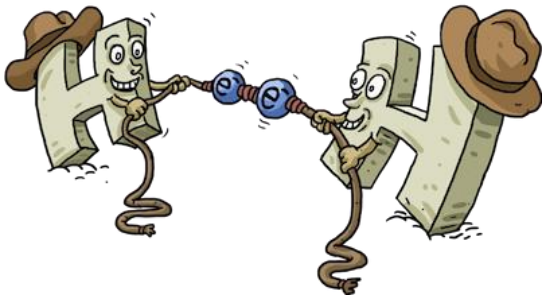
Section 1: Representations

1. 1 Chemical bonding is often represented through drawings and diagrams. A few examples of such representations are shown below.

Look at each of the representations and describe what you like and what you don't like about it as a tool to teach about chemical bonds and why. Fill in your answers on the next page.

Representation 1 	Representation 2 
Representation 3	Representation 4



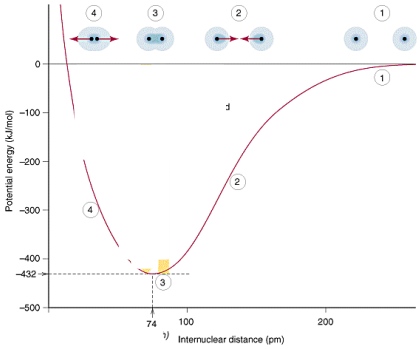


Representation 5

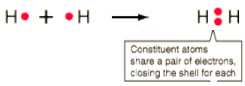
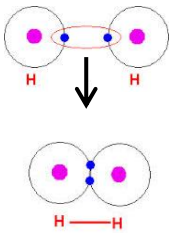
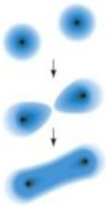
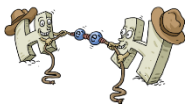
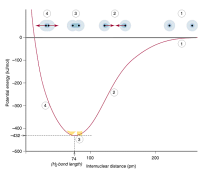
Using the learners in your class to represent chemical bonds as follows:



Representation 6



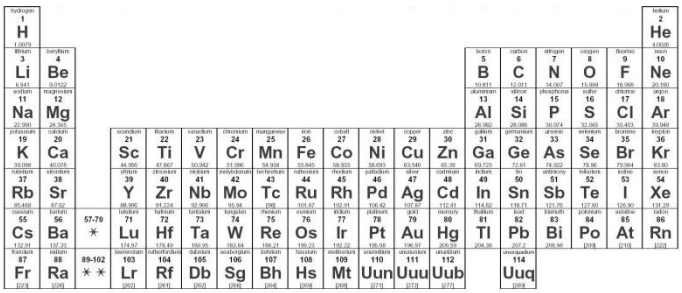
	What I like and why (Strengths of the representation)	What I don't like and why (Weaknesses of the representation)

Representation 1 		
Representation 2 		
Representation 3 		
Representation 4 		
Representation 5 		
Representation 6 		

1. 2 Which one of above representations did you like the most? Describe how you would use it in a lesson in the space provided below. If you did not like any of these, you can draw your own representation below.

The representation I like most is number _____
I did not like any of them, I prefer this one:
I chose this representation because …
In a lesson I would use it as follows:

Section 2: Learners' prior knowledge



2. 1 Learners need to know about the Periodic Table before chemical bonding can be taught. Some of the ideas that are discussed in the section on the Periodic Table are shown below. Which one of these is the most important when you teach about chemical bonding for the first time? Give a reason for your answer and explain how you would use it in your teaching.

A: Metals are on the left hand side and non-metals are on the right hand side of the Periodic Table.

B: Elements in the same group have similar chemical properties.

C: The electronic configuration of atoms can be deduced from the Periodic Table.

D: The properties of substances can be deduced from the position of the elements in the Periodic Table.

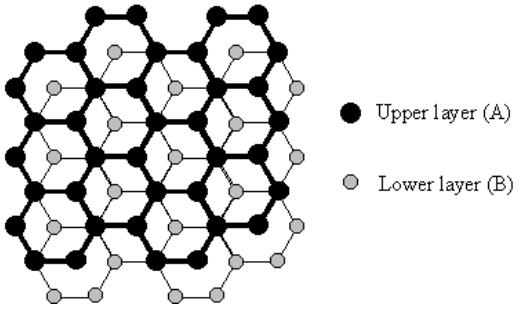
E: Noble gases are found in group 18 and have a full electron shell.

