Grade 11 Agricultural Science Teachers' Topic Specific Pedagogical Content Knowledge in Teaching Organic Compounds: Action-Research in Selected Schools in Libode District

By

P.P. Mbono

Submitted in fulfilment

For the Degree of Master of Education

In the School of Education,

University of KwaZulu-Natal, South Africa

Preface

This study was undertaken at the University of KwaZulu-Natal, School of Education, Science and Technology Education Cluster under Professor Nadaraj Govender.

This study represents my original work and has not been submitted in any form for any degree to any other university. Where use has been made of the work of others, it is duly acknowledged in the text.

P.P. Mbono (Student number: 216057817)

University of KwaZulu-Natal

Supervisor: Professor Nadaraj Govender (UKZN)

Abstract

In Agricultural Sciences, the teaching of chemistry and especially the topic of organic compounds is becoming an area of concern among Agricultural Sciences educators with poor chemistry background who are teaching in rural schools. These educators' poor content and pedagogical knowledge, and pedagogical content knowledge of general chemistry and specifically organic chemistry also affect their learners' understanding of science. This is a concern not only for the Department of Education, as poor results are produced in external examinations, but also for learners who then change career choices from Agricultural Sciences to other subjects perceived to be easier. Agricultural Sciences learners who are taught by teachers who are trained in chemistry are normally exposed to better teaching, as their teachers have good chemistry content knowledge thus minimising alternative conceptions that learners often exhibit. Teachers' difficulties in understanding and therefore teaching organic chemistry is most visible when they interact with learners while trying to find easier ways of making the content meaningful in their classes. Such interaction is expressed as their topic specific pedagogical content knowledge (TS-PCK).

This qualitative study sought to explore Grade 11 Agricultural Sciences teachers' TS-PCK in teaching organic compounds. There are two research questions in this study. Firstly, what problems do Grade 11 Agricultural Sciences teachers encounter in teaching the topic organic compounds? And then, how can action research help Grade 11 Agricultural Sciences teachers to improve their TS-PCK in teaching organic compounds?

It is an action-research study of selected schools in Libode District, Eastern Cape. A qualitative case study approach was chosen. Three Grade 11 Agricultural Sciences teachers were chosen as participants of this study by a purposive sample method, in line with the qualitative research design. Data generation and collection for this study was mainly through interviews with the teachers. The interviews were transcribed, data coded and themes emerged from this data analysis.

The findings of the study confirmed that teachers who had not studied chemistry previously at a tertiary institution held more alternative conceptions in organic chemistry than those who had done so. The teachers without chemistry studies at university level were also found to have insufficient content knowledge for teaching chemistry in Agricultural Sciences. The results also confirmed that the use of workshops based on action research was a practical solution in rural areas for supporting teachers and building their confidence with regard to understanding and teaching the difficult chemistry concepts in Agricultural Sciences.

Dedication

I dedicate this dissertation to my Mother (Nomzi V Mbono) and Father (Mthuthuzeli Mbono) who made it possible for me to study for my Masters. To them I dedicate this work.

For the LORD grants wisdom! From his mouth come knowledge and understanding. ***(Proverbs 2 verse 6)***

Acknowledgement

I would like to send my gratitude to the following people who contributed to the success of this study:

- Professor Nadaraj Govender: You played an incredible role and guidance throughout the study. You gave me an idea of what the word mentoring means. Thank you for your dedication, your generosity and time.
- My child ***Chuma Mbono*** for her understanding when I was absent for a while in her life for studies. Thank you my daughter, may God bless you.
- To my Agricultural Sciences learners: Thank you for understanding when I had to leave you one time without you knowing while doing this study.
- ***Nomzi Mbono***, my Mother for her encouragement and my sisters Zine Mbono, Phumza, Phumela, Thenjiswa and Brothers Sisa and Nkuthalo Mbono. Thank you for your support both verbal and monetary support.
- Mahambehlala my colleague. Thank you for your support in times of need.

Contents

List of Figures

List of Tables

Appendices

Chapter 1

1.1 Introduction

As a Life Sciences and Agricultural Sciences teacher, teaching mostly Grade 11 Agricultural Sciences for 3 years, I have found that the chemistry content was difficult to teach in high school Agricultural Sciences. I first taught at Libode District and came to teach in KwaZulu-Natal (KZN) at an independent school. During my tertiary studies in Life Sciences, chemistry was not covered in-depth, and as a result I experienced conceptual problems in the important chemistry topics in Agricultural Sciences. Since I lacked in-depth subject matter knowledge of chemistry, my confidence as a teacher was often affected and I avoided the topics or taught them minimally. My feelings of inadequacy arising from this problem made me to consult chemistry teachers to assist me with some chemistry concepts. In addition, the results from the assessment of learners at the schools where I taught suggested that inadequate teaching of these chemistry topics in Agricultural Sciences may have negatively affected learners' performance. Some of my colleagues in the Agricultural Sciences district cluster in Libode, Eastern Cape were also experiencing comparable problems. In our district, the Agricultural Sciences cluster (a group of science teachers together with subject advisor) meet at the beginning of each year. Here we would discuss the previous year's examination results and analyse them in the hopes of improvement in the coming year. In the examiners' reports that are presented to us, comments showed that learners continuously experienced problems in the chemistry aspects; more especially among those learners who were not studying Physical Sciences. These learners depend a lot on the Agricultural Sciences teacher for support in understanding the basic chemistry concepts.

Back when, years ago, I was a high school learner, our school comprised only one solid structure and one prefab as classes for all learners and staffroom for educators. It was hard. We even had to study alongside commerce learners in the same classroom because of lack of space. Study halls had dusty floors that were not clean and so not favourable for learning; it was apparent that certain learners were adversely affected by this residue and suffered from various infections. School grounds were poor and the study hall lacked instructional aids that that would excite learners.

The map below in Figure 1.1 shows the rural Libode district in the province of Eastern Cape, where the study took place. The nearest large town is Mthatha, which has a university that educates future teachers. The three schools that were chosen for this study are close to each other, while others are scattered far away from each other in Libode District.

Figure 1.1 Map of Libode (https://www.google.com/maps/place/Libode)

This study is focused on Agricultural Sciences Grade 11 teachers' understanding of topic specific pedagogical content knowledge (TS-PCK) in the special topic of organic compounds in the Basic Agricultural Sciences curriculum. Agricultural Sciences as defined in the Curriculum and Assessment Policy Statement (CAPS) document "is the study of the relationship between soils, plants and animals in the production and processing of food, fibre, fuel and other agricultural commodities that have an economic, aesthetic and cultural value (Department of Basic Education, 2015, p. 8). The content for Grade 11 Agricultural Sciences in the CAPS document is divided into four knowledge areas; namely, Basic chemistry, Soil sciences, Plant science and Optimum resource utilization" (Department of Basic Education, 2015, p.8). This study is focused on the first strand (Basic Agricultural Chemistry) and more specifically on the sub-topic of organic compounds. According to Cobern and Tobin (2003), "chemistry is the branch of science concerned with properties and interactions of the substance of which matter is composed" (p. 1). In teaching chemistry, teachers are expected to have some skills suited to teaching learners to understand important concepts, solve problems using rules and methods and develop critical thinking skills. Learners are understood to be curious, thereby needing to be actively involved in the lesson. This section will discuss the organic and inorganic compounds together with the elements of life that are found in the periodic table.

The study also focuses on topic specific pedagogical content knowledge (TS-PCK) of Agricultural Science Grade 11 teacher's in organic compounds in the Basic Agricultural Chemistry section.

1.2 Rationale for the Study

It is educationally accepted best practice for effective teaching and learning that learners should be taught by teachers who are qualified in their specific disciplines and who have a thorough knowledge of the subject matter content (Kind, 2009; Sibanda, 2013). In contrast to this best practice, there is a serious concern among educationists and parents about children who fail science examinations due to poor teaching, especially in the more difficult science topics (Özmen, 2014). Where the teachers themselves have poor knowledge and skills for teaching, this poses a threat to quality learning and performance and to the future careers of learners, resulting in wasted energy, and financial and human resources. This also has a bearing on the long term development in the country as education is seen to be the avenue through which poor and under-resourced communities may be uplifted.

Research into the teaching and learning in the subject Agricultural Sciences in South Africa is scarce; instead, in South Africa, researchers have focussed largely on mathematics, physical and life sciences and technical education. Moreover, because Agricultural Sciences is largely taught in technical and vocational education and training (TVET) colleges and in schools attended largely by black Africans, it is perceived to have a Cinderella status compared to these other higher status subjects. This contrasts with the situation in tertiary education, where Agricultural Sciences is well established at some universities and is gaining further momentum for reasons related to economics and the challenges of climatic change. However, in other countries such as the United States and India, where agricultural teaching is widespread, there has been adequate research.

In South Africa, the Agricultural Sciences matriculation examiners' reports indicate that some learners hold serious alternative conceptions, such as mixing of terminologies (Department of Basic Education, 2015). In the examination report of Department of Basic Education (2015), it is documented that teachers have not significantly changed learners' alternative conceptions. Furthermore, the problem is not limited to Agricultural Sciences. According to Sibanda (2013), there is a national concern about the lack of improvement of learners' performance in the chemistry section of Physical Sciences, so that the problems of poor conceptual knowledge and problem solving still persist. She further states that learners exhibit a lack of interest in science. To address such a problem, in some countries researchers have tried methods of improving teaching so as to make sciences more relevant to learners' day-to-day lives. Costa, Marques, and Kempa (2009) also explain that, for most teachers, chemistry topics continue to present problems because they build on each other. In addition, these authors noted that excellent content knowledge is an important prerequisite for teachers to teach successfully. Similarly, Chan and Yung (2018) proposed that teachers should be familiar with the subject matter of chemistry in order to be able to transfer it to learners in forms that can be easy for them to grasp – this aspect is referred to as teachers' pedagogical content knowledge (PCK). Levy Nahum, Mamlok-Naaman, Hofstein, and Taber (2010) hold that proof exists that alternative conceptions displayed by learners originate from teachers' lack of good science content that do not enhance learners' understanding. In particular, some teachers consider the structural representation of a matter to be one of the difficult parts of the Science curriculum. These difficulties have been attributed to chemistry's "subjective and abstract nature, the difficulty to understand and visualize the models, and the lack of a physics grounding to understand the concepts of charge and electric and magnetic fields" (De Quadros et al., 2011, p. 236).

This means that as long as teachers lack deep understanding of their subject content the problems pertaining to the teaching of science will remain unsolved. According to Simkins (2010), even though sciences remain one of the most significant foci in South African schools, science subject teachers have been unsuccessful in stimulating and drawing learners into participation, which negates the department of education aim of increasing the number and quality of examination passes in the sciences. He further notes three reasons for poor performance in science. Firstly, it does not integrate learners' everyday experiences adequately; secondly, teachers do not explain clearly to learners the dividends that success in science would pay after their hard work; while lastly, teachers are unable to demonstrate the significance of sciences in pupils' daily lives.

In both Agricultural Sciences and Life Sciences there are new content areas, such as an increased chemistry component in each. Due to the inadequacy of their previous teacher education courses, some teachers have limited knowledge and experiences in these specific new content areas; moreover some may have never studied chemistry or physics, even at high school. Furthermore, the inability of some teachers to even recognise alternative conceptions in science and chemistry, let alone correct them, is a compounding factor in the poor results of matric students (Department of Basic Education, 2015; Harvey, 2013). Also there is a worldwide lack of competent educators in the sciences. This has led to learners being taught by teachers who had not been trained for science subjects. Many learners are affected by this problem, leading them to diverge from their original selection of careers because of poor results in these science subjects (Kanyane, 2005).

The problem of a shortage of suitable qualified chemistry teachers or lack of chemistry education in Life Sciences and Agricultural Sciences is not unique to South Africa. Instead, there is a concern worldwide about teachers who teach chemistry with only biology degrees. This mismatch has direct implications in the way such teachers transfer their limited chemistry content to learners in their classrooms (Nixon, 2015; Ryan, Campbell, & Luft, 2016).

According to the South African CAPS document (2012), the aims of schooling and curriculum are:

(A) The NCS Grades R to 12 learners should be allowed to utilise their knowledge and skills and apply them meaningfully to their surrounding areas in a meaningful way.

(B) The NCS Grades R-12 serves the purposes of developing learners with expertise that is essential for their workplaces.

(C) The NCS Grades R-12 is based on addressing problems caused by the apartheid government and NCS focuses on building a positive attitude among the previously disadvantaged learners and to so build a healthy society that is free of socio-economic imbalances caused by the past apartheid government.

(D) The NCS Grades R to12 aims to produce learners that are able to see problems and critically think on the solutions of a problem. It tries to raise learners that are critical thinkers and are able to solve problems.

(E) Inclusivity ought to be a central portion of the organization, planning and teaching at each school. The identification of learners' barriers should be identified first and teachers should at all times also try to meet learners' requirements, so as to fast track the concept of inclusivity.

It is therefore, of paramount importance that all education bodies, that is schools, universities and departments of education, should play their part in addressing the problem of outdated and non-stimulating classroom practices in schools (Sharp, Green, & Lewis, 2017). However, as long as this problem remains, learners will continue to experience difficulties in learning science and hence in reaching their career goals (Hanafi, 2017). Many documents confirm that adequately trained teachers are vital to quality teaching and learning (Cebrián-Robles, Franco-Mariscal, & Blanco-López, 2018; Oliveira, Lopes, & Spear-Swerling, 2019). It was further emphasized by Olaleye (2012) that poor learner achievement emanates from educators not having sufficient topic specific pedagogical content knowledge (TS-PCK) in order to teach effectively. Several reasons are offered by Olaleye for the insufficiency, such as teachers wanting to cover too much content without being cognizant of learners' understanding, their preparing learners superficially, only for writing examinations, as well as the call to finish the syllabus with a specified time. She further comments that these factors fuel alternative conceptions and lead to learner-failure in science classrooms.

This study focuses on three teachers, who teach chemistry sections in Agricultural Sciences, but hold only a biological sciences degree, with few or no chemistry modules. This means that these are teachers who never studied any chemistry content at university level. The teachers, firstly, lack deep content knowledge in chemistry and, secondly, have difficulty teaching specific topics such as *organic compounds in Basic Agricultural Chemistry* to their learners. This is largely due to their weak chemistry content knowledge thus affecting their PCK and learner performances.

1.3 Objectives

The *objectives of this study are to:*

Explore topic specific pedagogical content knowledge (TS-PCK) problems of Grade 11 Agricultural Sciences teachers encountered in the teaching the topic organic compounds.

Explore how action research can help Grade 11 Agricultural Sciences teachers' to improve their topic specific pedagogical content knowledge (TS-PCK) in the teaching of organic compounds.

1.4 Research Questions

The two key research questions for this study were:

Research Question 1: What problems do Grade 11 Agricultural Sciences teachers encounter in teaching the topic organic compounds? And,

Research Question 2: How can action research help Grade 11 Agricultural Sciences teachers to improve their topic specific pedagogical content knowledge (TS-PCK) in teaching organic compounds?

In particular, for Research Question 1, the study explored the teachers' knowledge of their learners' preconceptions related to organic compounds, their subject matter knowledge of organic compounds and their teaching approaches (pedagogical knowledge) in addressing their learners' difficulties in learning about organic compounds.

1.5 Significance of the study

The results of the study should help universities to design curricula that would assist pre-service teachers in Agricultural Sciences with the chemistry content knowledge relevant to the chemistry section in Agricultural Sciences. It would further support other institutions, such as Technical and Vocational Education Training (TVET) colleges, that offer Agricultural Sciences in teacher education programmes by increasing the emphasis on students' conceptual development in chemistry specific topics. The results of the study would also improve the teaching of chemistry topics in Agricultural Sciences as the teachers would engage with the problems of teaching and learning organic chemistry. The collaboration of teachers in this study would also help subject advisors and Heads of Department to gauge the need to further support teachers in teaching the chemistry topics in Agricultural Sciences. The workshops for teachers would also help improve their TS-PCK and possibly stimulate them to maintain future collaborative links amongst themselves.

1.6 Summary of Chapter 1

In this chapter, the researcher introduced the nature of study which states the difficulties in teaching and passing Agricultural Sciences organic chemistry section in grade 11. This was followed by the rationale behind the study and as an Agricultural Sciences teacher I have experienced some of the difficulties and with teachers that I taught with in my area who also did not do this chemistry section, the research questions that underpin the study and the significance of this study which states that universities and college will now recognise the importance of special training all Agricultural Sciences teachers in the organic chemistry section.

Chapter 2

2.1 Introduction

In this study, the researcher seeks to explore the topic specific pedagogical content knowledge in teaching organic compounds as part of Basic Agricultural Chemistry among Agricultural Science teachers' in the Libode District, Eastern Cape.

Most research in science education has been externally conducted in different disciplines having its focus on the importance of PCK and its component TS-PCK (Bucat, 2004). However, few studies have been concerned with Agricultural Sciences Grade 11 teachers' PCK, more especially in the section Basic Agriculture Chemistry of the South African CAPS curriculum.

In the extended review in Section 2.2 on topic specific pedagogical content knowledge, the following connected themes will be considered: teacher's pedagogical content knowledge, their Knowledge about the curriculum, Instructional strategies, And learners' preconceptions and learning challenges as well as their subject content knowledge and Knowledge of assessment practices**.**

2.2 Topic Specific Pedagogical Content Knowledge (TS-PCK)

A diagram from Rollnick and Mavhunga (2014), which summarised the TS-PCK holistically, was used in this study as it was judged to contain the most appropriate teaching and learning factors. It is presented in Figure 2.1.

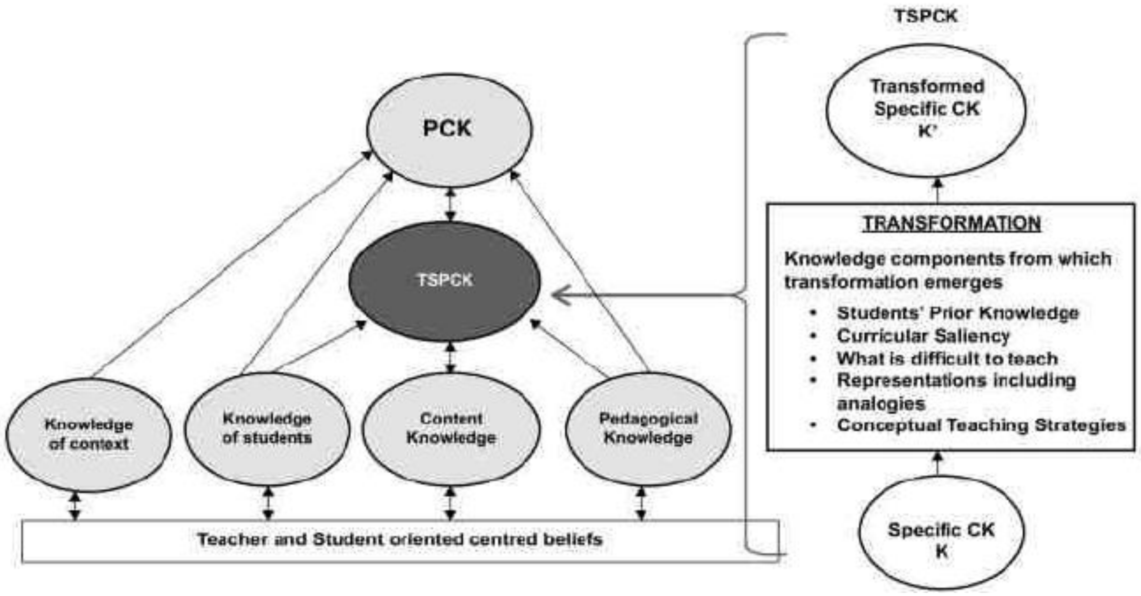


Figure: 2.1 Topic Specific Pedagogical Content Knowledge Rollnick and Mvhunga (2012).