The most important one is: ……B
Reason for my choice:

I will use it in teaching in the following way:

Section 3: Conceptual teaching strategies

3. 1 In a lesson to show the links between the properties of materials and chemical bonding, a teacher uses the diagram on the right to explain why graphite is a good material to use in pencil 'lead':



'Graphite is made of carbon atoms arranged in six-membered rings and packed in layers. It is a good material to use in pencils because the layers can easily slide over each other. '

Despite the explanation the teacher finds that the learners still struggle to understand the links between this property, the structure of graphite and the chemical bonds involved.

How would you teach this lesson? Consider the following in your answer: what teaching strategy will you follow; what content will you include and the order in which to teach the content, what to rather leave out; are there any ideas that learners typically struggle with, and how you would address these; what representations, pictures, examples or analogies will you use.

Appendix 3

1. You wrote a test based on Chemical bonding and a TSPCK test that goes with it. How was your experience with the content test? How was your experience with the TSPCK test?
   1.1 How would you describe the test?
   1.2 Which areas did you find difficult?
   1.3 Which areas did you find easy?
   1.4 How do your marks compare in the pre and the post test result?
   1.5 Can you elaborate on the shits (or lack of observed?)
2. You were exposed to a 6 week TSPCK intervention. Describe your experience during this period.
   2. 1. How did you find the material handed to you during this process?
   2. 2. To what extent would you say the intervention develop your knowledge?
   2. 3. Which sections of the intervention did you most enjoy?