Each of the five factors will be discussed in detail below together with other relevant studies in chemistry education.

2.2.1 Teacher's pedagogical content knowledge (PCK)

Shulman (1986) defined PCK as teachers' ability to change content knowledge into forms that are proper for learners' understanding of the scientific concepts. There is an increasing necessity for research to be conducted on science teachers' pedagogical content knowledge (PCK), since the current trend shows poor classroom practice by teachers, which affects learners' learning in schools (Bucat, 2004; Großschedl, Harms, Kleickmann, & Glowinski, 2015). This need was to address the deficit of most science education research having previously been more often focused on learners' alternative conceptions and not on teachers' PCK (Bucat, 2004). Bucat (2004) explains that pedagogical content knowledge is concerned with understanding or information about "teaching and learning that takes into account the particular learning demands of the subject matter" (p. 215). Rice and Kitchel (2015c) outline PCK as being the combination of content knowledge and pedagogical knowledge that forms a persuasive knowledge base on which teachers base their instructional strategies. Ryan et al. (2016) argue that because of the bond between science teachers' content knowledge (CK) and how these science teachers teach, that is their pedagogical knowledge (PK), it is important to understand how their PCK influences their teaching. In other words, their way of teaching directly reflects the pedagogical content knowledge they hold. It has also been noted by Angell, Ryder, and Scott (2005) that PCK for teachers directly affects their understanding of learners' reasoning, their teaching strategies and their interpretation of the curriculum. They further state that PCK also includes the teachers' understanding of scientific concepts in the subject they teach. They also highlight that for new teachers who are teaching out of their specialization, teaching the conceptual aspects of the subject may be a traumatic experience for them. Bucat (2014) adds that the teacher who possesses good PCK knows the ability of his or her learners, and so could rearrange the content in the way he or she thinks learners would grasp it. Even long before Bucat, Grossman (1990), had already noted that one of the importance constituents of PCK is teachers' knowledge about instructional approaches and information about learners' alternative conceptions and their understanding about the topic. She explained that once teachers are aware of these components, they become more effective in teaching and their learners begin to excel. As Bucat further notes, experienced teachers normally hold a better pedagogical content knowledge than pre-service teachers, which accounts for differences in the way they teach science and the way they view the nature of science in each content area they teach. Therefore acquiring effective PCK helps teachers design ways to deliver the subject matter effectively to their learners. Such PCK growth occurs through the experience of teachers in the field and is therefore developmental. Teachers' PCK is an important component of my study, which is aimed at exploring teachers' problems in teaching organic compounds, including the concepts themselves, and to find possible ways for teachers to improve their content knowledge and TS-PCK.

Chapoo, Thathong, and Halim (2014) note that PCK as "the capacity of teachers to help learners construct knowledge is subject to the tactful blending of content and pedagogy" (p. 442). Their research among three science teachers in Thailand led to the conclusion that these teachers were lacking in PCK.

According to Bucat (2004) every individual teacher holds unique content knowledge, which makes them different from each other, and so the way they transfer this knowledge to their learners also differs. He holds that teachers cannot be expected to transmit identical content, but instead they represent the knowledge in ways that will make learners understand it and succeed. Bucat further states that the way teachers represent content will depend on the nature of the subject matter, and they are expected to represent it in ways that are easily accessible to learners, by using different codes and examples. He concludes by remarking that until teachers find ways of re-packaging their own content knowledge for learners, teaching will be in vain: learners will be left confused after each lesson.

In the study conducted by Santrock (2007), the findings indicated that, in contrast to the traditional way of transmitting content knowledge, nowadays learners are expected to experience the things they learn, they learn best through constructing knowledge themselves. This means that teachers need to cater for such methods of teaching the content by adopting a constructivist approach and so creating an environment that is conducive for learners' experiencing the content.

According to Lucenario, Yangco, Punzalan, and Espinosa (2016), teachers' PCK is an integral aspect of learners' success. This was observed in many schools where teachers received PCK professional development and so taught their learners in effective ways. They further contend that PCK is individually contextual, being affected by an individual teacher's ability to integrate different teaching methods and by the experience they bring to the classroom. Darling-Hammond (2006) elucidates that once the development of those who teach becomes a focus, teachers will know better how to integrate the content knowledge they have to suit those who are taught. He further says that knowledge of teaching methods also depends on the knowledge of the subject and concepts within the subject. Further, Lucenario et al. (2016) contend that the professional development must be the foundation of science research as this would then help teachers understand better those they are teaching.

According to Kind (2014), teaching without a comprehensive understanding of the necessary content knowledge has a negative effect on the teaching and learning processes, which also impacts on the choice of teaching methods to be used. She contends that the lack of content knowledge leads to unsatisfying science lessons. In terms of chemistry education, Kind further asserts that alternative conceptions in organic chemistry are a norm for most high school science teachers. In her study, Kind (2009) shows that most science teachers demonstrated a lack of knowledge on chemical bonding, as only 45% of participating teachers could answer the given questions correctly. She further says that this lack of understanding is passed onto learners, who acquire most of their alternative conceptions from their teachers. As is evident in the study conducted by Lin, Cheng and Lawrenz (2014), teachers and their learners shared alternative conceptions on gases. The learners said that when carbon dioxide dissolves in water found in the soil it produces oxygen, whereas it would be correct to say it produces carbonic acid, which weathers the rocks to produce nutrients for plants.

Rice and Kitchel (2015b) proposed that with an increase with the number of beginner teachers, it is important to examine their content knowledge and the capability of transferring such knowledge to their learners. With regard to novice teachers, Feistritzer, Griffin, and Linnajarvi (2011) conducted an exploratory study on novice science teachers' content knowledge. Their findings indicated that these science teachers showed a lack of knowledge of instructional strategies, learners' knowledge and the information about the core curriculum. For these reasons, Sağır and Küçükaydın (2016) contend that, out of the four knowledge bases (knowledge of the students, Context Knowledge, Content Knowledge and Pedagogy Knowledge) that science teachers need to possess, the teachers' pedagogical content knowledge also forms part of the knowledge system that is vital for effective teaching and learning processes.

Teachers' conceptual knowledge will have an impact on learners' acquisition of concepts. A study was conducted by Akkuzu and Uyulgan (2016a) in Turkey to examine the conceptual knowledge of learners, from all the sciences, in the topic of organic compounds. The findings of this study showed that these learners lacked conceptual understanding of the functional groups and had little understanding of some topics such as how functional groups affected acidity and basicity, and intermolecular bonding. For this reason, they recommended that teachers should know how to help learners link their prior knowledge to the new knowledge they are to learning in class.

Learners' language and terminology is also significant in science education. Akkuzu and Uyulgan (2016a) maintain that if the meaning of a conceptual term is not clearly understood, this will affect understanding information involving that particular concept. Therefore, teachers are encouraged to emphasise the use of correct terms so as to minimise some misconception in chemistry sections. Science topics typically include many abstract concepts, therefore the knowledge that teachers have in topics like organic chemistry should not only be based on the mastering of content knowledge but in transforming content knowledge into forms that will be accessible to their learners (Davidowitz & Rollnick, 2011). Similarly, Shulman (1986) defined PCK as teachers' ability to change content knowledge into forms that are proper for learners' understanding of the scientific concepts. Like many others, Somers (2013) maintains that teachers' content knowledge (CK) impacts science teachers' classroom instruction methods, which are the ways they teach in the classroom. The importance of PCK has been supported by most researchers. For instance Halim, Abdullah, and Meerah (2014) advocate that PCK is the key to the whole processes of teaching and learning, as it unlock skills of how teachers can transfer their own content knowledge to their learners.

Nixon (2015) asserts that "for a science teacher, this knowledge, known as content knowledge, includes an understanding of the facts, laws, theories and practices of science" (p. 3-4). Driel, Berry, and Meirink (2014) assert that the improvement in the area of content knowledge will automatically enhance the science teachers' pedagogical knowledge thereby improving their classroom effectiveness. This means that a clear understanding of the content is important to enable the teacher to transfer the knowledge in ways that he or she thinks may have positive influence on learners. They conclude by saying content knowledge is the foundation for development of teachers' pedagogical content knowledge. results from the study by Rollnick, Bennett, Rhemtula, Dharsey and Ndlovu (2008) indicated that the South Africa chemistry teachers' content knowledge (CK) was established to be an important element of their teaching. This had an impact on the teachers' subject matter knowledge (SMK) for teaching, the way it is assessed and the teaching strategies.

In the subject of Agricultural Sciences the teacher has to know all related concepts in chemistry in order to be able to explain the content to learners (Department of Basic Education, 2015). However, with Agricultural Sciences involving abstract concepts in organic chemistry, many problems exist around the topic, with having been personally observed. The Department of Education South Africa has worked with many teachers through content workshops for teachers but still teachers are afraid of the topic (Adedokun & Balschweid, 2008). According to Nichols (2019), who is a university teacher of Agricultural Sciences in the United States, although students do experience problems in Agricultural Sciences they would cope if teachers could transfer their knowledge to learners successfully. The chemistry aspect of Agricultural Sciences is a section that needs a teacher with good chemistry knowledge in order to teach learners effectively and the Department of Agricultural Sciences needs to fund higher institutions in order to train teachers in ways that would facilitate learners grasping the content (Kohn, 2019; Yue et al., 2019).

2.2.2 Teachers' knowledge about curriculum

A study was conducted by Gudyanga and Madambi (2014a) at a secondary school to explore teachers' perspectives in teaching chemical bonding. In this qualitative study, it was established that teachers focus their teaching on the academic examinations that their learners will write and ignored the alternative conceptions that learners may still retain afterward. The emphasis of this research was on alternative conceptions related to ionic and covalent bonding and the researchers concluded that, when teachers are not competent in this section, they are the key contributors to learners' alternative conceptions. For example, the learners in this study were observed to have confused the ionic bond and covalent bond and further said ionic bond formation results in shared electrons while covalent bonding transfers electrons. For this reason, the need for science teachers to enhance their own knowledge of the curriculum is as important as their everyday lesson plan. They should know minor topics and major concepts and spend much time in connecting these for their learners (Friedrichsen et al., 2009; Mthethwa-Kunene, Onwu, & de Villiers, 2015).

Großschedl et al. (2015) embrace the view that knowledge about curriculum content and teaching go together, and teachers' knowledge about the curriculum influences their teaching. They further stress that experienced teachers usually move away from textbooks towards a constructivist approach and more often seek explanations from their learners rather than asking factual questions. De Quadros et al. (2011) believe that teachers need to know what learners have to know and why they must learn that particular topic. Luft and Zhang (2014) assert that most new teachers do not usually grasp the curriculum arrangement within a year and it may take up to two years to make sense of the arrangement of their subject curriculum. According to Gilbert, de Jong, Justi, Treagust, and van Driel (2002), in a book on research based chemistry education, since most chemistry learners are interested in knowing what is happening to their day-to-day experiences, the modern curriculum should, therefore, be designed to follow such experiences. They further contend that some curriculum changes fail to meet learners' need to discover chemistry to be interesting and relevant to their daily lives. Furthermore, they explicate that another reason for curriculum reform is the notion that learners require a curriculum to have a practical use in their future. They conclude by saying this requirement for a curriculum change has led to what their referred to as a 'context-based approaches to teaching chemistry' (p. 97). This means that, in reality, for teachers to teach well in their classrooms, it is important for them to understand how each topic relates to learners' lives so as to integrate that curriculum theory with the learners' daily experiences. Gilbert et al. (2012) also emphasised that in trying to make chemistry interesting and being relevant to learners, there are now science workshops and science centres that can help to present science in more interesting ways for learners and for them to view it in a positive realistic light. According to Esselman and Hill (2016) Some learners are motivated by computerised teaching aids, which may be used to address some of their alternative conceptions. They expain that computers are full of expanded definitions and examples, which learners can use. Demirdöğen, Hanuscin, Uzuntiryaki-Kondakci and Köseoğlu (2016) highlight that when teachers know their content they become motivated to teach effectively and learners normally get the same motivation as they gain more meaningful knowledge from their teachers. Akaygun and Aslan-Tutak (2016) add that, when teachers are not fully capacitated because of insufficient training and their learners are normally unable to relate to organic chemistry concepts like gases and understand their direct and indirect contribution to people lives. "And their direct and indirect contribution to people lives.

2.2.3 Knowledge of Instructional Strategies

Instructional strategies are very important as they bridge the knowledge gap between teachers and learners and act as a way of communicating knowledge with learners. (Wael, Asnur, & Ibrahim, 2018) explain that "Instructional strategies are techniques teachers use to help students become independent, strategic learners. These strategies become learning strategies when students independently select the appropriate ones and use them effectively to accomplish tasks or meet goals. Instructional strategies can:

•motivate students and help them focus attention

•organize information for understanding and remembering

• monitor and assess learning" (p. 67).

Gregory and Chapman (2012) also allude to the importance of instructional strategies, which they define as techniques used to deliver a particular piece of content in a creative manner and they also note that they are advantageous if they push learners to be independent. Curtiss et al. (2016) also allude that some of the advantages of instructional strategies used to transfer information successfully from one person to the other, which include enabling learners' to relate content to their day to day lives. For health education programmes in Alberta, Canada, successful instructional strategies include "cooperative learning, group discussion, independent study, portfolio development, journals and learning logs, role-playing, cognitive organizers, literature response, service learning, issue-based inquiry" (Canada & Alberta, 2002, p. 67).

In addressing instructional strategies in teaching organic chemistry, Omwirhiren and Ubanwa (2016) suggested that alternative conceptions found among learners in organic chemistry, such as "ionic bond electrons are shared and covalent bond electrons are also shared" are instigated by teachers who do not use effective instructional approaches such as modelling, laboratory work and problem solving strategies. Similarly, Gudyanga and Madambi (2014a) backed the view that alternative conceptions of learners in organic chemistry are not based on learners prior knowledge but rather stem from the inadequate content knowledge of the teachers who pass on alternative conceptions in chemical bonding or other topics. They further reported that most "chemical concepts are central to chemical bonding" (p. 11) hence teachers' instructional strategies should also focus on early remediation on alternative conceptions such as these in chemical bonding. Their research also shows that teachers' knowledge of instructional strategies varies according to their experiences. Novak also suggested that teachers' teaching strategies should cater for learners' integration of prior knowledge rather than focusing on memorization of concepts (as cited by Pabuçcu & Geban, 2013). Davidowitz and Rollnick (2011) assert that learning organic chemistry is full of challenges and is perceived as being difficult for some learners; therefore suitable creative approaches need to be embedded in teachers' strategies in order to facilitate understanding among learners. To enhance learners' understanding of difficult concepts in organic chemistry, the use of models discussion and drawn structures of compounds have been observed as being effective.

Carneiro, Parulekar, Shridhar, and Ladage (2016) assert that although the styles of teaching of organic and inorganic compounds vary among teachers, nonetheless, most teachers deprive learners of critical thinking skills through using the lecturing method. They hold that this method has led to learners losing interest in some topics. Friedrichsen et al. (2009) emphasise the importance of using strategies that will integrate learners' prior knowledge. Likewise, it is expected by curriculum planners in South Africa teachers would keep learners actively involved in the lesson (Department of Basic Education, 2015). Research in teaching chemistry content reflects that the use of interactive teaching methods, such as problem based strategies or discussion, works for learners and if teachers are not using such methods, it will show in learners' disappointing results (Carneiro et al., 2016; Lan & Robin, 2008). These authors point out that the instructional strategies used are affected by the number of factors such as knowledge of teachers, the number of learners in the class and the content to be taught.

A valuable teaching strategy is to use visual aids in teaching of organic chemistry. In this regard, learners can then focus more on the visual ways of learning organic chemistry so as to easily understand organic chemistry concepts only if the teachers allows them to use visual aids (Akkuzu & Uyulgan, 2016b).

A study conducted by Pabuçcu and Geban (2013) used a conceptual text oriented instructional method; the results indicated that learners who were involved in practical learning performed better than those who had used a theoretical means of learning chemical bonding.

In the study conducted by Mthethwa-Kunene et al. (2015), which sought to explore teachers' PCK, it was found that even though "teachers used topic-specific instructional strategies such as context based teaching, illustrations, peer teaching, and analogies in diverse forms, they failed to use physical models and individual or group student experimental activities to assist students' internalization of the concepts" (p. 1). This means that for each concept taught, the teachers should find means to consolidate and transfer their knowledge to learners in ways that engage the interest of learners, as suggested by Mthethwa-Kunene et al. (2015). Kazeni and Onwu (2013) explored the effectiveness of teaching using context based and traditional teaching approaches and the results showed that the context based teaching strategies and the models used within, worked more effectively. The authors added that learners normally receive more knowledge and experience when the lesson is context-based, as they can relate this to their day-to-day environment. They explain that the learners' environment should act as a natural environment on which teachers can base the information they pass onto their learners. Similarly, Simkins (2010) proposes that, amongst many reasons why science subjects have no attraction for many learners, is the mode of teaching by rote memorization of factual concepts, rather than experiencing the content in the real world. Dube and Lubben (2011) expound that the rationale behind context-based teaching is to include learners' own experiences in the teaching and learning of science. They hold the view that when learners' prior knowledge is stimulated, it becomes easy for teachers to note alternative conceptions and rectify them. Such an instructional strategy involving the integration of learners' prior knowledge has enjoyed much success in schools where it was properly used (Gilbert, Bulte & Pilot, 2011).

Amongst other scholars, Sani, Bichi, and Ayuba (2016) confirmed that most alternative conceptions that were observed in class are predominantly due to poor instructional strategies used by teachers in classes, as well as the learners' lack of exposure to the laboratory work and other activities that promote problem solving. Luft and Zhang (2014), in support of many other scholars, indicate that most newly hired teachers use teaching strategies based on their own secondary school experiences. In 2007, Luft wrote that in order to support newly hired teachers. There is a need for research on teachers during their early years of teaching in order to find the best ways to support them in aligning their teaching strategies with the most effective ways of teaching. In a later study, Luft et al. (2011) contend that the environment in which the new teacher works predominantly influences the instructional strategies used by the teacher. Moreover, they believe certain beliefs are held by teachers, including the idea that learners are like empty vessels waiting for teachers to fill them with information, may persist and are used to justify their use of a particular instructional strategy in the classroom. Gilbert and Treagust (2009) suggest that their research has identified learners' alternative conceptions, so that teachers may then adopt appropriate instructional strategies in order to remediate those alternative conceptions. They say that when teachers are capacitated with enough knowledge on best instructional strategies then learners normally perform better because of the link they have with their teachers. Furthermore, Gilbert and Treagust believe that helping teachers understand specific instructional strategies will, therefore, help learners grasp the content better.

In a report on the use of laboratory work as a teaching strategy, (Gilbert, De Jong, Justi, Treagust, & Van Driel, 2006) write that their research "highlights the potential benefits of laboratory work, although many of the studies and reviews have consistently reported that the teaching laboratory has had little to no effect on achievement, attitudes, reasoning, critical thinking, scientific thinking, cognitive style, understanding science, science process skills, manipulative skills, interests, or retention in science courses" (p. 77). This anomaly has been attributed to the particular way in which the laboratory is being used by teachers. Studies conducted by Kazeni and Onwu (2013) showed that if the material is available in the laboratories but is not used effectively, then the supply of materials is in vain. On the other side of the argument, Gilbert and Treagust (2009) clarify that the use of laboratory work is of paramount importance in the curriculum as it mirrors scientists' exploration of the day-to-day world. They further state that until teachers improve on laboratory work, there will be no improvement in the results and understanding of the concepts of chemistry. One important aspect of using laboratory work effectively is in using the pre-and-post lab discussion by learners (Carnduff & Reid, 2003). These authors believe that such discussions create a conducive environment in which the organic chemistry learners can identify the link between what they can see in the laboratory and what they are taught and perhaps find difficult in the classroom. Furthermore, they explain that the first pre-lab discussion will highlight for learners what they need to observe in the laboratory and why is important. The second post-lab discussion will then help learners understand how they should do the analysis of the collected data and how they should make connections between the results and what they learnt in their classroom (Carnduff & Reid, 2003).