2.3 Which sections of the intervention would you say needed improvement?

Appendix 4

CODE	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Mark Scored / 13	% score /100
RAM	0(1)	0(1)	1(1)	0(0)	1(1)	0(1)	0(1)	1(1)	0(1)	0(1)	1(1)	1(1)	0(0)	5(11)	40. 71(78. 35)
ROB	0(1)	0(1)	1(1)	0(1)	1(0)	1(1)	0(1)	0(1)	1(1)	0(1)	1(1)	0(1)	0(0)	5(11)	40. 71(78. 35)
SEK	1(1)	0(1)	1(1)	0(1)	1(1)	0(1)	0(1)	1(1)	0(1)	1(1)	0(1)	0(1)	1(0)	6(12)	46. 32(88. 04)
VOA	1(1)	0(1)	1(1)	0(0)	1(1)	0(0)	0(1)	1(1)	0(1)	0(1)	1(1)	0(1)	0(1)	5(11)	40. 71(78. 35)
AKA	1(1)	1(1)	1(1)	1(0)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	0(1)	11(12)	78. 35(88. 04)
SAM	1(1)	0(1)	1(1)	0(0)	1(1)	1(0)	1(1)	0(1)	1(1)	0(1)	1(1)	0(1)	0(1)	7(11)	52. 15(78. 35)
NAI	1(1)	0(1)	1(1)	0(1)	1(1)	1(0)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	0(1)	9(12)	64. 58(88. 04)
GOM	1(1)	0(1)	1(1)	0(0)	1(1)	0(0)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	0(0)	8(10)	58. 26(71. 12)
TOK	1(1)	1(1)	1(1)	1(0)	0(1)	1(0)	1(1)	1(1)	1(1)	1(0)	1(1)	0(1)	0(0)	10(9)	71. 12(64. 58)
MOF	1(1)	0(1)	1(1)	0(0)	1(1)	0(0)	1(1)	0(1)	0(1)	1(0)	0(1)	1(1)	1(0)	7(9)	52. 15(64. 58)
MOK	1(1)	0(1)	1(1)	0(0)	1(1)	0(0)	1(1)	0(1)	1(1)	0(0)	1(1)	1(1)	1(0)	8(9)	58. 26(64. 58)
UOM	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	11(13)	78. 35(100. 0)
MAD	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	11(13)	78. 35(100. 0)
SEF	1(1)	1(1)	1(1)	1(0)	1(1)	0(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	12(12)	88. 04(88. 04)
SON	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	12(13)	88. 04(100. 0)
MAT	1(1)	0(1)	1(1)	0(1)	1(1)	0(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	9(13)	64. 58(100. 0)
SIT	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	0(1)	10(13)	71. 12(100. 0)
MAV	1(1)	0(1)	1(1)	0(0)	1(1)	0(1)	1(1)	1(1)	0(1)	1(1)	1(1)	0(1)	0(1)	7(12)	52. 15(88. 04)
MIH	1(1)	0(1)	1(1)	0(0)	1(1)	0(0)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	9(11)	64. 58(78. 35)
KHO	1(1)	0(1)	1(1)	0(1)	1(1)	1(1)	0(1)	1(1)	1(1)	0(1)	1(1)	1(1)	0(1)	8(13)	58. 26(100. 0)
MKH	1(1)	1(1)	1(1)	0(0)	1(1)	1(1)	1(1)	1(1)	0(0)	1(1)	1(1)	0(0)	0(0)	9(9)	64. 58(64. 58)
SET	1(1)	0(0)	1(1)	0(0)	1(1)	0(0)	1(1)	1(1)	1(1)	0(0)	1(1)	0(0)	0(0)	7(7)	52. 15(52. 15)
NDL	1(1)	1(1)	0(0)	0(0)	1(1)	1(1)	1(0)	1(0)	1(1)	0(0)	1(1)	1(1)	0(0)	9(7)	64. 58(52. 15)
MBL	1(1)	1(1)	1(1)	0(0)	1(1)	0(0)	1(1)	1(1)	1(1)	0(0)	1(1)	1(1)	0(0)	9(9)	64. 58(64. 58)
TTA	1(1)	1(1)	1(1)	0(0)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	1(0)	1(1)	1(1)	11(11)	78. 35(78. 35)
AKY	1(1)	1(1)	1(1)	0(0)	1(1)	0(0)	1(1)	1(1)	1(1)	0(0)	1(1)	1(1)	0(0)	9(9)	64. 58(64. 58)
SIA	1(1)	1(1)	1(1)	0(0)	1(1)	1(1)	1(1)	1(1)	1(1)	0(0)	1(1)	1(1)	0(0)	10(10)	71. 12(71. 12)
MUH	1(1)	1(1)	1(1)	1(1)	1(1)	0(0)	1(1)	1(1)	1(1)	0(0)	1(1)	1(1)	0(0)	10(10)	71. 12(71. 12)
PRS	1(1)	0(0)	1(1)	0(0)	1(1)	0(0)	1(1)	1(1)	1(1)	0(0)	1(1)	1(1)	1(1)	9(9)	64. 58(64. 58)
GOO	1(1)	1(1)	1(1)	0(0)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	1(1)	11(12)	78. 35(88. 01)
SAH	1(1)	0(1)	1(1)	1(0)	1(1)	0(0)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	11(11)	78. 35(78. 35)
IVI	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)	12(13)	88. 04(100. 0)
BEA	1(1)	0(0)	1(1)	0(0)	1(1)	1(1)	1(1)	1(1)	1(1)	0(1)	1(1)	1(1)	0(0)	9(10)	64. 58(71. 12)
TII	1(1)	0(0)	1(1)	0(0)	1(1)	0(0)	1(1)	1(1)	1(1)	0(0)	1(1)	1(1)	0(0)	8(8)	58. 26(58. 26)
NOP	1(1)	1(1)	1(0)	1(0)	1(1)	1(1)	1(1)	1(1)	1(0)	0(0)	1(1)	1(1)	1(1)	12(9)	88. 04(64. 58)

Item mean out of 35: 24. 5 (28. 5)
Person mean score out of 13: 9. 1 (10. 6)
Person reliability . 51 (. 50)
Item reliability . 89 (. 82)

Appendix 5

CODE	LPK /4	RPS /4	CTS /4	Total /12	% scores /100
RAM	2(3)	2(3)	2(2)	6(8)	50. 00(66. 67)
ROB	2(2)	2(3)	2(2)	6(7)	50. 00(58. 33)
SEK	1(1)	2(2)	1(2)	4(5)	33. 33(41. 67)
VOA	3(3)	2(2)	2(2)	7(7)	58. 33(58. 33)
AKA	2(2)	2(3)	1(2)	5(6)	41. 67(50. 00)
SAM	3(3)	2(2)	2(2)	7(7)	58. 33(58. 33)
NAI	3(3)	2(3)	2(2)	7(8)	58. 33(66. 67)
GOM	2(2)	3(3)	1(2)	6(7)	50. 00(58. 33)
TOK	2(2)	2(2)	2(2)	6(6)	50. 00(50. 00)
MOF	2(2)	1(2)	2(2)	5(6)	41. 67(50. 00)
MOK	3(3)	2(3)	2(2)	7(8)	58. 33(66. 67)
UOM	4(4)	2(2)	2(2)	8(8)	66. 67(66. 67)
MAD	3(3)	2(2)	2(2)	7(7)	58. 33(58. 33)
SEF	3(3)	2(2)	1(1)	6(6)	50. 00(50. 00)
SON	2(3)	2(2)	2(2)	6(7)	50. 00(58. 33)
MAT	2(2)	2(2)	2(2)	6(6)	50. 00(50. 00)
SIT	1(1)	2(2)	1(1)	4(4)	33. 33(33. 33)

MAV	2(2)	1(1)	1(1)	4(4)	33. 33(33. 33)
MIH	2(2)	2(2)	1(1)	5(5)	41. 67(41. 67)
KHO	3(3)	2(2)	1(1)	6(6)	50. 00(50. 00)
MKH	3(3)	3(3)	2(2)	8(8)	66. 67(66. 67)
SET	2(2)	2(3)	1(1)	5(6)	41. 67(50. 00)
NDL	1(1)	2(2)	1(1)	4(4)	33. 33(33. 33)
MBL	2(2)	2(2)	1(1)	5(5)	41. 67(41. 67)
TTA	3(3)	2(2)	1(1)	6(6)	50. 00(50. 00)
AKY	3(3)	2(2)	2(2)	7(7)	58. 33(58. 33)
SIA	3(3)	2(3)	2(2)	7(7)	58. 33(58. 33)
MUH	3(3)	2(3)	2(2)	7(7)	58. 33(58. 33)
PRS	2(3)	1(2)	1(2)	4(7)	33. 33(58. 33)
GOO	2(2)	2(2)	1(1)	5(5)	41. 67(41. 67)
SAH	2(3)	2(3)	1(2)	5(8)	41. 67(66. 67)
IVI	1(2)	2(2)	1(2)	4(6)	33. 33(50. 00)
BEA	2(2)	2(2)	1(2)	5(6)	41. 67(50. 00)
TII	1(2)	2(2)	1(2)	4(6)	33. 33(50. 00)
NOP	2(3)	2(2)	2(2)	6(7)	50. 00(58. 33)

Item mean (%) 65. 00 (74. 30)

Person mean 5. 6 (6. 4)

Person reliability . 50 (. 50)

Item reliability . 97 (. 97)

Appendix 6

CODE	SEL.
RAM	A
ROB	A
SEK	A
VOA	A
AKA	E
SAM	B
NAI	A
GOM	A
TOK	A
MOF	C
MOK	B
UOM	B
MAD	A
SEF	A
SON	E
MAT	E
SIT	E
MAV	E
MIH	A

KHO	A
MKH	E
SET	A
NDL	A
MBL	A
TTA	E
AKY	B
SIA	D
MUH	E
PRS	A
GOO	E
SAH	E
IVI	D
BEA	A
TII	D
NOP	A

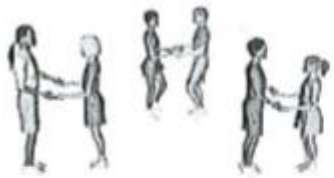
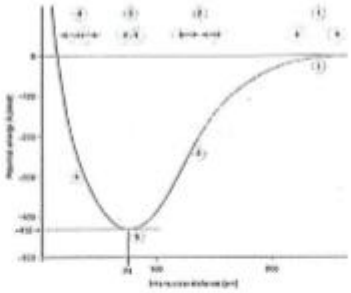
Appendix 7

CODE	PREFFERRED REPRESENATION
RAM	1
ROB	4
SEK	4
VOA	2
AKA	5
SAM	4
NAI	1
GOM	5
TOK	1
MOF	1
MOK	6
UOM	4
MAD	1
SEF	5
SON	1
MAT	4
SIT	5
MAV	5

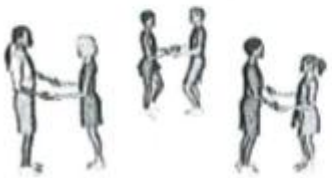
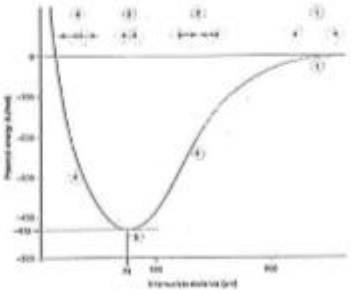
MIH	4
KHO	5
MKH	1
SET	6
NDL	5
MBL	5
TTA	1
AKY	4
SIA	1
MUH	2
PRS	5
GOO	1
SAH	3
IVI	4
BEA	1
TII	1
NOP	5