Practical work in laboratories, or even classrooms, should be planned and enacted more often. In the study conducted by Olaleye (2012) teachers were observed using the lecturing method whereby learners were left passively uninvolved in the lesson. Merely listening had the result of learners losing their focus. According to Cuttance (2013) in order for teachers to have learners' attention and to be listening actively in their science classrooms they need to engage them in the learning processes through the use of teaching techniques such as laboratory work. He further said that this should include specifically the use of real-life classroom work. This has been supported by Njoku (2004), who says that, in order to achieve the goal of teachers using practical activities in science classrooms, teachers will have to be trained and be supported in every way in order to enhance their classroom effectiveness. Atherton (2011) elucidates that the most effective teaching methods are those of a constructivist nature, which allow learners to be actively involved in the lessons and lessons to be learner-centred. This view is supported by Olaleye (2012), who adds that "Learning results from experience, thinking, memory and all the other cognitive processes that build connections between new information and prior knowledge" (p. 13). This means that science teachers should engage learners in laboratory work and other practical activities, with discussions and even classroom presentations, in order to enable them to learn meaningfully. In addition, Olaleye suggests that learners be allowed to interact with their classmates and with teachers in chemistry lessons; such exposure to classroom collaboration normally makes learners happier and more active in the classroom. It is clear from this summary of research that in order for learners to understand chemistry through effective learning they have to be engaged in their lessons.

2.2.4 Knowledge about learners' alternative conceptions and learning difficulties in organic chemistry

In this section, I will address teachers' understanding about learners' alternative conceptions on the following:

2.2.4.1 Learners Alternative conceptions and Difficulties in Terminology

The term misconception is used to describe a situation where incorrect information is believed, instead of what is really needed, because of lack of understanding of a certain concept (Bensley & Lilienfeld, 2015; Geyer, Kuczenski, Zink, & Henderson, 2016; Sarma, 2015). Alternative conceptions may relate to ideas that learners or teachers have in their minds as a definition or explanation for a certain concept, but which is considered to be an incorrect explanation (Omwirhiren & Ubanwa, 2016). This is a highly significant component of teachers' PCK, necessary for teaching science effectively.

Furthermore, Mthethwa-Kunene et al. (2015) add that teachers' experiences play an important role in whether they take the trouble to determine learners' preconceptions, alternative conceptions. This view is supported by Van Driel, Jong, and Verloop (2002) who state that if teachers are experienced and therefore cognisant of their learner's alternative conceptions, they will design lessons in a way that will address learner's problems; for example, in the teaching of terms related to minerals and organic molecules they will use some videos and visit some laboratories nearby. According to Geddis (1993), most novice teachers believe that teaching is just the transference of information to learners and they focus on teacher-centred pedagogy. He further states that teachers' PCK should show the ability to transform the subject matter into forms that are more accessible to learners. He contends this can only be possible if the teachers understand and correct their own alternative conceptions and if teachers can teach terminologies effectively by using examples that learners can see and experience.

In a study conducted by Omwirhiren and Ubanwa (2016) among learners in a secondary school with the aim of exploring organic chemistry alternative conceptions, more especially substitution and addition reactions, the findings confirmed that learners demonstrated alternative conceptions in this section of organic chemistry. According to Omwirhiren and Ubanwa (2016), learners demonstrated a number of alternative conceptions, including the common one that students think that the word 'organic' means natural. According to Omwirhiren and Ubanwa (2016), "The word 'organic' is often associated only with being natural, which stems from the notion of organic produce, which is grown naturally without the use of pesticides" (p. 15). To address such a conception, a teacher could engage learners in an Agricultural Sciences practical to demonstrate how organic farming is carried out without the use of pesticides and fertilizers, and thus differentiate between the two meanings of 'organic' for different contexts

2.2.4.2 Learners Alternative conceptions and Difficulties in Bonding and Organic Chemistry Concepts

In the specific topics of Bonding and organic chemistry, learners' alternative conceptions include, for example, the belief that chemical bonding is bonding through physical means, and that organic compounds are soluble in water and can melt and boil faster but less than water (Bryan, 2014). Often, a common mistake is to assume that the real difference between inorganic and organic compounds is whether or not a substance contains carbon. Diamond is pure carbon, yet it is inorganic (Omwirhiren and Ubanwa, 2016). Omwirhiren and Ubanwa further says that learners also believe that carbon dioxide is organic as it contains carbon and oxygen, both elements associated with life, yet, to chemists, it is an inorganic compound. Bryan (2014) also states that not only do learners display alternative conceptions in classifying whether a substance is an acid or a base, but their teachers held the same alternative conceptions in this and for other concepts. Bryan (2014) notes that learners had learning difficulties or alternative conceptions concerning hydroxyl compounds, which included the idea that "Phenols do not show any visible reaction with carboxylic acids because both are acids, and acids do not react with each other" (p. 4). This means that learners' alternative conceptions in this topic can affect their performance in the subject. Acid-base reactions are indeed possible between a strong acid and a weak acid, such as phenols, which then acts as a base.

Pérez, Pérez, Calatayud, García-Lopera, and Sabater (2017) explain that learners come to class with some conceptions that emanate from their experience. Therefore, teachers need to identify these and address them through suitable teaching methods. For instance, learners' conception of mixtures is important in organic chemistry, as many processes of separation involve organic chemicals. In this regard, Shin, Lee, and Ouarda (2015) hold that most students thinks that a heterogeneous mixture is a mixture that is not uniform, and where the different components of the mixture cannot be seen. According to Shin et al., a "heterogeneous mixture is simply any substance that is not uniform in composition – it's a non-uniform mixture of smaller constituent parts and using various means, the parts in the mixture can be separated from one another" (p. 6). It is clear from such an example that learners' alternative conceptions need to be resolved or else they could become be permanently embedded in the lives of learners making them think the opposite of what is considered to be correct in science. In another study conducted by Nikolić and Marković (2015), learners were found to hold the misconception that saturated fatty acids, such as butyric and lauric acids, have a double bond between carbon atoms of the fatty acid chain, but then also say this cannot be so because if they are saturated they cannot have a double bond, However, Li et al. (2014) explain that "saturated fats are solid at room temperature like margarine, while unsaturated fats are liquid at room temperature like olive oil. This is because saturated and unsaturated fats differ in their chemical structures. Saturated fats have no double bond between molecules" (p. 12). This means there are no gaps and the fat molecule is saturated with hydrogen atoms. Similarly, Seven et al. (2017) found in their study that learners had alternative conceptions about the organic compound, butane, with which learners are familiar as it is found in cigarette lighters. The learners considered butane gas to be less flammable than ethane black in colour and able to be transported as a liquid. Combinatorial Chemistry Online Volume 10, Issue 12, December 2008", (2008) clarifies that butane is a colourless gas with a faint petroleum-like odour. For transportation, it may be stanched (odour added) and shipped as a liquefied gas under external pressure.

Peters, Walters, and Moldowan (2005) conducted a study on conceptions of alkanes as organic compounds, and they found that learners held the misconception that alkanes are inorganic compounds that consist of hydrocarbon chains that are fully saturated. It seems that learners confuse alkanes with alkenes with regard to their properties. Lee et al. (2019) further explained that hydrocarbons are organic compounds that contain only carbon and hydrogen. In addition, Lee et al. (2019) added that "alkanes are hydrocarbons or organic compounds made up of carbon-carbon single bonds, hence they are saturated with the simplest alkane being methane with only one carbon atom" (p. 23). The concept of 'saturation' may be a language barrier for these learners as here it means that there is a maximum number of bonds around the carbon atom(s). Rocha, (2016) clarifies that saturated fatty acids are acids that are fully bonded to hydrogen atoms which fill in all around the carbon chain.

Understanding the nature of acids and bases is applicable in both organic and inorganic chemistry. Karpudewan, Roth, and Sinniah (2016) conducted a study on conceptions related to organic compounds, which confirmed that among the alternative conceptions held by learner's alternative conceptions in this topic is the idea that a base is a substance that can neither accept a hydrogen ion (proton) nor yield a hydroxyl ion (OH^-), even when dissolved in water. Nevertheless, they did know that a Bronsted-Lowry base is a substance that takes up protons (hydrogen cations H^+), and is therefore called a proton acceptor. This shows that this section is problematic for learners who do not understand fundamental chemistry concepts. The authors indicated that in order to resolve this misconception a teacher could use analogies and examples to explain to the learners about the properties of bases. For instance, ammonia is a base because it is accepts hydrogen ions from the water. It is further explained that “The ammonium ion is its conjugate acid – it can release that hydrogen ion again to reform the ammonia” (Oberem, Adu-Damoah, & Mbatha, 2011, p. 22).

Chemical bonding is central to understanding molecules, structures and their reactions in organic chemistry. For example, covalent bonds are the building blocks in carbon based organic compounds, including DNA and proteins. Nonetheless, chemical bonding is highly problematic with most students at different levels (Davidowitz & Rollnick, 2011). In the study conducted by De Souza et al. (2015), it was observed that learners exhibited the misconception that valence electrons are the innermost electrons of an atom, because they had never be given a chance to visualize the valence electrons in a concrete way. However, according to Oberem et al. (2011), “valence electrons are the outermost electrons around an atom and are the most likely to be involved in chemical reactions” (p. 15). This idea helps to explain the significance of understanding the role of valence electrons in atoms. Demonstration of the atom and valence electrons using videos can work effectively for learners and the teacher may also use analogies to further illustrate the idea of valence electrons. The use of analogies was also supported by Cannon (2016), who adds that “in chemistry, a valence electron is an electron that is associated with an atom, and that can participate in the formation of a chemical bond; in a single covalent bond, both atoms in the bond contribute one valence electron in order to form a shared pair” (p. 55). The analogy of a bottle filled with water, where the water represent protons and neutrons and the bottle represent valence electrons, would makes it clear that the valence electrons are found on the outside as where they might be shared. Analogical representations include the use of visual aids or models to display a particular concept to learners (Reed, 2015).

Another study was conducted by Mauksch and Tsogoeva (2017) on conceptions of chemical bonding in organic chemistry and the findings show the learners' misconception that "in one group of organic compounds called the hydrocarbons, the single, double and triple bonds of the alkanes, alkenes, and alkynes are not examples of functional groups" (p. 77). Mauksch and Tsogoeva (2017) defined functional groups in organic chemistry as specific groups of atoms or bonds within molecules. It seems that learners did not regard a bond as a distinguishing feature of functional groups, whereas, according to Mauksch and Tsogoeva (2017), "They are responsible for the characteristic chemical reactions of those molecules. Functional groups are attached to the carbon backbone of organic molecules" (p. 37). Functional groups determine the characteristics and chemical reactivity of molecules. The same functional group undergoes the same chemical reactions, regardless of the size of the molecule it is a part of. Functional groups are less stable than the carbon backbone so they are more likely to take part in chemical reactions. In the hydrocarbons, the single, double, and triple bonds of the alkanes, alkenes and alkynes are the functional groups (Mauksch & Tsogoeva, 2017). These authors further recommended that in order to deal with this misconception, the teacher may give his or her learners a list of several organic compounds and ask them to identify the functional groups among them. Schwarzenbach, Gschwend, and Imboden (2016) hold that "a chemical bond is a lasting attraction between atoms that enables the formation of chemical compounds. They further say that the bond may result from the electrostatic force of attraction between atoms with opposite charges, or through the sharing of electrons as in the covalent bonds" (p. 85). They conclude their article by saying the teacher could involve learners in a practical demonstration of chemical bonding using some examples such as ionic bond which talks about metals and non-metals and how to separate them physically and chemically.

Fats are hydrocarbon organic molecules which occur in everyday life as cholesterol and triglycerides. From studies by Atkins and De Paula (2011) and Garrett and Grisham (2005) it was found out that learners often misunderstand the interaction of hydrophobic molecules such as fat and water. Atkins and De Paula (2011) say many students think that individual oil and water molecules repel each other. They further addressed this misconception and said that when a hydrophobe is dropped in an aqueous medium, hydrogen bonds between water molecules will be broken to make room for the hydrophobe; however, water molecules do not react with hydrophobe (Atkins & De Paula, 2011; Garrett & Grisham, 2005). It is said that "Hydrophobic interactions describe the relations between water and hydrophobes (low water-soluble molecules). Hydrophobes are nonpolar molecules and usually have a long chain of carbons that do not interact with water molecules. The mixing of fat and water is a good example of this particular interaction. The common misconception is that water and fat doesn't mix because the Van der Waals forces that are acting upon both water and fat molecules are too weak. However, the behavior of a fat droplet in water has more to do with the enthalpy and entropy of the reaction than its intermolecular forces" (Atkins & De Paula, p. 65, 2011). They concluded that video simulations can work effectively and suggested some YouTube lessons that show the exact processes.

Solubility and boiling points in organic chemistry are often misunderstood. Akkuzu and Uyulgan (2016a) in their study found out that learners have a misconception related to solubility of organic compounds, such as with alcohols when the number of branches increases learners believe that its solubility would decrease. Leaners explain this as being due to an increase in branching meaning the surface area of the non-polar hydrocarbon part decreases and solubility increases. Padsalgikar (2017) explains that branching increases the "solubility as the branched structure of the polymer increases regions of interaction with the solvent." He further adds that branched chain compounds have lower boiling points than corresponding straight chain isomers. He then explains that this is due to the branching of the chain making a molecule more compact and thereby decreasing surface area (p. 78). Thus, "intermolecular attractive forces which depend on the surface area, also become small in magnitude on account of branching. Consequently, boiling points of branched chain alkenes are less than straight chain isomers" (Padsalgikar, 2017, p. 20). Akkuzu and Uyulgan (2016a) also found, among learners, the incorrect organic chemistry notion that as the amount of branching of molecules increases, the boiling point of the substance increases. In fact the boiling points of any series of isomeric organic compounds, not only isomeric alcohols, decreases with increasing degree of branching, due to the weaker Van der Waals dispersion forces between branched organic molecules compared to straight chain isomeric molecules.

Bryan (2014) in his study found that learners had the misconception that amino acids have high melting and boiling points because the compounds possessed strong intermolecular forces in the form of hydrogen bonds. Bryan (2014) showed that this explanation in terms of hydrogen bonds is found in standard school textbooks. Instead, as Wu (2013) explains, the high melting points for amino acids are due to their ability to form zwitterions. This ability causes electrostatic attraction between molecules, so that more energy is needed to break the bonds.

De Quadros et al. (2011) clarify that learners' misconception arise from the lack of integration of the chemistry content with learners' real world, which could be due to a lack of tools and equipment for practical work. They further state that teachers reported some problems themselves relating to their lack of content knowledge, which then leads to learners' alternative conceptions. In a study conducted by Mthethwa-Kunene et al. (2015) it was found that teachers lacked knowledge of learners' preconceptions, which might be the results of alternative conceptions that prevail in science subjects. Akkuzu and Uyulgan (2016a) assert that most alternative conceptions in organic chemistry stem from a lack of knowledge, teachers' use of inappropriate instructional strategies, recurring teachers' alternative conceptions, their prior experiences, and textbooks. They conclude by saying that if these alternative conceptions continue they may affect the way learners' learn. Learners should be taught organic chemistry concepts in depth so as to eliminate such recurring alternative conceptions (Raker, 2011).

Dauzvardis, Knapp, Shein, and Lisensky (2019) noted that learners hold a prevailing misconception that the prefix 'hydro', such as in the word hydrocarbons, means 'from water'. Instead, scientifically, the prefix 'hydro' refers to hydrogen not water. So therefore, hydrocarbons are defined as organic compounds that contain *only* carbon and hydrogen atoms. They are thus group 14 hydrides. As a teaching strategy, one could divide learners into groups and explore the meaning of organic compounds terms and concepts (Dauzvardis et al., 2019). As these alternative conceptions are also held by teachers and so they are the main source of some alternative conceptions, it is therefore evident that there is still much conceptual learning needed, starting with those who teach alternative conceptions (Pabuçcu & Geban, 2013). Dauzvardis et al. (2019) also indicates that learners often bring common everyday usage of words into chemistry. For instance there is the misconception that the word ‘alcohol’ means a drink such as beer, which many learners think this is the formal meaning of the word in chemistry. However, it was clarified that alcohols in chemistry are group of compounds with a functional groups defined by the presence of a hydroxyl group (-OH). According to Dauzvardis et al. (2019), “Alcoholic beverages contain ethanol, which is one type of alcohol, specifically consists of 2 carbon atoms and a hydroxyl group. As an activity, one can have students compare different types of alcohols and identify the common functional group (-OH) present in all. This misconception can also be used as a teachable moment where one can also lead into a socio-cultural discussion on the toxicity of ethanol and how it affects the mind, body and society” (p. 77).

Baraniuk, Foucart, Needell, Plan, and Wootters (2017), in their study, found that learners exhibited a misconception that all compounds contained in the animal body are organic; even, for example, salt. Scanlon and Sanders (2014) have clarified this misconception and asserted that water, salts, acids, and bases are four inorganic compounds that are essential in the body; water being the most important of them. Scanlon and Sanders (2014) explain that there are many compounds crucial to life that are not considered to be organic. Examples include certain salts and minerals. While the term organic means carbon containing, carbon dioxide (CO_2) is a carbon containing compound used in respiration/photosynthesis, but it is not considered an organic compound. Therefore, carbon dioxide (CO_2) and carbon monoxide (CO) are considered to be exceptions to the definition of organic compounds. To solve this misconception teachers can engage in an activity with students where students can be shown a number of different common organic and inorganic compounds and ask: *Is this compound organic or inorganic? How do we know?* For example, $C_5H_4N_4O_3$ –

uric acid (organic), H_2O – water (inorganic), NaCl – salt (inorganic) and CH_4 – methane (organic). Researchers suggest that in organic chemistry, teachers should engage learners in a research activity or assignment to gather information to clarify and consolidate further their conceptions (Schaefer, Spiess, Suter, & Fleming, 1990). The difficulties faced by learners in learning chemistry have been observed to be persistent. (Akkuzu & Uyulgan, 2016b).

In the study conducted by Akkuzu and Uyulgan (2016a), learners displayed a misconception that the bond formed by a carbon (C) atom with the hydrogen (H) atom is called hydrogen bond. However, to be scientifically correct, the bond between C and H in a molecule is a covalent bond and a strong intramolecular bond. Intermolecular forces are generally weak but, due to the added electrostatic attraction increasing the intermolecular bond strength, hydrogen bonds are much stronger than van der Waals. These authors suggested a computer based teaching resource to solve this misconception, such as engaging learners in practical activities or demonstration through videos such as YouTube.

Teachers should be aware of language difficulties related to concepts in chemistry. For example, Kaya (2016) found out that learners exhibited an alternative conceptions related to the terms 'condense' and 'reduce' in chemistry. Learners believe that condensation reactions result in something taking up less space than before. Instead, condensation reactions are reactions in which two compounds are combined and water is released. Reduction reactions are also explained incorrectly as something being made smaller or becoming reduced in size, whereas reduction reactions involve adding a hydrogen atom to a double bond. Kaya (2016) suggests that teachers could show video animations of condensation and reduction reactions or use molecular model kits to demonstrate exactly what happens to the atoms during a condensation and reduction reaction.

Kaya (2016) also found that learners think that the concepts found in organic chemistry do not apply to inorganic compounds. For instance, diamond, and sodium carbonate are derived from minerals and have typical inorganic properties even though they contain carbon. Organic functional groups are also often found in inorganic compounds and thus, they share the same chemical properties (Combinatorial Chemistry, 2008). Even organic and inorganic compounds can be characterized as acidic, basic or neutral.

To address solubility and boiling points, activities to address misconception could include students conducting investigations in the laboratory on the "properties of alcohols. Students can explore the solubility of alcohols in polar versus non-polar solvents. Here, students should conclude that both water (inorganic compound) and alcohols (organic compound) contain a polar hydroxyl group (–OH), which is an organic functional group. The hydroxyl group gives both molecules a polar property and thus, both are soluble in polar solvents" (Kaya, 2016, p. 60).

2.2.5 Teachers' knowledge about subject matter (SMK)

Teacher's subject matter knowledge is a very important as the concepts that teachers believe they will teach their learners. According to O'Dwyer and Childs (2014) teaching organic and inorganic compounds is full of difficulties as those who teach these topics often lack sufficient knowledge about them.

Moreover, in her study, Duis (2011) found that some teachers were not aware of their own alternative conceptions and so they were not able to distinguish alternative conceptions among their learners' preconceptions. One such example from (Agten, Dawson, & Hackeng, 2016) is where teachers were unable to explain dehydration synthesis correctly to learners and said dehydration synthesis occurs in all molecules not only the hydroxyl group in proteins. According to Carneiro et al. (2016) teachers who teach inorganic and organic chemistry usually focus on delivering the content to their students and do not focus on what might be the challenges faced by their learners. The authors give as an example the situation where teachers were not able to identify the misconception, when learners said sodium nitrate fertilizer has no negative impact on the soil, irrespective of whether applied in large or small quantities. They hold that teachers mostly focus on teacher-centred instruction and this means that the teacher is unaware when learners lose focus on the subject matter. Pabuccu and Geban (year) note that teachers are often not aware of subtle alternative conceptions such as learners in organic chemistry thinking that ionic charges determine the polarity of the bond alternative conceptions. Instead, according to chemists, the polarity of a bond is determined by the differences in electronegativity, which is a measure of the tendency of an atom to attract a bonding pair of electrons. If the difference between the electronegativity values for each atom is too small to form an ionic bond but large enough to be significantly different, a polar covalent bond is formed (Lee & Prausnitz, 2010).

Rollnick and Mavhunga (2014) advanced that teaching chemistry needs to include an effective way of transforming the content into forms that are suitable for learners; this depends largely on teachers' pedagogical content knowledge. This means that learners' understanding of chemistry concepts depends on the way teachers' are able to transform the content for learners. So, for instance, the chemistry of life topic, which includes organic chemistry, cannot be taught effectively without teachers' having strong content knowledge and knowledge about how learners' learn chemistry.

In the study conducted by Pendur (2012), it was found that teachers lacked knowledge of alkanes and, since these are central to teaching of organic chemistry, this deficit may be the source of many alternative conceptions and difficulties they have today. He attributes this lack of knowledge to teachers' previous school curricular studies.

According to Ryan et al. (2016) all science teachers need to comprehend the subject matter they are teaching as this will enable them to teach effectively. In particular, subject matter knowledge increases with teachers' classroom experience. They express a concern that in science education there are so many educators employed to teach subjects for which they do not have a relevant degree and this affects the teaching and learning processes. In particular, they note that some new teachers with only basic chemistry are allocated to teach chemistry, which poses a threat to the quality of teaching and learning of chemistry. They hold that as teachers increase their school classroom experience, they also increase their organic chemistry concepts and the ways of teaching those concepts.

Irrespective of where the teacher comes from, most pre-service teachers possess unorganized subject matter (Kind, 2014). Hill, Nixon, and Luft (2017) assert that, even though SMK is very important, it is difficult for teachers to formally learn this component when they are already practising teachers. Teachers should get deeply into SMK early in their careers because they are likely teach it for a number of years and in depth SMK will raise their self-confidence when teaching (Van Driel, Berry, & Meirink, 2014). Hill et al. (2017) supports this perspective and clarifies that SMK improvement has had a great impact on learners' pass rate. However, Luft, Dubois, Nixon, and Campbell (2015) state that new teachers still develop their SMK as they gain experience of the classroom. Bartos, Lederman, and Lederman (2014) contend that only when there is a space for teachers to plan and reflect can SMK be developed and useful. They also suggest that further learning of SMK takes place when a teacher uses more new concepts from his or her existing selection of concepts, thereby increasing his or her SMK. Ifenthaler, Masduki, and Seel (2011) add that since knowledge is logical with main concepts followed by examples, the teacher should begin by explaining the main concepts or big ideas first, then use some relevant examples as he teaches in the classroom. Luft et al. (2015) holds that if educators want to enhance their SMK, they must improve their repertoire in the conceptual domain of the discipline and practice engaging with these concepts in the classroom. Bartos and Lederman (2014) assert that, in order to enhance SMK, teachers need to reflect on every classroom practice so they may identify those that need strengthening. Teachers with five and more years' experience were found to have better SMK than those with little experience (Luft et al., 2015). Conceptual change texts can be used by a teacher to activate students' prior knowledge and alternative conceptions and to help them to understand fundamental concepts, such as in chemical bonding. Concepts should be elaborated upon, such as through the use of explanations, analogies and examples. Analogies can be used in conceptual change texts to deal more effectively with students' alternative conceptions (Pabuçcu & Geban, 2013).

Dugdale (2016) found that learners had a misconception that non-metals do conduct electricity. However, in reality, non-metals are brittle, not malleable or soft, poor conductors of both heat and electricity, and they tend to gain electrons in chemical reactions. Some non-metals are liquids. This contrasts with metals, such as lithium, which are electrical conductors) (Kaya, 2016). The teacher can engage learners in a practical investigation that includes metals and non-metals and also encourage them to differentiate between metals and non-metals (Kaya, 2016).

Padsalgikar (2017) states that learners hold a misconception that hydrogen bonds are formed between atoms that donate or accept electrons. However, it was clarified that hydrogen bonding occurs between a hydrogen atom from one molecule and a more electronegative atom (e.g., oxygen, fluorine or chlorine) from another molecule. The reason hydrogen bonding occurs is that the electron is not shared evenly between a hydrogen atom and a negatively charged atom. Padsalgikar (2017) that a teacher could place the learners into small groups and let them differentiate between covalent, ionic and hydrogen bonds. The teacher should also give examples and perhaps use some videos.

Polymers form part of organic chemistry and should be related to everyday life. . Padsalgikar (2017) further asserts that learners hold a misconception of thinking that all polymers are manufactured synthetically. Padsalgikar (2017) gives the advice that in clarifying this misconception, a teacher could divide learners into groups to list and discuss the synthetic polymers such as polypropylene. In addition, all the important biological macromolecules in living organisms are polymers; this includes proteins, DNA, RNA, and carbohydrates. Wool, hair, and fingernails are made mostly of polymers too.

2.2.6 Knowledge about Assessment in Science

Teachers need to be acquainted with curriculum processes and content in assessing their learner's learning and should know what methods of assessment should be used in each section relating that to the set goals (Magnusson, Krajcik, & Borko, 1999; Morrison, Ross, Morrison, & Kalman, 2019; Suskie, 2018). Retnawati, Hadi, and Nugraha (2016) confirm that there is not much research conducted in the assessment methods that teachers' use and why they use them. Kamen (1996) is of the view that some teacher's assessment methods are influenced by what they have learnt in their institutions and that informs their practice of assessment. More importantly, it is emphasized that teachers are influenced by what they believe about the teaching and learning processes. In particular, some believe that informal assessments are a waste of time and not of any benefit to learners (Nortvedt & Buchholtz, 2018). Izci and Siegel (2019) hold that in chemistry, assessment is used to support instructional strategies, more especially informal assessment such as homework and oral questions, as they stimulate learners thinking skills and revision, making them ready for their examinations. Jones et al. (2017) advance the idea that assessment in agricultural chemistry is done to test how familiar learners are with the section and to see the progress they have made. Burke and Lobell (2017) added that testing learners is a requirement for improving their performance as assessment will tell which parts of a topic learners understand better.

2.3 Knowledge Components for the Transformation of Content Knowledge into Topic Specific Pedagogical Content Knowledge (TS-PCK)

Topic specific pedagogical content knowledge (TS-PCK) (see Figure 2.1) has been defined as the ability to reason about teaching the topic through the five components regarded as important for the transformation of content knowledge. There are:

- Learners' prior knowledge,
- Curricular Saliency: what makes a topic easy or difficult to understand and to teach?
- What is difficult to teach?

- Representations, and
- Conceptual teaching strategies (Rollnick & Mavhunga, 2014, p. 354).

This idea of TS-PCK evolved in science education research because when PCK is used in a particular topic like organic chemistry, it takes on the specificity of the topic and its concepts; these differ when this knowledge is applied for the whole discipline. Researchers hold that TS-PCK helps teachers reason the more specifically about the content knowledge of the topic with regards to learners' prior knowledge, the arrangement of the topic in terms of the essential (or core) and minor concepts, as well as the pre-concepts (Mavhunga & Rollnick, 2013). Topic Specific-PCK is reflected in the capability of a teacher to design and transform his or her content knowledge for teaching in a certain topic. Therefore, I adopted these constructs or components of TS-PCK from Mavhunga (2014) research; these are described here to show how PCK links with subject matter knowledge when teaching organic chemistry.

The five features as identified in the TS-PCK model (Figure 2.1) are discussed in detail next.

2.3.1 Learners' Prior Knowledge

This component refers to the teachers' knowledge of preconceptions, which may include alternative conceptions that learners may hold about a certain topic before that topic is taught by the teacher. Gonen and Kocakaya (2010) hold that learners do not come into the class being empty, but they hold some conceptions that may be valid but are not scientifically accepted. For instance, learners usually think that the only difference that separates organic compounds from inorganic compounds is the carbon atom. Teachers usually ask learners of their own knowledge before explanation of the concept so as to integrate their knowledge into the prepared content by teachers. Organic chemistry is an essential topic for Agricultural Sciences learners but there has been a concern about alternative conceptions that prevail in the difficult section of chemical bonding in the organic compounds (Neville & Newman, 2000; Özmen, 2014). Ozmen (2014) states that some teachers explore and seek out learners' alternative conceptions related to organic compounds, such as the frequently recorded idea that covalent bonding transfers electrons alternative conceptions. It was further noted by Dickson, Thompson, and O'Toole (2016) indicate that learners had difficulties understanding the difference between electron transfer and sharing, as are involved in ionic and covalent bonding, respectively. Learners also believed that chemical bonding is a physical process. Pabuçcu and Geban (2013) also found that learner's alternative conceptions had serious alternative conceptions in organic chemistry. The main misconception identified was that learners thought that nitrogen atoms could share five electron pairs in bonding and teachers usually attend to such concepts and teach them properly using different teaching methods. More importantly, teachers need to first find pre-existing misconception held by learners in order to address them and ensure conceptual learning (Osborne and Freyberg, as cited by Akkuzu & Uyulgan, 2016a). Once teachers understand learners misconceptions, they usual use this information to correct positively and fill in the gaps that learners have so as to correct the misconceptions held by the learners. Pabuçcu and Geban (2013) hold that learners' alternative conceptions emanate from their previous experiences, therefore if the teacher wants to remediate them he or she must first allow learners to come out with their knowledge. According to Nicoll (2010) although some professional development is put in place as remediation for alternative conceptions in chemistry, many alternative conceptions still persist in topics like bonding. According to Sime-Ngando et al. (2016) students often miscomprehend the relations amid the hydrophobic molecules and water. They further explicate that students normally think that these repel each other. Ngando et al. elucidate that the hydrophobic molecules are attracted to water molecules but having a weaker bond than that which is between water molecules. In teaching of Agricultural Sciences chemistry content, students have shown some problems in understanding the differences between structural and geometric isomers (Sime-Ngando et al., 2016). Furthermore, students miscomprehend how the nature of the bond is influenced by the relative electronegativity of atoms that are covalently bonded, leading to polarity of the covalent bond (Sime-Ngando et al., 2016). They further say that, this may have shortcomings in the way students can predict how chemical groups can change the properties of organic compounds.

Nahum, Hofstein, Mamlok-Naaman, and Ziva (2004) conducted a study that revealed learners difficulties in chemical bonding and structures were due to the abstract nature of molecules, ions and hydrogen bonds. They expressed a concern as this topic is essential for a strong foundation for all other chemistry topics. In a similar manner, the study by Hanson (2017) explored alternative conceptions in covalent bonding, where many alternative conceptions were identified concerning the properties of atoms in the bond, indicating that covalent bonding is another challenging topic for learners to understand alternative conceptions. Similarly, Gudyanga and Madambi (2014b) discovered that learners exhibited alternative conceptions in the chemical bonding in organic compounds. Uce (2015) also expounded on the abstract nature of chemistry, as was evident in the results from his study. The learners had alternative conceptions about ionic and covalent bonding and they thought that "sodium chloride was a molecule in which sodium and chloride atoms were bonded together covalently" (Uce, 2015, p. 491).

Another misconception in bonding identified among learners by Hayek (2015) alternative conceptions is the notion that the only reason iodine (I_2) is a solid is that the covalent bonds between the atoms are very strong, instead of the better explanation that iodine (I_2) is a solid simply because of relatively strong intermolecular forces of interaction. Iodine is a large atom with a relatively large surface area and since it is a non-polar molecule, the only possible intermolecular interaction is the London Dispersion Force (LDF). The magnitude of LDF increases with the increase of surface area, and therefore, the strong intermolecular interaction between the molecules of iodine will pack the molecules closer together and so form a solid. The solid structure is maintained by intermolecular forces rather than bonds (metallic, covalent, or ionic).

In a study conducted by O'Dwyer and Childs (2011), it was noted that learners have difficulties in classifying organic compounds and lack understanding needed to differentiate their components. If teachers have a proper PCK it becomes easy for them to identify misconceptions held by learners as they hold better pedagogical content knowledge than their learners. In this regard, Omwirhiren and Ubanwa (2016) emphasises that students normally experience some difficulties in organic chemistry. He holds that students should start learning organic chemistry at an earlier grade to accommodate those learners who take time to comprehend such topics. Teachers should work on finding learners' misconceptions and expose learners on best internet videos and science libraries in order to gain more information about these science concepts. More specifically, Özmen (2004) writes that learners normally confuse essential amino acids and non-essential amino acids. Learners' claim that essential amino acids can be synthesized by humans, which contrasts with the definition that non-essential amino acids can be synthesized by the human body whereas essential amino acids must be obtained from the daily diet (Davidowitz, McCue, & Levin, 2017). If teachers can expose learners to internet this would enable learners to correct their knowledge gaps themselves. Also in the topic of amino acids, Polikanov, Steitz, and Innis (2014) found that learners held the misconception that a polypeptide bond is a bond formed when only two amino acids are bonded together chemically. For teachers to enhance their PCK on some of these chemistry concepts, videos on educational sites such as ‘Xtralearn’ are available so that they know which concepts are proper and where. They further explained that polypeptides are chains of amino acids and essential portions of proteins in cells. So polypeptides help make up proteins by bonding numerous amino acids together. Proteins are created by the bonding of two or more polypeptides, which are then folded into a specific shape for a particular protein. Once again, this shows that learners come into the class holding their own concepts of bonding, which need to be addressed when teaching chemistry content (Gonen & Kocakaya, 2010).

In general organic chemistry, Akkuzu and Uyulgan (2016a) indicated that that learners were not able to fully grasp intra- and intermolecular bonds. They further explain that learners continuously fail to accurately transfer ideas from general chemistry into organic chemistry. They contend that to enhance learners’ understanding of functional groups and intra- and intermolecular forces and avert alternative conceptions, basic chemistry topics should be reinforced and learners’ prior knowledge be activated and integrated with new knowledge; both being reinforced through class activities that require critical thinking. Weimer (2002) adds that it remains essential for learners to be allowed to express their views in class through the guidance of their teachers.

In another study, Pabuçcu and Geban (2013) identified learners' alternative conceptions that atoms are bonded together to fill their octets, which contrasts with the explanation that, Marie (2017) gives in terms of atoms forming chemical bonds in order to make their outer electron shells more stable. The type of chemical bond formed maximizes the stability of the atoms that form it. An ionic bond, where one atom essentially donates an electron to another, forms when one atom becomes stable by losing its outer electrons and the other atom become stable (usually by filling its valence shell) by gaining the electrons. It was further suggested that in order to try and deal with this misconception conceptual change strategies could be used by the teacher, which includes analogies, examples and explanations. (Pabuçcu & Geban, 2013) suggest that some videos can be useful for learners to understand the bonds, by seeing them in some sort of concrete fashion. (Pabuçcu & Geban, 2013) further found that learners thought equal sharing of an electron pair occurs in all covalent bonds so that all covalent bonds are nonpolar. (Pabuçcu & Geban, 2013) hold a contrary stance to the learners in that "covalent bonding occurs when pairs of electrons are shared by atoms. Non-metals will readily form covalent bonds with other non-metals in order to obtain stability and can form anywhere between one to three covalent bonds with other non-metals depending on how many valence electrons they possess. Although it is said that atoms share electrons when they form covalent bonds, they do not usually share the electrons equally" (Fulton, 1993, p. 105).

Mavhunga and Rollnick (2016) note that "at a topic level, PCK enables teachers to create a bridge between content of specific topics and students' understanding" (p. 2). This means that teachers are able to transform their content knowledge into forms that learners may able to assimilate. Akkuzu and Uyulgan (2016a) contend that learners fail to understand organic chemistry because of lack of conceptual understanding and because most learners do not have a background in chemistry it is difficult for them when they are the novices. Duis (2011) advocates that teachers should be actively involved in finding out the learners' alternative conceptions, through oral questions in class and small quizzes, alternative conceptions so they may help learners come up with scientifically accepted conceptions. Furthermore, Bhattacharyya and Bodner (2005) hold that even graduates demonstrate a very low level of conceptual understanding, which they suggest stems from memorizing concepts instead of understanding them, which is promoted by the way teachers teach in class. In therefore, learners' prior knowledge is one of the most important aspects for a teacher to check, as such previous knowledge may or may not be appropriate in science, which may sometimes be the cause of failure in Agricultural Sciences and science in general.

2.3.2 Curriculum Saliency

This component of TS-PCK, curriculum saliency, refers to teachers' knowledge of the arrangement of the curriculum topics and each topic's place and purpose in the curriculum. Malcolm (2015) notes the importance of teachers' decisions about which topic or concepts are significant as some teachers may choose whether a topic is treated in detail or superficially regardless of curriculum requirements. In South Africa these requirements are stipulated in the Department of Education and Training (DET) curriculum and CAPS Physical Sciences curriculum document (Wedekind, 2013). Furthermore, this component also pertains to teachers' belief about whether a topic involves core or minor concepts. Thus, teachers' personal views and beliefs influences the way they plans their lessons leading and about how much time to allocate to each topic. Chemistry curricula usually begin with concepts or terminologies such as molecules, atoms, compounds and matter before moving to more abstract concepts such as lipid structure, carbohydrates and proteins. Pérez et al. (2017) and Nahum et al. (2004) elucidated on the difficulties faced by learners including basic understanding related to chemical structure and bonding, such as molecules, ions, hydrogen bonds. They emphasize that these concepts are fundamental in understanding many chemistry concepts. Akkuzu and Uyulgan (2016a) note that when teachers use the concepts accurately and sequence them appropriate the result is good structuring of and connections in learners' knowledge. They further explain that because of the link between concepts, if one concept was not understood or weakly understood, then anything involving that term will be problematic, and in alternative conceptions. They further highlight the importance of teachers' familiarity with recurring alternative conceptions so they might address them before introducing learners to the new knowledge. They hold that this results in smooth learning as learners will only have set of conceptions to be learned; the ones that were tested and were approved to be correct knowledge. Sibanda (2013) holds to the necessity for teachers to have an understanding of the teaching and learning of all topics, so they may make decisions about which topics are to be taught first and which ones are to be taught last. Sibanda holds that research has focused on learning sequence from the point of view of learners and less research has been focused on teachers' planning sequence for teaching and assessment.