Appendix 8

Representations

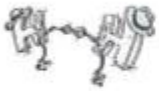
Representation 5	Representation 6
Using the learners in your class to represent chemical bonds as follows: 	

	What I **like** and **why** (Strengths of the representation)	What I **don't like** and **why** (Weaknesses of the representation)
Representation 1 	This shows that H & H came together in a bond. Learners are familiar with the + sign from maths so bonding means two things joining. H has one valence e- so forms 1 bond. This is shown	This one is difficult for learners whose ideas of atoms are not developed. Using such an example in class will make learners who struggle with microscopic ideas suffer

Representation 5	Representation 6
Using the learners in your class to represent chemical bonds as follows: 	

	What I **like** and **why** (Strengths of the representation)	What I **don't like** and **why** (Weaknesses of the representation)
Representation 1 	It shows electrons. Since bonding is about either giving or sharing electrons. This is the best representation	If a learners asks about bonding, this cannot give an everyday example.

Representation 4 	This is very good for learners who battle with microscopic representations	This representation can cause a lot of misconceptions It looks like atoms fight for electrons. What I know is that (+) and (-) attract.

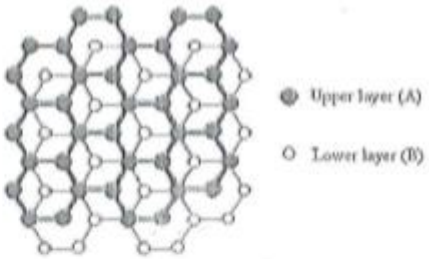
Representation 4 	It shows that electrons are shared between two hydrogen atoms.	I don't understand how H atoms can be happy to share but also pull the rope as if they are competing for electrons.

Representation 5 	This representation is very handy because learners become the learning resource This will be good in schools without resources	It can be difficult for learners and can take them a while to start thinking in terms of microscopic ideas.

Representation 5 	The use of what learners can see is important. In this case It can easily make learners do the same in class to show bond formation	Atoms are not like people difficulties. It is difficult to explain something so small using people & big bodies

5.2 In a lesson to show the links between the properties of materials and chemical bonding, a teacher uses the diagram on the right to explain why graphite is a good material to use in pencil 'lead':

'Graphite is made of carbon atoms arranged in six-membered rings and packed in layers. It is a good material to use in pencils because the layers can easily slide over each other.'



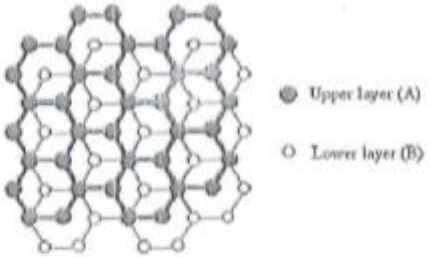
Despite the explanation the teacher finds that the learners still struggle to understand the links between this property, the structure of graphite and the chemical bonds involved.

How would you teach this lesson? Consider the following in your answer: what teaching strategy will you follow; what content will you include and the order in which to teach the content, what to rather leave out; are there any ideas that learners typically struggle with, and how you would address these; what representations, pictures, examples or analogies will you use.

Graphite consists of layers of carbons atoms. The layers have the ability to slide over one another because of the existance of weak forces betweem them. This can explain why you can sharpen pencil All my learners have the prior experience of using pencils and have seen its behavior The idea of delocalised electrons may be a challenge to learners because of the fact that carbon can form four bonds in organic chemistry. The bonds in this can be called strong covalent bonds. Covalent bonding refers to the sharing of electrons.

Section 5: Conceptual teaching strategies

5.2 In a lesson to show the links between the properties of materials and chemical bonding, a teacher uses the diagram on the right to explain why graphite is a good material to use in pencil 'lead':



'Graphite is made of carbon atoms arranged in six-membered rings and packed in layers. It is a good material to use in pencils because the layers can easily slide over each other.'