2.3.3 What makes a topic easy or difficult to understand and teach?

This component of the TS-PCK model refers to knowledge that the teacher possesses about certain concepts that may be difficult for learners to understand in each topic. Based on such knowledge about learners' challenges teachers would find ways of representing those particular concepts and suitable teaching strategies to tackle or overcome those difficulties. According to Lucenario et al. (2016), policy makers all over the world are starting to assist educators to cope with the need for different teaching methods for learners with different learning styles in difficult concepts. Furthermore, they assert that Japan is one country that is encouraging studies to be conducted in order to improve teachers' PCK. Moreover, they believe that during these studies teachers will be able to work together while improving their daily professional practice. According to Rollnick and Mavhunga (2016) it is best to focus on a specific topic that seems to be challenging rather than tackling a whole subject, so that teachers may get a special remedy for what they regard as their greatest point of challenge. This stems from a belief that helping improve teachers' teaching and learning would enable the effective transformation and transfer of content knowledge to learners.

2.3.4 Representations including powerful examples and analogies

This aspect of TS-PCK refers to various conceptual representations that a teacher uses in teaching a particular topic; for instance, illustrations, examples, analogies and models, which support teachers in reinforcing a particular concept. When teachers are teaching the basic agricultural chemistry topic of organic compounds, specifically on bonding, they should use examples that are relevant to learners' lives. According to Roche (2013), basic agricultural chemistry includes teaching learners first about atoms, explaining them with objects or stick models and showing how and why molecules are formed, which then advances into more abstract concepts of chemical bonding and intermolecular bonds. Nahum et al. (2004) hold that for teachers to teach chemistry content well, they need to have an understanding of suitable models to use to help learners understand the unseen phenomenon. Furthermore, they clarify that teachers should know how their learners construct their own intellectual models, and how to use the models successfully in their classrooms. Van Driel, Verloop, and de Vos (1998) maintain that using models is part of a teacher's efforts to represent challenging and abstract concepts in a variety of ways so as to enable their learners have a full understanding of them. Harrison and Treagust (2010) hold that models are crucially important, in that they provide a good link between methods and products of science. As alluded to by Gilbert and Justi (2016), the effective teaching of chemistry requires an individual educator to be strong in his or her understanding of the models that are used in chemistry and why they are used differently in different topics. They further expound that it is also important to know how their learners mentally construct representational models and how they can utilize those models constructively in their classrooms. Lastly, they agreed that teachers who teach chemistry should be acquainted with the use of models in their lessons as some of these models may convey a different meaning to learners if they were misrepresented. Sometimes learners can get confused with models and think that they are just play tools. So although models are an excellent strategy for effective teaching and modelling of chemistry, studies reveal that only few teachers among those with a chemistry major were able to use models effectively (Grosslight, Unger, Jay, & Smith, 1991; Gulyas, Pfefferle, Wolf, & Waitz, 2015). Bachsmann, Wolf, and Waitz (2015) also suggest that the use of models creates a mental image for learners of what matter is and how it is made up. Furthermore some models are of a predictive nature, like an atom, meaning that models can be used to create a mental image for learners to predict how an atom would look. Other models that are often used by chemistry teachers to enable learners to access abstract concepts include balls and sticks to represent molecules to show learners what molecules may look like (Gilbert & Justi, 2016).

Role playing such as in a game, collaborative learning, or assigning learners for different duties would also enable learners to express their knowledge of processes that takes place in chemistry, because these learners could act a part played by a certain concept, or make an object in clay in a fun environment.

Concept mapping is one way that chemistry teachers could link chemistry concepts. Concept maps uses labelled nodes for the representation of certain concepts for learners (Stevenson, Hartmeyer, & Bentsen, 2017). Furthermore, concept mapping allows the identification and categorization of certain concepts, as well as for the teacher and learners to make connections amongst those concepts (Jaafarpour, Aazami, & Mozafari, 2016). According to Govender (2015), the benefits of concept mapping include easy revision of previous work with learners, facilitating learners making connections between terminologies of a particular topic and argumentative sharing of information; all of which open opportunities for critical thinking skills to be developed.

Prain and Waldrip (2006) refer to multiple representations as playing an important role in teaching science effectively. They hold that by using these representations, learners' curiosity is easily captured and their understanding increases. Rowles and Brigham (2005) note that instructional strategies that work effectively in chemistry are those that do away with memorization of content and focus on comprehension of the whole subject. They believe this also comes through learners' engagement with classroom activities, and they believe that learners must always be put at the centre of the lesson. Nevertheless, findings by Olaleye (2012) indicate that the most frequently mentioned strategies used by chemistry teachers were teacher explaining, teacher drawing diagrams and plotting graphs, writing notes and demonstrating experiments; all of which support a conventional chalk and talk teacher-centred approach. He added that "almost two-thirds of the teachers used oral questions and answers method to assess students' understanding of a concept and few teachers used project/problem solving and practical modes of assessment to evaluate lesson objectives" (p. 51). Furthermore, the teachers in that study believed that there was a good level of student's engagement in class activities.

2.3.5 Conceptual Teaching Strategies

This component from the TS-PCK model (Figure 2.1) refers to teachers' knowledge of suitable teaching strategies that he or she can employ in teaching a particular topic in order to minimize, change or eradicate the alternative conceptions and difficulties that learners might have in the topic. Taber (2009) explains that most alternative conceptions that learners possess stem from the methods used to teach them. Sibanda (2013) suggests that instructional strategies are of paramount importance as they determine how easy or difficult the chemistry section will be for learners, and thus how effectively the teacher will be in transferring the required content to learners. She further states that inappropriate instructional strategies are the main contributors to the learning problems experienced by learners, particularly where teachers use confusing teaching strategies, or where learners are not given time to express their views. She states that teachers' need to have a clear understanding of the concepts in chemistry before teaching it so as to create models and teaching strategies that will suit the concepts. Mphathiwa (2016) also emphasizes that teachers are faced with the challenge of using a variety of instructional strategies so as to accommodate learners with different learning styles. Luft et al. (2011) also state that teachers' beliefs also contribute to how they will transfer knowledge in class. Similarly, Vavrus, Thomas, and Bartlett (2011) support the notion that some teachers believe that learners prefer learner-centred instruction while others believe in teacher-centred instruction. Thus, teachers' beliefs, and hence teaching strategies, all affect the way knowledge is transferred and gained by learners. The authors further assert that, teachers' PCK may also be developed through changing their beliefs, thereby putting a focus on new ways of transforming the content knowledge so that learners are able to integrate it into their daily lives. Cambron-McCabe, Lucas, Smith, and Dutton (2012) note that difference between PCK in a specific topic and PCK in a discipline; the latter is bigger so sometimes the discipline PCK is difficult for teachers to easily understand what they are actually dealing with. She proposes that TS-PCK enables teachers to know what this topic entails and how it is taught, and this allows them to find ways of transferring it to their learners effectively.

2.4 Summary of Literature Review

As described from the literature in this study, teachers are required to have good PCK, SMK, CK and knowledge of assessment as well as of instructional strategies in order for them to teach effectively in their lessons. The literature reveals that those teachers with less TS-PCK would easily hinder their learners' performance because they do not teach as effectively as those who have considerable TS-PCK. The literature shows that such teachers with insufficient TS-PCK are also found in subjects such as Agricultural Sciences as well as other sciences.

2.5 Limitations of the Literature

A few international studies were undertaken in Agricultural Sciences but the chemistry section aspect of this subject has not been well researched. The literature on South African studies in Agricultural Sciences is limited, with none focused on teaching organic chemistry in the Agricultural Sciences. Hence this study could not draw upon many previous studies of organic chemistry in Agricultural Science.

2.6. Theoretical framework of the study

The purpose of this study was to explore Agricultural Sciences teachers' topic specific pedagogical content knowledge in teaching organic compounds. Accordingly, my study is based on PCK. There are several groups of researchers in the field of PCK and TS-PCK, such as Gess-Newsome and Lederman (2001), Grossman (1990), Loughran, Mulhall, and Berry (2004), Magnusson et al. (1999), Mavhunga and Rollnick (2013), Shulman (1986), Van Driel and Berry (2010). Shulman's seminal work, developed further by others, is based on teachers' knowledge and this is used as the theoretical framework of this study. It includes seven categories of knowledge needed by a teacher, which in relation to leaching science are pedagogical content knowledge, knowledge of science instructional strategies and the science curriculum, knowledge of learners' preconceptions and learning challenges, knowledge of assessment in science, and knowledge of the context of the school. Shulman (1986) describes pedagogical content knowledge (PCK) as the knowledge that is unique to a teacher and that differentiates him or her from a subject expert. He asserts that it is concerned with teaching instruction that takes into consideration the learning requirements and difficulties of learners in a subject topic. However, Grossman (1990) reconsidered Shulman's work or model to show the interaction between PCK and PK, SMK, and knowledge of the context (where the school is situated). Grossman further pointed out that knowledge of context relates to each individual school or district curriculum requirements, the support provided to learners in the school, teachers' pedagogical content knowledge which determines how one teaches, and their abilities to teach. However, I adopted the full components of PCK from Magnusson et al. (1999), who added further components to build upon Grossman's work. For the purpose of data collection and analysis for my study, I will use this model as a theoretical framework. Magnusson et al. (1999) outlined the components which I have summarized below for this study.

Orientation towards teaching in science refers to the teacher's information about the objectives for teaching science in a specific grade. Magnusson et al. (1999) expound that "The significance of this component is that these knowledge and beliefs serve as a conceptual map that guides instructional decisions about issues such as daily objectives, the content of student assignments, the use of textbooks and other curricular materials, and the evaluation of student learning" (p. 97). For example, teaching of organic compounds should help learners to understand the chemical properties of food (Yang & Xing, 2010). As chemistry has many abstract concepts, ranging from simple to complex. Therefore in teachers' orientation, they would need to plan the design their teaching in a different and relevant way for each grade level (Duis, 2011).

Knowledge of science instructional strategies refers to knowledge about the science learning area instructional strategies and topic specific instructional strategies. Topic strategies are specifically for the topic and subject specific strategies focus only on teaching the science subject. Teaching of chemistry requires different instructional strategies for different topics, for instance, the use of practical work in topics like bonding may need demonstrations and practical experience to be acquired by learners (Park & Oliver, 2008). Espinosa, Nueva España, and Marasigan (2016) add that chemistry teachers should possess a repertoire of teaching strategies to teach different difficult concepts.

Knowledge of assessment methods in scientific disciplines refers to teachers' knowledge of approaches for assessing learners and how to assess them in relation to topic objectives. Teachers should be engaged in both assessment for learning (formative) and assessment of learning (summative). According to Gafoor and Shilna (2014), the use of assessment in organic chemistry helps to identify any learners' alternative conceptions in topics like bonding and chemical reactions. The use of concept maps or multiple choice questions could be used to this end.

Knowledge of learners' preconceptions and alternative conceptions in science topic refers to teachers' knowledge about possible learners' preconceptions and alternative conceptions in this topic; what is required of them in learning the content of the topic; how to facilitate their learning; and what challenges they face while learning the topic. According to Duis (2011), learners normally hold alternative conceptions in science, which are identified by the few teachers who know their content knowledge and can then design ways to correct them. Sendur and Toprak (2013) add that alternative conceptions normally held by learners in organic chemistry concern the physical properties of alcohols, structural isomerism and oxidation and synthesis of alcohols.

Knowledge of the science curriculum includes knowledge about the science curriculum stated goals, material to be used in each topic and the instructional strategies to be used. In addition, this aspect includes knowledge about the arrangement and sequence of the topics in the curriculum. As it is represented in

Agricultural Sciences, the first topic is basic agricultural chemistry, which includes organic compounds. This is normally an area of difficulty for some learners (Jain et al., 2016; Rice & Kitchel, 2015a). The content to be taught in each topic is influenced by the big ideas and concepts that it contains. The depth of content knowledge that each teacher possesses may differ between topics. It is a common view nowadays that knowledge of ways of transforming content knowledge differ among teachers. Therefore, a teacher who has a good TS-PCK is the one who displays suitable ways of transforming content knowledge in each topic so that learners may understand the concepts easily. In this study, the researcher planned the study through the lens of the critical research paradigm. Therefore the research methodology used was qualitative action research in an attempt to bring about some transformation of content knowledge among the teachers.

Chapter 3

Methodology

3.1Introduction

Henning, Van Rensburg, and Smit (2004) and Vosloo (2015) define methodology as a combination of logically understandable methods that complement each other and which are suited to generating data and making findings that address the research questions.

For this study, the researcher chose the critical research paradigm. Critical research talks to emancipation of teachers who have total freedom to practice educational day to day duties and the best skills to teach content and transform it to ways that are easy for learners to grasp. The research methods that are used in this study are informed by the chosen. This chapter will outline the methods of collecting data, the research questions, methods of sampling and action research, the trustworthiness of the study and the research cycles.

3.2 Research Paradigm–Critical Theory

Given the extent and the purpose of this research, the critical research paradigm or critical theory was employed in this study. The critical research paradigm involves a positive interaction between the researcher and the participants (Dammak, 2015; Vosloo, 2015). Vosloo further states that the "critical theory researchers emphasize the importance of the interactive relation between the researcher and the participants and the impact of social and historical factors that influence them" (p. 8). As a researcher, I have been actively involved in the participants' physical context. I chose this paradigm because it actively involves engaging critically and reflectively with the participants in this study. As stated by Dammak (2015), this paradigm involves emancipation of participants in their context through "participation of the researcher in the social action being studied" (p. 9). The researcher was fully involved in the participatory action research with the participants so this research method allowed the researcher to work with his participants in the emancipatory action or process. This paradigm also allowed me to interact with my participants in exploring their TS-PCK relevant to teaching the organic chemistry section in Agricultural Sciences.

Critical theorists hold the notion that the relationship between community and the school should be examined and also changed for the better (Cohen, Manion, & Morrison, 2007). Furthermore, critical theorists advise one to go beyond merely questioning of the participants, and move into action. The researcher in this study first explored the problems teachers face and the way they teach. Then later he conducted an educational action research (methodological approach) to ensure some transformation of teachers' practices. Critical theory in education research deals with the transformation of teachers in education to act in a certain way that would improve their actions at work (McNiff, 2013). This means that action research should begin with an understanding of the situation or context of a particular community and then go beyond that to assisting or acting in a community of practice in order to consolidate the good action in line with the vision of schools. In this regard, Cohen et al. (2007) explain that: "Its intention is not merely to give an account of society and behaviour but to realize a society that is based on equality and democracy for all its members. Its purpose is not merely to understand situations and phenomena but to change them. In particular it seeks to emancipate the disempowered, to redress inequality and to promote individual freedoms within a democratic society" (p. 26). Thus critical theory helped the researcher to emancipate to some extent the educators to act and take responsibility for their situation. It is believed that when educators are emancipated, their skills will improve in ways that would enable their learners to be motivated and understand their content knowledge and perform better in class. Thus, “In this enterprise critical theory identifies the ‘false’ or ‘fragmented’ consciousness that has brought an individual or social group to relative powerlessness or, indeed, power, and it questions the legitimacy of this. It holds up to the lights of legitimacy and equality issues of repression, voice, ideology, power, participation, representation, inclusion and interests” (Eagleton, 1991, p. 26). Critical theory advocates that teachers should be actively engaged in action research to transform the position in which they find themselves. In this study, action research was implemented with regard to exploring topic specific pedagogical content knowledge (TS-PCK) of Agricultural Sciences teachers in organic chemistry. The action research was done in phases and is discussed in this chapter.

3.3 The Research Method

As the way of starting the journey, it is acknowledged by research studies that teachers, especially those who are not well qualified in chemistry, have difficulties in teaching organic chemistry. This study therefore explored Agricultural Sciences teachers' topic specific pedagogical content knowledge in teaching basic agricultural chemistry section.

This is a qualitative research study and employed a qualitative action research method, which was judged to be suitable to address teachers' problems and elicit some transformation of their content knowledge. This method is discussed in detail in the next section after the location of the study.

3.4 Location of the Study

This study is conducted in the Eastern Cape Province, more specifically in Libode district. The Libode district is one of the biggest educational districts in Eastern Cape. It is composed of mainly rural schools with a few schools that may be referred to as semi-urban. Libode is not a town according to geographical location, but rather a village, so there are only a few schools near the main business centre; others being located in distant rural areas. Libode is one of many poor locations in South Africa, where developmental progress has been very slow in its communities continue to experience poor service delivery. The province of the Eastern Cape is a very underdeveloped province; by that I mean few government services are provided for the mostly rural schools. The Libode district is poverty stricken. For instance, there are only two newly built schools provided by the government; the remainder are overcrowded, poorly maintained, and inadequately resourced. It has a poor reputation; the very disappointing matric results mean that most learners have been failing their final examinations.

The schools that are there are neglected by the provincial Department of Education. There is little professional support for teachers, who are therefore disadvantaged.

3.5 Objectives

The objectives of this study are to:

a) Explore topic specific pedagogical content knowledge (TS-PCK) problems of Grade 11 Agricultural Sciences teachers encountered in the teaching the topic organic compounds.
b) Explore how action research can help Grade 11 Agricultural Sciences teachers' to improve their topic specific pedagogical content knowledge (TS-PCK) in the teaching of organic compounds.

3.6 Research Questions

1) What topic specific pedagogical content knowledge (TS-PCK) problems do Grade 11 Agricultural Sciences teachers encounter in teaching the topic organic compounds?
2) How can Action Research be used to help Grade 11 Agricultural Sciences teachers' to improve their topic specific pedagogical content knowledge (TS-PCK) in teaching organic compounds?

3.7 Sampling

According to Rule and John (2011) it is not possible for a qualitative case study researcher to select everybody to be involved in the study. In this qualitative study, the researcher chose a purposeful sampling method. According to Guarte and Barrios (2006), purposive sampling is the selection of participants within a particular population according to their having a certain judgement or understanding on the characteristic of interest. The researcher therefore selected three Grade 11 Agricultural Sciences teachers purposively, based on their suitability for the purpose of this research, the proximity of the schools where they taught, and their belonging to the same socio-background (Rule & John, 2011). The Agricultural Sciences teachers were chosen because they have relevant information about topics and experience in teaching Agricultural Sciences chemistry, more specifically organic compounds. These three Agricultural Sciences teachers were able to meet as a community of practice and continue to work with the information gained from the workshop that was presented (after an initial test) so as to further improve their TS-PCK in organic compounds. For this professional development workshop to be sustainable, the researcher selected the three schools since the teachers would be able to meet frequently and assist one another, for as many years as they continued to work in the same area.

3.8 Action Research Approach

3.8.1 What is Action Research?

Action research (AR) is defined as a "participatory, democratic process concerned with emergent hands-on knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview which we believe is emerging at this ancient moment" Flynn (2016, p. 255). Brydon-Miller, Greenwood, and Maguire (2003) further note that action research links and integrates the theoretical part of the research with the action in order to solve pressing issues. The action research links with critical theory in the sense that they are both concerned with the emancipation of teachers, who can work together in a community of practice and thereby improve their content knowledge. In this action research study, teachers were involved in finding their own solution to problems experienced in their rural context; in this case, they worked together in trying to emancipate themselves from the problem of lack of content knowledge.

Action research is also, according to Stringer (2013), the orderly approach used in investigation that allows researchers to discover real solution to problems they face in their day-to-day living Stringer also asserts that participants affected by a situation should be practically involved in the process of investigation. He further recommends that the researcher should provide guidelines for and support to the participants during the research process. In addition, he explains that action research "seeks to build a body of knowledge that enhances professional and service occupations – teaching, social work, health care, psychology, youth work, and so on – provide appealing avenues of employment" (Stringer, 2013, p. 1). These ideas are supported by scholars like Hendricks (2006) and Sagor (2000), who point out the indisputable benefits of action research to teachers, thereby allowing teachers to acknowledge their ability as change agents. This key idea of change agents is reinforced by scholars such as Warrican (2006), who explain that action research enhances the knowledge of teachers involved in the research and promotes their efficacy and help them to advocate for school and curriculum change. Goodnough (2016) clarifies that AR enables the advancement of strong PCK with respect to curriculum outcomes, instructional methods and the way of assessing learners. Farrell (2003) adds that AR authenticates teachers' skills and knowledge related to the teaching and learning processes. In this study teachers were engaged in 'authentic settings' and were assisted through workshops to enhance their understanding and knowledge of TS-PCK in organic compounds. The process of action research enabled these teachers to know better and deeply understand what is happening inside their classrooms, through AR phases (Stringer, 2013).

3.8.2. Cycles of action research

In this study, I adopted and adapted the cycles of AR from Lewin (1948) and Stringer (2013), which refers to the three cycles of action research. The cycles of action research used in this study are, namely, reconnaissance, reflection and planning and action (Ebbutt, 1985) as outlined below.

i) **Reconnaissance cycle**

The beginning of the first phase, referred to as reconnaissance, is the phase in which the researcher must first find out all he or she can about the research. Accordingly, in this study reconnaissance refers to pre-professional development phase of this research, which involved semi-structured interviews (Appendix D). The data so generated would address the first research question: "What topic specific pedagogical content knowledge (TS-PCK) do Grade 11 Agricultural Sciences teachers enact in teaching the topic organic compounds?"

ii) **Reflection cycle**

The second, or reflection, cycle refers to how Grade 11 Agricultural Sciences teachers' enact their topic specific pedagogical content knowledge (TS-PCK) in teaching organic compounds. This is also a pre-professional development phase of the action research. The data was collected through the test that was written by teachers early in the study. An example of questions that were asked is (Appendix I): 'What is the name of an alkane that has two carbons and six hydrogens? 'After writing the test, the teachers reflected on their scores and incorrect answers. This stage of reflection was facilitated by discussions. These discussions helped the researcher to know what teachers felt about their knowledge in this chemistry section and how interested they were in professional development.

iii) **Planning and action cycle**

The third cycle or phase is called planning and action. It involved the professional development phase. Here, the teachers were invited to the two-day workshop organized by the subject advisor on the organic chemistry content. It was based on their knowledge on this chemistry section as shown in the pre-workshop test. This workshop developed the teachers in terms of their chemistry content knowledge, so that they would be able to transform it into forms that would make it accessible to learners. Teachers then reflected on the effect of the workshop had had on their knowledge development. A post-professional development interview was done during this cycle. After the reflection process, the teachers continued to work together; assisting one another in their environment as the community of practice.

The three cycle AR process helped the teachers develop their TS-PCK together as they worked towards the common goal of making learners understand chemistry concepts better. In this action research process, the teachers found that many problems affecting their practice in their rural context could be resolved to some extent through working together in action and reflection cycles.

This AR cycle process helped the community of teachers, firstly, to understand themselves as subject specific teachers and, then, to act on their recurring problems so as to improve the situation. This coming together and sharing of pedagogical problems only became possible once they were part of the action research. This means that through this impetus of action research, Agricultural Sciences teachers will be further motivated to continue to engage with each other so as to improve their chemistry content teaching. The AR process helped teachers to emancipate themselves while being practically involved in the cycles of action research.

For research question 2:

In accordance with the theoretical aspect of this research, data analysis used in this study was by the thematic method which underpinned the qualitative analysis. In this case the data was read and re-read until themes emerged and themes were coded for this study. Cohen et al. (2007) outlines some of the steps that the researcher should follow when analysing qualitative data, as follows:

Transcription: having the interview tape transcribed, noting not only the literal statements but also non-verbal and paralinguistic communication. They then suggest **Listening to the interview for a sense of the whole**: this involves listening to the entire tape several times and reading the transcription a number of times in order to provide a context for the emergence of specific units of meaning and themes later on. The interviews conducted in this study were accordingly transcribed, which along with the audio recording re-read and listened to several times until the themes emerged. *I* Cohen et al.'s next steps are: **Delineating units of general meaning**: this entails a thorough scrutiny of both verbal and non-verbal gestures to elicit the participant's meaning. **Delineating units of meaning relevant to the research question**: once the units of general meaning have been noted, they are then reduced to units of meaning relevant to the research question. **Training independent judges to verify the units of relevant meaning**: findings can be verified by using other researchers to carry out the above procedures. **Eliminating redundancies**: at this stage, the researcher checks the lists of relevant meaning and eliminates those clearly redundant to others previously listed. **Clustering units of relevant meaning**: the researcher now tries to determine if any of the units of relevant meaning naturally cluster together; whether there seems to be some common theme or essence that unites several discrete units of relevant meaning. **Determining themes from clusters of meaning**: the researcher examines all the clusters of meaning to determine if there is one (or more) central theme(s) which expresses the essence of these clusters" (p. 370). These points were followed in this study and the themes were discussed and explained in the following chapters. The phases of the data collection for each research question were discussed below. As shown in Figure 3.1 below, there were three phases to the research. The first phase indicates the first formal meeting where the problems that teachers had were discussed. At this meeting, teachers were given a chance to write a test as a way of finding out their own understanding of some concepts in organic chemistry. The test was taken from a previous Agricultural Sciences matriculation examination. When it was given to teachers it was found that teachers had misunderstand some concepts in the topic. The second phase of the research provided the opportunity for teachers to reflect on what they had written in the test and how they feel about it. Teachers alluded to thinking that they had not obtained full marks on the test. The third phase of the action research came a week later. It incorporated a professional development workshop for the teachers based on what had been observed in Phase 1 and reflected on in Phase 2. In all this a theoretical framework of PCK was used to analyse

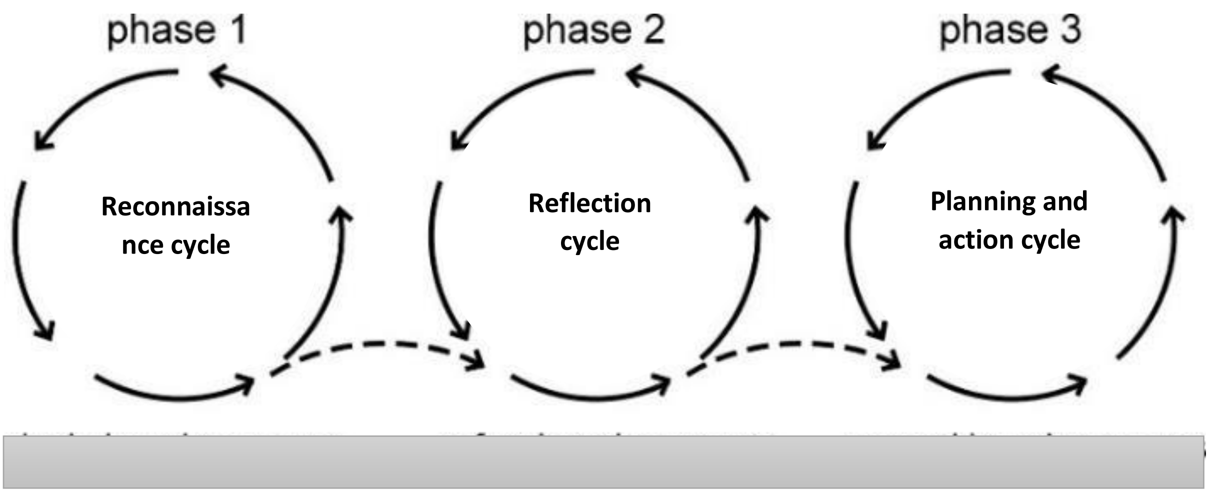


Figure 3.1 Cyclic diagram of phases for post PD

3.9 Methods of Data Collection

3.9.1 Summary of Data Collection Process

Table 3.1 outlines the methods of data generation for each research question. The research instruments are then discussed in details.

Table 3.1 Methods of Data Generation

Research Questions	Instruments	Method	Analysis
1. What problems do Grade 11 Agricultural Sciences teachers encounter in teaching the topic organic compounds?	Semi-structured interviews (Appendix D)	Interviewed Grade 11 teachers about TS-PCK in teaching organic compounds	Transcribed interviews and analysed for themes and categories. Using a theoretical framework
2. How can action research help Grade 11 Agricultural Sciences teachers' to improve their topic specific pedagogical content knowledge (TS-PCK) in teaching organic compounds?	Semi-structured interviews	Discussion in workshops sessions (Phases 2 and 3 in Figure 3.1) probed how Agricultural Sciences teachers enact their TS-PCK in teaching	Read interview transcripts. Coded transcripts. Using a theoretical framework Analysed why teachers enact

Research Question 2b: How can Action Research to help Grade 11 Agricultural Sciences teachers improve their topic specific pedagogical content knowledge (TS-PCK) in teaching organic compounds?	organic compounds?	TS-PCK in the way they do.

3.9.2 Semi-structured interviews

To collect the data for this study in order to answer the research questions, the researcher used semi-structured interviews. According to Creswel (2013) interviews are one form of data collection method in the qualitative research study. Thus, the researcher used interviews to get data about teachers' PCK in their teaching of organic compounds. Bodner and Orgill (2007) further clarify that semi-structured interviews are relevant and commonly used as sources of comprehensive data in qualitative case study research. This method helped the researcher to ask probing questions to get the required data. Here the researcher used one-on-one interview with the three teachers. These interviews were divided into two phases: the first phase and the second phase.

The first phase referred to as the pre-professional development (pre-PD) interviews, conducted among the three teachers. In this phase, the researcher interviewed teachers to find out “What problems do Grade 11 Agricultural Sciences teachers encounter in teaching the topic organic compounds?” An example of questions that were asked is the following:

Using one example briefly explain the differences between covalent bond and ionic bond.

This meeting with each teacher occurred at the hall as a convenient venue at one of the schools we used for the research. Teachers then wrote the test comprising questions extracted from previous Grade 11 question papers, which covered the content of organic compounds in Agricultural Sciences so as to evaluate their own knowledge content (see Appendix K). In order to gain teachers' understanding of the difficulties in the topic, the interviews and a test was used to see whether they do have content knowledge (CK) on the topic. The first phase of interviews therefore focused primarily on discovering the problems they had in this topic, so as to better understand where they would need help. After this test and interviews, the second phase commenced a week later.

The second phase is referred to as the post-professional development (post-PD) interviews. This phase involved teachers commenting on what action researchers could do for them. The second question of this study was answered using data from these post-PD interviews. The interview guide passed through a piloting stage to identify and correct any unclear questions. This piloting was done prior to data collection, and involved Agricultural Science teachers who were not part of the study. They were interviewed and some changes were made to correct the wording and clarify questions. An example of a question that was corrected is: ‘What instructional strategies works better for the school in teaching this topic’. This was corrected to become: ‘What instructional strategies works better for you in teaching this topic?’ One for the piloting was to reduce any interpretation difficulties that teachers face when answering the interview questions (Gilbert & Treagust, 2009). It also enhanced credibility of the questions.

3.9.3 Data Analysis Procedures

In this study the researcher sought to explore the topic specific pedagogical content knowledge (PCK) in teaching organic compounds as part of Basic Agricultural Chemistry among Agricultural Science teachers' in the Libode District, Eastern Cape. In analysing data for this study, the researcher used a qualitative thematic data analysis method. Proponents of thematic data analysis, such as Tesch (2013), hold the idea that the views of participants are taken seriously and presented accurately when analysing the qualitative data. The data analysis, organization, and interpretation was done using Tesch's method of qualitative data analysis for qualitative research. This method uses themes and themes were discussed which form part of Chapter 3 of this study. The data from the interviews was transcribed first and was read and re-read until themes emerged from it. The themes were categorized, coded and sub-themes explained or defined in this study. The data generated by the interviews and extracted from the interview transcripts were used to answer both research questions. In analysing the data, the researcher described and summarized the data in terms of the themes. Then through the lens of the theoretical framework of Critical Theory, the researcher used the data to discuss themes, quoting from the participants' words to substantiate the results, thereby answering the research questions.

3.10 Trustworthiness of the Study

This study employed a qualitative action research approach. Therefore, trustworthiness was necessary to enhance the quality and genuineness of the results. To this end, the researcher considered and made use of key trustworthy criteria, against which the results of qualitative research would be judged; namely, credibility, transferability, dependability and confirmability (Cohen, Manion, & Morrison, 2018; Cope, 2014; Shenton, 2004). These are described next.

3.10.1 Credibility

Credibility, according to Cope (2014) is the truthfulness of the collected data. The means that the participants' views must be interpreted and represented as authentically and accurately as possible by the researcher. To this end, firstly, ethical clearance was obtained for the study. Then three participants were selected so that the study could show a spectrum of experiences. In addition, the interview guide passed through a piloting stage and mistakes in the wording of questions or ambiguities were corrected in order to capture the authentic experiences of teachers. In this action research, the questions used during the semi-structured interviews and group discussions were the same for all participants, to ensure all participants got a chance to respond to the same questions and share their individual experiences. To further enhance credibility of this study, the researcher returned the data transcripts to the participants for verification. After data analysis, the themes that had emerged from the interview data were sent to other teachers (not those interviewed) to confirm the emergence of these themes. At the end the findings were submitted to the supervisor.

Finally, a Turnitin report was obtained to ensure that the researcher had not plagiarized the work of other scholars.

Validation of data collection instruments

The instruments used in this study were first tested using colleagues in research. Some of the questions that were used were augmented to thicken the availability of the data. The instruments were then given to the supervisor for check and approval. These instruments were designed using the research questions of this study and were and still are in line with the objectives of this study.

3.10.2 Dependability

Dependability, as stated by Cope (year), relates to repetition of the same findings over and over throughout the research processes. Shenton (2004) supports this idea by saying dependability is the extent to which a portion of work will produce the same findings when repeated many times using the same data generation methods. To ensure dependability, the researcher ensured that the data was reliable and repeatable and that all the research processes employed were consistent and in line with one another. Accordingly, in reference to this study, the researcher has described in detail the methods that were used to generate and interpret the data of this study (see Table 3.1) so that future researchers may get the same findings when repeating the research in the same context. In this study, the researcher used pre-professional development interviews, group discussions and semi-structured interviews and they all reflected similar results, thereby indicating the reliability of this study. Finally, the data was arranged into themes which also added to the reliability of this study and the themes were sent to other teachers and researchers for verification.

3.10.3 Conformability

Cope (2014) explains that confirmability refers to researcher's ability to demonstrate that the data embody participants' responses and not the researcher's possibly biased views. To ensure confirmability of this study, the researcher kept all the interview and observation or discussion schedules so that it was possible to check against original data for confirmation of findings. Such data can be produced for confirmation of the findings. Understanding that bias in interpretation is a common mistake that all researchers face, it is necessary to step aside and allow the true meaning to prevail from the themes according to the participants' views. Therefore, I as a researcher, did my best to stand outside of the views of all participants and interpret the themes based on their words. Nevertheless, bias may still have some impact on the trustworthiness of the results, with the views of the researcher being prominent in the study rather than those of a participants. The interviews as described above were the tools that helped the researcher to answer the research questions of this study. According to Shenton (2004) the outcomes of the study must relate to the information given by the participants as well as from their experiences, and not be based on the views of the researcher. Being aware of this possibility, the researcher did not interfere responses, and used their exact words to back up the research claims. The researcher did this by going through the generated data several times and reflecting on it, trying to avoid bias. All participants were given the same interview questions to avoid bias. The data generation methods used (interviews) were recorded and the interview transcripts were confirmed with all three participants. After confirmation they were then used in this study appropriately.

3.10.4 Authenticity

Authenticity refers to the aptitude of the scholar to write only the feelings and emotions displayed by the participants, as a reflection of their experiences; the researcher expressing these in a faithful manner. To warrant the authenticity of this study, the researcher has quoted verbatim from the participants to show their true feelings and emotions. Besides that, the researcher interpreted the participants' words as required by the qualitative approach to make sure that the researcher was not biased. As a standalone researcher who understand the principles of a qualitative research and reliability in a qualitative study, I made sure to use the relevant quotes for each research claim and these were interpreted directly, with no manipulating or biased interpretation.

3.10.5 Transferability

Transferability has also been described by Cope, and it refers to the findings that can be applied to other settings or groups (Cope, 2014, p. 89). To ensure transferability of this study, the researcher has provided the interview and test questions in the appendices of this study so that other researchers may use them to continue with this research or to compare responses or to adapt them for other studies. Furthermore, as Demmak, (2013). State that the "critical theory researchers emphasize the importance of the interactive relation between the researcher and the participants and the impact of social and historical factors that influence them" (p. 8). Therefore, as this paradigm relates to the individual experiences and history, it must be noted that the history and experiences of different individuals change and depend on the context of each individual participant. These teachers live in deep rural areas and are isolated from those in town, who have access to better resources such as projectors, computers and libraries. The teachers in this study have many difficulties; even in finding new information.

3.11 Ethical Issues

The codes of conduct and topics of rights and privacy include the use of consent forms, anonymity, withdrawal rights and confidentially in the use of teachers' data (Babbie, 2007; McKernan, 2013). For this reason, before the research was conducted, an application for ethical clearance was sent to the University of KwaZulu-Natal Research Office, and the certificate granting me permission to conduct the study is included in Appendix G. Another letter was sent to the Department of Education in the Eastern Cape Province, which then granted me permission to conduct the study in the three schools in Libode District (Appendix F). Letters of application to conduct the study were also sent to the three chosen schools to ask for a permission to conduct the study with the teachers, and they all allowed me to conduct the study (Appendix B).

The participants were informed about the following issues.

Participants' withdrawal: All the participants of this study were informed of their right to withdraw from the study at any time they felt the need to do so. They were informed that their participation was voluntary and that their participation in this study did not have a rule binding then to continue if they wished to withdraw. They were also given the details of whom to contact if they need further information about my study. The participants signed acknowledgement of the terms and allowed me to interview them and audio record the interviews.

The use of the collected data: Sbu, Mrs. Deo, and Eman which were the participants were told that the raw data collected would be taken to the University of KwaZulu-Natal and be stored or locked there for 5 years after analysis. They were also told that after the five, the data would be completely destroyed. This was done to protect the participants' information and to encourage their participation in the future. They may have been afraid to participate if their names behind the pseudonyms were revealed. Accordingly, they all agreed for their data to be used for this study.

3.12 Limitations of the study

This study is limited to only to the selected schools and does not cover all schools in the Libode District. The study is also limited by the distance of the schools (proximity) and the possibility of gathering participants together.

The teachers were reluctant to be video-taped during the collection of data so only the voice recorder was used in the collection of data. Some participants were not be available on certain days but the researcher managed to accommodate such situations.

Chapter summery

In this chapter the researcher explained the research approach for this study which is the action, cycles of action research used which were Reconnaissance cycle, Reflection cycle, planning and action cycle. Concepts such as the analysis of the data, methods of data collection and questions that the researcher sought to answer were explained in this chapter. Data analysis procedures were explained together with trustworthiness and limitations of the study.

CHAPTER 4

DATA ANALYSIS PRESENTATION AND DISCUSSION OF RESEARCH QUESTION 1

In this chapter, firstly the teachers' biographies are given. Then data is presented and analysed to answer the first research question. This presentation takes the form of extracts from the pre-PD interviews with the three selected teachers according to themes. From the analysis four problem areas are identified. The implications of each problem is then discussed in the context of the literature.