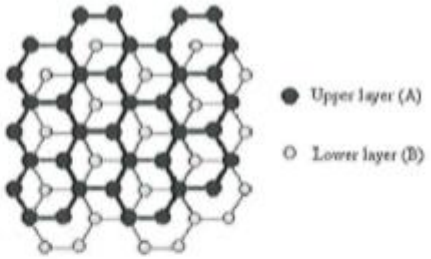
Despite the explanation the teacher finds that the learners still struggle to understand the links between this property, the structure of graphite and the chemical bonds involved.

How would you teach this lesson? Consider the following in your answer: what teaching strategy will you follow; what content will you include and the order in which to teach the content, what to rather leave out; are there any ideas that learners typically struggle with, and how you would address these; what representations, pictures, examples or analogies will you use.

I would start by telling learners that graphite consists of delocalised electrons. These are free electrons which are free to move anywhere. There are strong covalent bonds in graphite. At this point, I would remind learnes about forces that hold atoms together, in this case being van-der-Waals forces.

Section 5: Conceptual teaching strategies

5.2 In a lesson to show the links between the properties of materials and chemical bonding, a teacher uses the diagram on the right to explain why graphite is a good material to use in pencil 'lead':



'Graphite is made of carbon atoms arranged in six-membered rings and packed in layers. It is a good material to use in pencils because the layers can easily slide over each other.'

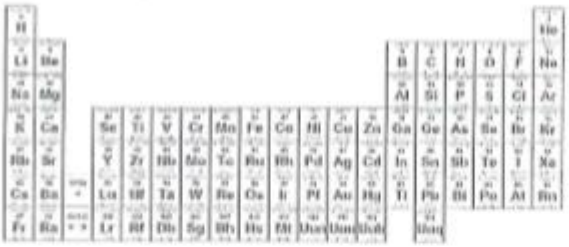
Despite the explanation the teacher finds that the learners still struggle to understand the links between this property, the structure of graphite and the chemical bonds involved.

How would you teach this lesson? Consider the following in your answer: what teaching strategy will you follow; what content will you include and the order in which to teach the content, what to rather leave out; are there any ideas that learners typically struggle with, and how you would address these; what representations, pictures, examples or analogies will you use.

In teaching this lesson, I would start by identifying the type of bonding in graphite. Graphite consists of covalently bonded atoms. The structure of graphite consists of delocalised electrons

Learners' Prior Knowledge

Section 4: Learners' prior knowledge



4.1 Learners need to know about the Periodic Table before chemical bonding can be taught. Some of the ideas that are discussed in the section on the Periodic Table are shown below. Which one of these is the **most important** when **you teach** about chemical bonding for the **first time**? Give a **reason** for your answer and explain **how you would use it** in your teaching.

A: Metals are on the left hand side and non-metals are on the right hand side of the Periodic Table.

B: Elements in the same group have similar chemical properties.

C: The electronic configuration of atoms can be deduced from the Periodic Table.

D: The properties of substances can be deduced from the position of the elements in the Periodic Table.

E: Noble gases are found in group 18 and have a full electron shell.

The most important one is: ..... E
Reason for my choice: All atoms have the desire to be like group 8 elements. These are noble gases. The octet rule says that all atoms should have outer levels such as atoms in group 8. Through bonding, elements have their outer most energy shell filled. It is important to make learners understand the noble gases and how they are special to be able to make them see why atoms bond.

4.1 Learners need to know about the Periodic Table before chemical bonding can be taught. Some of the ideas that are discussed in the section on the Periodic Table are shown below. Which one of these is the **most important** when **you teach** about chemical bonding for the **first time**? Give a **reason** for your answer and explain **how you would use it** in your teaching.

A: Metals are on the left hand side and non-metals are on the right hand side of the Periodic Table.

B: Elements in the same group have similar chemical properties.

C: The electronic configuration of atoms can be deduced from the Periodic Table.

D: The properties of substances can be deduced from the position of the elements in the Periodic Table.

E: Noble gases are found in group 18 and have a full electron shell.

The most important one is: .....E
Reason for my choice:

I will use it in teaching in the following way:
The reason why we have chemical bonding in the first place is because all the inorganic are shell needed to be filled. Noble gases don't have this problem so they don't bond with other elements. The rest of the periodic table imitates noble gases through bonding.

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The most important one is: .....A
Reason for my choice: Bonding takes place either between metal non-metals, or between non metals and non metals therefore, if learners don't understand how the periodic table is organized, they won't be able to identify the type of bond.