4.1 Teachers' brief biography

Table 4.1 Teachers' brief biography

TEACHER	**Mr. Sbu**	**Mr. Eman**	**Mrs. DEO**
Qualification	B. Ed (Agriculture and Life Sciences)	B. Ed. (Agriculture and Life Sciences)	B. Sc in botany and chemistry with minor in physics
Teaching experience	2 years	2 years	5 years
Grades taught	10-12	10 and 11	10 to 12
Subjects	Agricultural Sciences and Life Sciences	Agricultural Sciences and Life Sciences	Physical Sciences, Agricultural

			Sciences and Natural Sciences
School Type	Rural	Rural	Rural

From Table 4.1 above, it is evident that Mrs. Deo is a qualified science teacher who majored in botany and chemistry with a minor in physics but she did not major in Agricultural Sciences. Besides her other subjects, she teaches Grades 10 to 12 in Agricultural Sciences. Her academic background therefore gives her an advantage when teaching Grade 11 Agricultural Sciences, which has a chemistry component. She is the only Physical Sciences teacher available at the school but was also allocated Agricultural Sciences as apparently the departmental budget would not stretch to employing another teacher; the number of educators employed in the school being dependent on the number of learners in the school. Nevertheless, Mrs. Deo has been teaching Agricultural Sciences for about five years, which means that she understands some of the problems learners face in the Agricultural Sciences chemistry section. So this adds an advantage to the way she teaches in her classes and the way she supports her learners. Moreover, because Mrs. Deo has considerable experience in her 5 years of teaching Agricultural Sciences, she has been dealing with the alternative conceptions that learners face in organic chemistry for some time. This would then make it possible for her to know where Agricultural Sciences learners are challenged.

However, novice teachers have less experience in teaching Agricultural Sciences and lack the relevant content knowledge in the chemistry section. To be specific, Mr. Eman and Mr. Sbu were both Agricultural Sciences teachers and although qualified specialists in teaching Agricultural Sciences they lack the knowledge gained in tertiary chemistry modules. At the university where they studied, some students chose modules in Soil Sciences, which were combined with chemistry, while others chose Animal Sciences. These two teachers chose Animal Sciences and so were exposed too little chemistry, which would have been valuable for teaching Agricultural Sciences. Furthermore, these two teachers had seldom been exposed to departmental workshops as had teacher Mrs. Deo and, therefore, they do not have professional teaching support when they face challenges in the teaching and learning of Agricultural Sciences. Moreover, these are rural teachers and, in the Libode district, that means teachers get no extra workshops beside the meetings held in January for analysis of matric results. Furthermore, being relatively novice teachers, they are still on a learning curve in terms of the teaching and learning professional development. in particular, for them to teach at FET phase as novice teachers is challenging and they need external assistance, such as support from mentor teachers, which is not available in this district from the subject advisor.

4.2 Transcriptions and analysis for Research Question 1

Research Question 1, which the researcher in this study sought to answer is:

What TS-PCK problems do Grade 11 Agricultural Sciences teachers encounter in teaching the topic organic compounds?

This question was answered by conducting interviews with the three participants who teach Agricultural Sciences at Libode District for the three selected schools. The pre-PD interview questions (see Appendix A) were designed to probe teachers' problems in teaching organic chemistry content. The data was collected from the transcribed interviews, and emergent themes were obtained. The final themes obtained from the data and analysis of the data are presented as findings of this study for Research Question 1.

The interview transcripts for the teachers, Mr Eman, Mr. Sbu and Mrs Deo, are presented and categorized in the next subsections.

4.2.1 The significance of tertiary chemistry modules for teaching Agricultural Sciences

Researcher introducing the study to Mr. Sbu: May I know your educational qualification, for example, do you hold a Bachelors' degree, diploma or higher certificate?

Mr. Sbu: *I hold a bachelors' degree in Education and I did Agricultural Sciences.*

Researcher: You are teaching Agricultural Sciences in this school and it requires some chemistry knowledge. Did you do any content in chemistry either at high school or higher institution level?

Mr. Sbu: '*Yes. I did chemistry at high school as part of Physical Sciences from Grade 10 to 12. At high school, I also did some practicals'.*

Researcher: Did you enrol for chemistry modules in higher education?

Mr. Sbu*: 'Yes. I did study at tertiary level, but I did not have training in chemistry'*.

As can be seen, Mr. Sbu pointed out that he did not study any chemistry content in higher education, but only at high school level where he learnt some chemistry including organic chemistry at matric level. From the above introduction, some of the challenges that emerge from Mr. Sbu's poor classroom presentation of organic chemistry in Agricultural Sciences could emanate from his lack of experience in completing tertiary chemistry modules.

Researcher to Mr. Sbu: if you have it, does it help you in teaching Agricultural Science chemistry section?

Mr. Sbu: '*Yes partially so, the information that I have from high school I use it to teach Agricultural Sciences in Grade 11 at high school.'*

Mr. Sbu clarifies that the high school content partially helps him with some classroom presentations to his learners, though this may not be sufficient without the university chemistry modules. As he did B. Ed. (Agricultural Sciences), Mr. Sbu did not do chemistry modules at the university, but chose Animal Sciences, and that is why he lacks the chemistry content knowledge to teach adequately in high school Agricultural Sciences.

Researcher introducing Mr. Eman to the study:

Researcher: Did you do any content in chemistry either at high school level or higher education institution?

Mr. Eman: '*I have done in high school a bit of introduction in chemistry but at university, I did not do any chemistry modules.'*

Researcher: Do you think this is sufficient to teach Agricultural Sciences?

Mr. Eman: '*No. I wish I had done more tertiary modules organic chemistry*.'

Researcher: if you did the chemistry modules, do you think it will help you in teaching Agricultural Science chemistry section?

Mr. Eman: *., yes… definitely so, the information that I have from high school I use it to teach Agricultural Sciences in Grade 11 at high school but it is not enough to understand deeper concepts*.

He further stated that his high school basic Agricultural Science chemistry knowledge partially helped him determine ways in which he could present some of the content prescribed by the CAPS Agricultural Science curriculum.

From this quote, Mr. Eman indicated that his only introduction to basic Agricultural Science chemistry was at the high school level and he felt that this was not enough to teach the subject. He agreed that he had not studied any tertiary chemistry modules, even though he teaches chemistry in Agricultural Sciences.

In summary of the two teachers' interview quotes, it is evident that both Mr. Sbu and Mr. Eman have the same problem of lacking tertiary chemistry modules. It is a serious problem for them as they have to represent and teach organic chemistry content knowledge to their learners and they rely on previously learnt school level chemistry from some years before.

Teacher 3-Mrs.Deo

Researcher introducing to Mrs. Deo the study:

Researcher: Good day

Mrs. Deo: Good day

Researcher: What is your educational qualification? A bachelors' degree or diploma or higher education certificate?

Mrs. Deo: Bachelors' degree

Researcher: From which university and what specialization?

Mrs. Deo: *From University of KwaZulu-Natal, and I have a bachelors' degree in chemistry with majors in botany and zoology*

Researcher: Good, good, did you do any chemistry?

Mrs. Deo: '*Yes I did chemistry at higher institution'*

Researcher: since you said you have done chemistry portion at the university, does it help you in teaching Agricultural Science chemistry section?

Mrs. Deo: *It does a lot, because agriculture is all about plants and animals, of course the soil as well and therefore, when you speak about chemistry, it does come in because you can't do anything in agriculture without water and without the elements that is actually the periodic table. And the air and the food we eat and so many other materials and these are linked to agriculture. So then, agriculture by itself, cannot be understood fully without understanding the organic part of chemistry.*

In summary, Mrs Deo did concur that her tertiary education modules helped her represent and teach the chemistry content knowledge effectively as she could understand the concepts much deeper and then explain them to her learners.

The emerging problem from the above interviews of the three teachers experienced is summarized as a Problem #1.1.

Problem # 1.1 - LOCM

The lack of completing chemistry modules in tertiary education (LOCM) impedes Agricultural Sciences educators to teach the basic agricultural chemistry section adequately, while exposure to tertiary module(s) in chemistry supports them in their teaching.

4.2.2 The significance of Content Knowledge (CK) of chemistry for teaching Agricultural Sciences

Interview with Teachers: Mr Sbu, Mr Eman and Mrs Deo

Researcher: All correct, since Agricultural Sciences include this chemistry section, how do you evaluate the inclusion of this section in CAPS Agricultural Science document? Is it difficult but necessary for learners?

Mr. Sbu: Yes, *this chemistry section is necessary for learners in order for them to be able to understand agriculture very well, but it is difficult by the way even to teachers more especial us who did not do the chemistry module at higher institution....'*

Mr. Sbu explained that he faces a problem as this section is a difficult section for him. He expounded that this chemistry section entails some problems that make it very difficult, even for him, as well as for his learners to understand. He said this is a challenge he faces in his school. He also went on to reveal another problem, being the lack of pedagogical content knowledge when the researcher asked him what difficulties he faced when teaching organic compounds?

Researcher: Is it easy to explain the formulae of simple sugars (monosaccharides) to all your learners?

Mr. Sbu: '*It is very difficult, more especial the structural and chemistry representation of the chemistry elements like glucose and fructose and et cetera, they are a challenge to me since I did not do any chemistry section at the higher institution'*

This reveals that Mr. Sbu is not comfortable in this section of organic chemistry as he does not know some concepts pertaining to the organic chemistry section.

This may lead to his loss of confidence in teaching and then his learners would gain less from his teaching. Sheehan et al. (2011) explain that "The poor subject matter knowledge of these preservice teachers is likely to lead to the transmission of alternative conceptions to their students." (p. 1)

Researcher: Since Agricultural Sciences include this chemistry section, how do you evaluate the inclusion of this section in the CAPS Agricultural Science document? Is it difficult but necessary for learners?

Mr. Eman: '*Yes, it is difficult but necessary for learners because this is the only section that I know will help them in understanding the food they eat and all other household chemicals they use at home.'*

Here Mr. Eman reveals that this chemistry section is difficult to him but necessary for learners as they need to learn about their daily life practices and food they eat.

Mr. Eman also showed a lack of content knowledge when it comes to why farmers irrigate the soil during the afternoon and morning. For instance:

Researcher: Why do farmers prefer to irrigate their plants in the morning and in the afternoon than during the hot time of the day?

Mr. Eman: *The soil in the morning is still having some pores and so the plants are able to receive some water as compared to during the day, because during the day the sun is already striking the soil. So it will close the pore spaces of the soil, so it is preferable to irrigate in the afternoon.*

Researcher: So the pores close during the day?

Mr. Eman: *Yes they close during the day when it is hot*.

This shows that Mr. Eman does not have an understanding of why farmers do not want to irrigate during the hot times of the day but rather irrigate the soil in the morning and in the afternoon. He explicates that 'pore' spaces close and open and that is wrong because the soil 'pore' spaces do not open and close because of the day and night. Here he confuses the soil pore spaces with the plant stomata.

Mrs. Deo

In the same question Mrs. Deo also exhibited a lack of knowledge in teaching this section as she did not fully articulate the reason why farmers do not want to irrigate during the hot time of the day.

Researcher: Why do farmers prefer to irrigate their plants in the morning and in the afternoon than during the hot time of the day?

Mrs. Deo: *You know this is very obvious, like when it is hot time of the day, the heat is too much for the plants, and therefore, if you water during that time you are killing the plants because it is already hot and you are applying water, the plants are not going to respond to your water but if you water in the mornings when the heat is not so much hot and in the evening time when the sun has already gone to setting, then the plants are going to respond to water better than during the hot time of the day. And in the mornings, watering of your plants you will see that actually there is life to the plants better than when you water during hot time of the day*

On this point, it is evident that Mrs. Deo has a shallow understanding when it comes to watering the plants and will therefore also give her learners the same shallow information. It would have been better had she explained the reason that sunlight would heat the water causing it to evaporate from the soil and that will drag the salts that are there under the soil to top parts of the soil and that would lead to those plants dying because of salinization which is the increasing concentration of salts in the soil. She did not understand that plants do respond to water anytime, but the right times are those that will not cause the concentration of salts to increase on top of the soil, which in some soils lead to salinization. These times are in the morning and afternoon, when there is not too much heat to evaporate water from the ground. This aspect depends on different climatic conditions that occurs in different areas. If for example in very hot area, farmers would prefer to water plants and in the morning and afternoon, but in areas where it is not that hot they could water plants anytime of the day.

Mr. Sbu

When the researcher asked him if water is an organic or inorganic compound, Mr. Sbu replied as shown below.

Researcher: All correct, the availability of water is one of the important factors for the growth of plants. Would you regard water as organic or an inorganic compound?

Mr. Sbu: '*Water, is organic, is an organic compound'*

Researcher: Why organic?

Mr Sbu: It is needed for life … and life requires organic compounds as organic means molecules associate with living things.

When Mr. Sbu during the interview was asked whether water is organic or an inorganic compound, he gave a non-scientific answer, saying that water is an organic compound. This showed his relatively shallow knowledge of what constitutes an organic compound. Organic compounds are those that contain carbon as the main element. Water molecules contains only two hydrogen and one oxygen atoms (H_2O), and no carbon; thus it is an inorganic compound. Roundhill and Fackler Jr (2013) clarify that whenever there is no carbon, the molecules would be inorganic, because organic compounds are only made from carbon, hydrogen and sometimes oxygen or other elements. Of course carbon dioxide, carbon monoxide and carbonates are exceptions, being inorganic. However, both Mr. Eman and Mrs Deo had understood that water is an inorganic compound.The answer from the three teachers displayed that they lacked CK of some aspects of organic chemistry. Moreover, this lack of CK will have a direct impact on learners' acquiring further alternative conceptions in the classroom.

This misconception of 'what is organic and inorganic' alluded to by Mr. Sbu is a typical example of the problems that he mentioned in the biographic question about the subject he majored in, when he said he had not studied any chemistry content at the higher education institution. The knowledge he has from high school is the only knowledge that could assist him, rather inadequately, in teaching organic compounds. It is clearly insufficient for an Agricultural Science teacher. Moreover such a teacher may take some of his own conceptions for granted and not do any further research on the concepts. This lack of exposure to more advanced organic chemistry have led to the low level of CK that the teacher displayed concerning the organic and inorganic compounds. Furthermore the alternative conceptions that organic compounds are obtained only from living things is common. This notion is not universally true: for instance urea, which is an organic compound, can be synthesized from ammonium cyanate, which is an inorganic salt. Perry (2016) supports that water is an inorganic compound since it lacks carbon.

Teacher Sbu was also asked what would happen to plants if the level of carbon dioxide decreased in the atmosphere, he responded as follows**:**

Mr. Sbu: 'Plants will wilt if carbon dioxide decreases'

Mr. Sbu displayed a lack of CK in the way in which plants would be affected by low levels of carbon dioxide. He did not have an understanding that the plants would lose one of their essential requirements for making their own food. The requirements for plants to manufacture their own food are light, carbon dioxide (CO_2) and water. Thus, during the process of photosynthesis plants use sunlight as their energy to convert CO_2 into certain simple sugars like glucose, maltose etc. Therefore, if carbon dioxide is not there, plants will be unable to manufacture their own food.

When the teacher was asked about a decrease of CO_2, he said 'plants will wilt'. The teacher referred to an incorrect process of wilting, which is a process by which plant leaves lose water because of too much sunlight, or a dry wind et cetera (Bartlett, Klein, Jansen, Choat, & Sack, 2016). Moreover, the limits to the teachers' understanding would therefore limit the effectiveness of his teaching. This is one of the problems he faces in the classroom. Nevertheless, the other two teachers had no problem in this question as they explained it better.

The researcher asked Mr Eman a question on nitrogenous fertilizers.

Researcher: Nitrogenous fertilizers are important in the food produced, why do you think they are important for animals and human beings?

Mr. Eman: *They are vital because it is a major component of chlorophyll and a compound by which plants use energy to produce sugars from water and carbon dioxide.*

Mr. Eman had a problem with answering this question as he did not know what function the nitrogen plays in plants and human beings as well. Here he talks about the process of photosynthesis, but does not specifically mention the production or manufacturing of proteins, which is where nitrogen is essential, as the researcher had in mind. The information that he apparently lacks is that of how nitrogen is used in plants. It is absorbed in the form of ammonium salts or ions and used by plants to manufacture plant proteins. When humans consume the plants, the protein would be used for growth, repair of tissues in their bodies etc. (Khursheed & Mahammad, 2015). Nitrogen as a gas is not available for plants to absorb, but it has to be converted into nitrates and ammonium salts, which plants can absorb. The conversion happens by lightning and nitrogen fixing bacteria. In this topic Mr. Eman lacks CK in this chemistry concept, which is important for understanding and teaching Agricultural Sciences. Mr. Eman has a problem in understanding the nitrogen conversion aspects of plant processes in Agriculture.

The same teacher, Mr. Eman, displayed a lack of CK on being told by the researcher that some learners said that "Butane (C_4H_{10}) is less flammable, black and can be liquefied". When asked whether he thought this was correct as they had displayed this conception in class, he answered thus:

Mr. Eman: '*It's not flammable, it's less flammable.'*

From this answer it is clear that Mr. Eman also experiences some other problems related to the concepts and content in this chemistry section. His articulation in this case was just a guess, as he did not explain further as to why he thinks it is less flammable. According to Seven et al. (2017) butane is an extremely flammable, colourless, dangerous gas and can even burn in air. It is then clear that Mr. Eman is struggling with CK concerning the alkanes. This is a problem because alkanes like methane are part of the Grade 11 Agricultural Sciences curriculum. This would also affect his class, as they depend on his explanation to get their knowledge.

Another topic within chemistry also showed Mr. Eman's problematic CK, as shown below.

Researcher: Lastly, other learners were found to hold the idea that "heterogeneous mixture is a mixture that is uniform, and where the different components of the mixture cannot be seen". Do you think they are correct in this statement? And why would you think so?

Mr. Eman: '*Yes they are correct because according to the knowledge of how or based on the knowledge of genetics heterogeneous mixture is a mixture that mixes two alleles, so they are correct.*'

His answer revealed that he had little idea of what the researcher was referring to. Instead he confused terminology and concepts from two subjects, chemistry and biology. By referring to an irrelevant example in justifying the way learners have their misconception, he shows that he lacks CK in chemistry section; in this case related to Heterogeneous mixtures. A heterogeneous mixture is a mixture in which two substances mix but each retains its original properties; for example, pizza is made of different food mixtures such as meat that keep their own properties. Cereal and milk also form a heterogeneous mixture because these substances are not uniformly distributed in the mixture, meaning they can be more easily separated. (Nezamzadeh-Ejhieh & Zabihi-Mobarakeh, 2014; Pathiraja, Kim, & Choi, 2017). By contrast, a homogenous mixture refers to a mixture of substances that are combined or mixed in ways so that you cannot easily recognise each of them. These homogeneous substances are uniformly distributed within the mixture, unlike a heterogeneous mixture, which is not uniform (Nesrullajev, 2016; Patel & Chakraborty, 2016; Tingas, Kyritsis, & Goussis, 2015). This aspect of mixtures is one of the areas where the teacher faces a problem of lack of content knowledge for teaching because, maybe, he has struggled to understand the difference between the two concepts of homogenous and heterogeneous mixtures. This implies that he has not been teaching in ways that could further his confidence as a teacher.

Mr. Eman also shows other aspects of lack of knowledge in the chemistry section; for instance when the researcher asked ‘What difficulties do you face when teaching organic compounds? Is it easy to explain structural and chemical formulae of simple sugars (monosaccharides) to all your learners?

Mr. Eman: *It is difficult to explain chemical formulas and Lewis-Dot structures to the learners in the classroom.*

Researcher: Why?

Mr Eman: *Because I lack the basic concepts of Lewis dot structure and I need deep information on concepts like this.*

Here the teacher explains that he faces some challenges in the section of organic compounds, more especially structural and chemical formulae of simple sugars, which are required to be taught as stipulated in the CAPS document. It is obvious from his answer that the problem he faces in this section makes him lose confidence in teaching this section. This may, therefore, lead him to teaching ineffectively and in a way that learners would be disadvantaged (Blömeke, Suhl, & Kaiser, 2014).

In summary, teachers exhibited a significant lack of content knowledge (CK) in organic chemistry suitable for teaching Agricultural Sciences. They face some challenges when it comes to teaching this section and so alternative conceptions prevail as they teach. As CK play an important role in teaching any content in science, it is disconcerting that these teachers lack the CK that is essential in teaching chemistry.

Problem # 1.2 - LOCK

Teachers' significant lack of content knowledge (CK) in the chemistry section of FET Agricultural Sciences impedes their ability to teach CK of organic chemistry effectively.

4.2.3 Learners' problems in organic chemistry for understanding Agricultural Sciences as perceived by teachers

It is also evident that one of the problems that teachers face in teaching Agricultural Sciences organic chemistry effectively, as reported by Mr. Eman, occurs from the learners' side. According to Muijs and Reynolds (2017), some learners come to class with their alternative conceptions from their lower grades. The pace of delivery of content can be a problem for some learners. As Hassan and Mahmud (2015) have reported, the needs of both slow learners and gifted learners should to be accommodated such that neither group is disadvantaged. Consequently, teachers are petitioned to not be too fast. If teachers get confused in organic chemistry and so teach in an ineffective ways, that would confuse even gifted learners (Ahmad et al., 2015; Brown, 2017). This is reflected in Mr Sbu's words below.

Researcher: Now when you are resolving your learners' alternative conceptions are your efforts of any success?

Mr. Sbu: *Yes, to some extent, because you know in class there are those learners who will understand easy, some of them will not understand easy, so the majority of learners they actually understand.*

Mr. Sbu explains here that he faces problems where some learners in the same lesson would need more time explaining the same thing, while others would understand it the first time. These slow learners, therefore, make it hard for the teachers to teach Agricultural Sciences chemistry effectively. According to Varma, Bhasker, Manhas, Grover, and Phalachandra (2017) slow learners do not easily understand at first, but need further support and care for them to move from one level to another.

Sub-problem 1: Learners practice cramming in chemistry section (LPCICS)

One of the problems that was reported is that teachers face a short-term memorization of concepts in chemistry, which presents a big challenge to them as they have to always remind their learners of previous content been learnt. Mr. Sbu was asked by the researcher why he thought that in one group of organic compounds called the hydrocarbons, some learners think that "the single, double, and triple bonds of the alkanes, alkenes, and alkynes are not examples of functional groups". He responded thus:

Mr. Sbu: *"You know what learners they do not want to read for understanding, they want to read for passing".*

This is their concern: that learners just memorise chemistry concepts for examination and forget them afterwards. This means that when learners study without understanding the consequences will come back to the teachers concerned. He or she would have to repeat the same concepts that they had taught previously. This also talks to the situation where learners who progress to another grade, but have already forgotten what they were taught previously, so they need the teacher to reteach the things they had already been taught in the lower grade.

This problem of rote learning affects not only teachers in this area of the Eastern Cape, but has also been found by many studies to be main way in which many learners study (Gurses, Dogar, & Gunes, 2015; Tan, 2015; Tan, 2011). These various authors suggest that learners normally engage in ways of studying that would only allow them to have information in their head for a short time that is only for examinations. Then after the examinations the learners have forgotten the information learnt, and teachers need to teach them again instead of merely doing a brief revision. According to Tan (2011), rote memorization is not only a local problem, but widespread in the world. This was supported by Rehman, Ahmed, Rehan, Hassan, and Syed (2016) who asserted reasons for learners' relying on memorization include pressure and fear of failure as well as the way they are examined by their teachers. They further say that this is a result of their teachers requiring an exact copy of what learners had been given their notes. So, instead of making them critical thinkers in science, they become passive individuals in life.

Sub-problem 2: Lack of proper instructional approach to chemistry (LOPIATC)

The participants displayed the little ability to adopt applicable instructional methodologies. This links with the literature review concerning the findings by (Mavhunga & Rollnick, 2016). It is accepted that every topic or theme has its own best instructional techniques, which suit the manner in which students ought to assimilate the knowledge. One of the problems evident among teachers is the use of irrelevant instructional strategies for some chemistry concepts, instead of recommended instructional strategies that should be used in science, more especially in chemistry. When Mr. Sbu was asked by the researcher about effective instructional strategies he uses in teaching this chemistry section, he answered as follows:

Mr. Sbu: '*What I actually do, I make use of the chalkboard, and I lecture first…'*

In the literature outlined in Chapter 3, researchers allude to the use of representations, including models and analogies. It was further elucidated that instructors ought to have utilize repertoire of diverse representations and analogies, in order to assist students comprehend science concepts, as outlined in the theoretical framework. As Mr. Sbu has said, he usually just stands in front of the learners and lectures them. This is contrary to the recommendations of the constructivists who take the view that learners should be guided and the teacher lead them using some question and answer sessions and other problem solving activities (Harasim, 2017; Siemens, 2014). These authors both suggest that because teachers may not find problems that are suited to their learners, it is not easy for them to use other teaching approaches that allow learners to learn on their own. Nevertheless teachers should try to move towards a constructivist approach to learning.

This issue was cited by each of the three instructors who took part in this study. Their cry is a route by which they may befuddle science concepts. As has now been uncovered, all of the three participants had a similar issue of slow learners' alternative conceptions of science concepts. The literature review indicated the same point of slow learners being a challenge in the process of teaching and learning in science.

Problem #1.3

Teachers report that non-science learners in their classes slow them down and prevent them from completing the chemistry section in Agricultural Sciences timeously.

4.2.4 Alternative conceptions of learners as perceived by teachers

In the literature review of this study it was reported that some learners come into science classes with alternative conceptions. As in the literature review, here instructors uncovered that students' prior conceptions became an issue, more particularly for those who did not do other science subjects such as Physical Sciences. This became apparent when the researcher asked the teachers whether they were aware of any other alternative conceptions that their learners exhibited in organic compounds. For instance, most learners normally think that the prefix hydro- in the word hydrocarbons means water.

Mr. Sbu: *"….most of the time my learners they actually confuse an element with a compound and confuse these definitions"*

Mr. Sbu went onto explain how his learners come with the inappropriate conceptions. He said that his learners normally explained or defined the term compound using the definition or properties of an element. This is one of the challenges he faces. This challenge is echoed by Erman (2017), who expounds that most learners come with their own way of defining some science concepts. He supposes that this emanate from learners' slowness in the classroom. Hwa and

Karpudewan (2017) hold that teachers are faced with the problem of slow learners and because this some teachers fail to address the gifted learners.

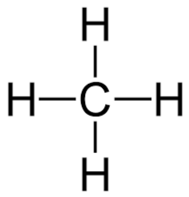
Teacher 2

Mr. Eman was asked the question about alternative conceptions.

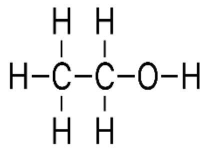
Researcher: Are you aware of any other alternative conceptions that your learners exhibit in organic compounds? For instance, most learners normally think that the prefix word hydro- from the word hydrocarbons means "water."

Mr. Eman: *The examples of the alternative conceptions are that when the learners are differentiating between organic and inorganic compounds they say that the only difference between organic compounds contain carbon and inorganic compound do not contain carbon of which that is not the case. There are inorganic compounds that contain carbon through geophysical processes and organic compounds that contain carbon through biological processes.*

In the literature review the researchers referenced that some students come to class with alternative conceptions and if the instructors cannot recognize then or does not eventually correct, they persist. In Mr. Eman's interview he explains the challenge of learners who do not know what the difference between organic and inorganic compounds. In the literature review it was explained that these learners would hold back the teaching and learning process in science class as they do not have basic chemistry concepts. Mr. Eman suggests that they believe that only organic compounds contain carbon, while inorganic compounds do not. This means that his learners' knowledge of the difference is confined to the presence or absence of carbon. According to Perry (2016) learners frequently present the challenge of confusing the difference inorganic compounds and organic compounds. Some examples of organic compounds include methane (CH_4) and ethanol (C_2H_6), as shown below.



Methane (CH_4) and Ethanol (C_2H_6)



However, there are also compounds that contain carbon but are classified as being inorganic; for example, carbon dioxide and carbon monoxide.

The definition of an organic compound is a compound that contains carbon and almost always hydrogen (with only a few exceptions). Inorganic compounds rarely contain carbon (although a few do) and typically have quite weak bonds. Inorganic compounds include metals, salts and other elemental compounds. Due to water's lack of carbon and weak bonds, this classifies it as an inorganic compound. Therefore, it was not enough for learners to only say the main difference is the presence or absence of carbon.

In response to the same question about organic and inorganic compounds, Mrs. expressed the same experience of learners misunderstanding the concepts. Among the many alternative conceptions reported throughout this dissertation, it is evident that students truly require help from suitably responsive Agricultural Sciences educators. All the participating teachers shared the same concern of learners' misunderstanding of concepts, as Mrs. Deo reported below.

Researcher: Do you remember other alternative conceptions that they say? Just in class

Mrs. Deo: *Like in the classroom you can see that the chemical and physical changes, for them the physical is exactly what they see. Therefore, when you tell them about the chemical change that is the part that they do not know.*

She alluded to the learners' problems that arises when she asks them of the difference between chemical and physical changes. This indicates that indeed science learners maybe continue to hold the misconception until educators rectify that. She makes an example that they only think of what they can see as physical, but they do not have an idea of what chemical change is. According to Zheng (2003) physical change does not result in the formation of a new substance while a chemical change results in the formation of a new substance. An example is the combustion reaction. When you light a candle the wax combines chemically with oxygen to produce light. Another example is when sugar is cooked to make caramel and all the atoms are repositioned to make a new substance with a different colour and taste (Li & Cong, 2017).

Similarly, Mr. Sbu was asked about what are distinctive learner's misconception in this topic? For example, basically, a common mistake is to assume that the difference between inorganic and organic compounds is whether or not a substance contains carbon. Diamond is pure carbon, yet it is also inorganic. Carbon dioxide contains carbon and oxygen, both elements associated with life, yet it is also an inorganic compound. Why is this misconception so prevalent?

Mr. Sbu*: "They usually confuse you know when you talk about the functional groups of organic compounds, and we have the hydroxyl groups and the carboxyl groups so it is very easy for my learners to confuse carboxyl groups and hydroxyl groups because they usually take the oxygen and the hydrogen bonded as functional group and confuse it with what, with the carboxyl group although that is not the case, so it is easy for them to confuse them"*.

This was the second difficulty that he mentioned where learners confuse functional groups, among others things. This difficulty reflects earlier information which students may have distorted, perhaps as a result of the manner in which they had been taught. The challenge that these teachers have with learners are related to slow learners in chemistry who have misunderstood the basic chemistry concepts.

Teacher 2

As Mr. Eman was asked that:

Researcher: What are the alternative conceptions?

Mr. Eman: *When they are differentiating between hydrogen bonding, they don't know what hydrogen bonding is, for instance in ethanol there is what is called intermolecular bonding that forms between two different atoms. For example, in ethanol as I have already said that there are different molecules that are twisted so if a double bond is in the same molecule that bond is not a hydrogen bond*.

Researcher: Yes, so what is the misconception there?

Mr. Eman: *The misconception is that learners they said if in water, a hydrogen bond is that H is connected to O in the same molecule that is, H is covalently bonded to an O of which it's not the answer that they should give.*

In this instance, he reported a problem teacher's face where learners cannot differentiate between hydrogen bonding and intramolecular bonding. Mr Eman infers that it is hard for his learners to give the difference as they think that the hydrogen bond is the same as the intermolecular bonding, which are the forces present between molecules. (Hunt, Ashworth, & Matthews, 2015; Jeffrey, Terrett, & MacMillan, 2015). Intramolecular bonding is the bonding that holds a molecule together, while intermolecular forces occur between molecules. Examples of intermolecular bonding are shown below in Table A.

Table A: ***A summary of examples of intermolecular bonding***

Intramolecular force	**Example**
Covalent bond	Sharing of electrons occurs here
Ionic bond	Transfer of electrons occurs here

Mrs. Deo

Mrs. Deo was also asked about alternative conceptions, ass follows.

Researcher: Are there any problems you face in teaching this section? For example, there are alternative conceptions that organic compounds are soluble in water and can melt and boil faster than inorganic substances. And another example, chemical bonding is bonding through physical means that is what learners normally say in class. Are there any other alternative conceptions?

Mrs. Deo: *But also, when they are writing the chemical formula you can see that instead of starting with Carbon, do you remember the hydro- or let me say in organic compounds, usually they must start with C and that is carbon followed by hydrogen. Therefore, for them even starting with C or H for them they can start from H-C which does not really make any sense.*

From this reply it is clear that Mrs. Deo faced a similar problem of learners having a poor understanding of chemistry concepts; in this case, with regard to writing of chemical formulae. She explains that her learners do not adhere to the sequence of representation of the chemical formula as advocated by chemists. For instance, she holds that learners normally think that C for carbon and H for hydrogen in a molecule or compound can just be put anywhere or a person may start with any letter for instance H_2O written as O_2H. As such it is wrong chemically, and neglects the rules that make it easier to read a chemical formula.

Problem #1.4 -LMOC

Teachers report that learners hold alternative conceptions or alternative conceptions in basic organic chemistry, which are difficult to change. This is in line with what the literature review indicates: that learners come to class with some alternative conceptions that distort what their teachers have taught them.

Summary

The four themes given below have emerged from the data, as explained in this section. These are supported by direct quotes from the interviews, which is the only source of data employed by the researcher in this study.

#1.1 Lack of tertiary module(s) (LOTM) in chemistry which impedes Agricultural Sciences educators from teaching the chemistry section effectively. Some of the teachers lacked tertiary chemistry modules and that affect their teaching.

#1.2 Exposure to tertiary module(s) (LOTM) in chemistry supports Agricultural Sciences educators to teach the chemistry section.

#1.3 Teachers' significant lack of content knowledge (CK) to teach organic chemistry for Agricultural Sciences (AGRSC). Non-science learners' impede

AGRSC educators from teaching chemistry section effectively in Agricultural Sciences.

#1.4 Learners hold alternative conceptions in basic organic chemistry (LMOC).

The problem outlined emerged after scrutinizing the data that had been collected from all three educators who participated in the study. These themes were used to answer Research Question 1. Other themes from the post-PD interviews were used to answer Research Question 2, in the next chapter.

Throughout their interviews the teachers highlighted the specific problem that threatened their being effective teachers of Agricultural Sciences organic chemistry. They indicated that they had never been exposed to any tertiary modules in chemistry. They thus had insufficient content knowledge for teaching organic chemistry effectively in their classroom.

From this chapter the researcher can conclude that teachers face different problem in teaching basic agricultural chemistry. These deficits in TS-PCK, as referred to in the literature review, include teachers' lack of PCK where teachers themselves were found to have lacked pedagogical content knowledge, learners' lack of chemistry background where learners more especially those that did not do physical sciences had many misconceptions in chemistry concepts and slow learners' misunderstanding of chemistry concepts and those learners would hinder teachers' pace in teaching these chemistry concepts. The literature review indicates that teachers' lacks understanding of sciences concepts can result in their not teaching effectively. The literature review provided a basis through which the teachers' TS-PCK could be examined, and indicates links with what the researcher experienced on this study. The challenges they face sometime affect the effectiveness of their classroom lessons and could even disadvantage other gifted learners. Nixon (2015) propose that teachers with less PCK lack confidence in their classrooms and do not teach effectively, as they are not sure of what and how to teach in some area.

4.2.1 Discussion for Research Question 1

Introduction

Most prior research on student and teacher difficulties in Agricultural Sciences have focused on students' pass rates at university. Furthermore, these studies have largely been international studies (Martins, 2017; Prabhuraj, Patil, Bheemanna, Prabhakar, & Singh, 2016). There is very limited information about teachers' difficulties related to South African Grade 11 chemistry section, more especially organic compounds.

In this study the researcher sought to explore Grade 11 Agricultural Science teachers' topic specific pedagogical content knowledge needed for teaching organic compounds. The researcher developed the following Research Question, which were answered using data from the pre-PD interviews:

What problems do Grade 11 Agricultural Sciences teachers encounter in teaching organic compounds?

This study was conducted some years after the chemistry section was introduced in Agricultural Sciences, although, as already stated, little research had been conducted in relation to chemistry in Agricultural Sciences, more especially a deficit was noted in relation to South African high schools (Khursheed & Mahammad, 2015; Martins, 2017). The researcher looked at organic compounds, for which nothing had been published in the South African education literature.

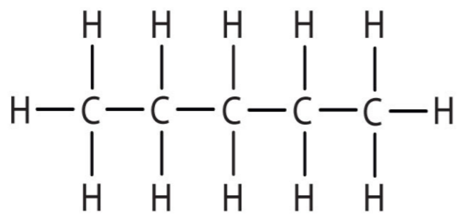
From the data in this study, the researchers' findings are based on the following themes, which are discussed.

Problem 1: Lack of tertiary module(s) (LOTM) in chemistry which impedes Agricultural Sciences educators teaching the chemistry section.

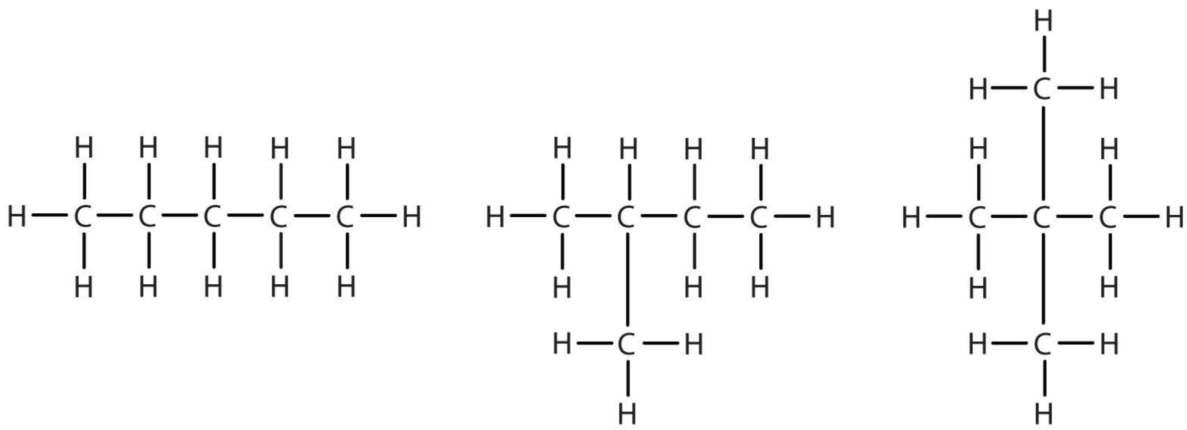
The literature review referred to the importance of TS-PCK in science and to the subject matter being at the core because teachers who lack subject matter knowledge may not be able to deliver meaningful instruction to their learners when they themselves do not have a full understanding of the content. As far as teaching Agricultural Sciences is concerned, some of the chemistry concepts are taught at the university level. However teachers going into the field are required to teach learners whatever and is required by the curriculum, irrespective of what they had been taught. Some of the teachers like Mr. Eman and Mr. Sbu, who participated in this study had not been exposed to chemistry concepts usually learned in the first year at university, such as isomers, lipids and carbohydrates. This major theme emerged after the analysis of the interview transcripts where it was discovered that teachers do not have sufficient chemistry content knowledge for teaching Agricultural Sciences. For example, when the researcher asked Mr. Sbu: Did you do any content in chemistry either at high school or higher institution level? He reported that,

'I did chemistry at high school in Physical Sciences in chemistry so I did it there. At high school, at tertiary I did not have training in chemistry. This is because I chose Animal Sciences instead of chemistry and continued with it till the fourth year.

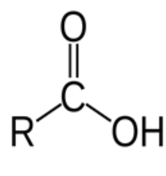
When the researcher asked Mr. Eman the same question, he responded: '*I have done in high school a bit of introduction in chemistry but at university, I did not do.'* Tt is therefore clear from the statements by the above two teachers that they lack tertiary modules in chemistry, so many of their struggles emanate from this lack of first year tertiary chemistry modules. A study by Kind (2014) showed that the majority of teachers who teach chemistry in high school did not study chemistry as a subject of choice in tertiary education. Ryan et al. (2016) emphasize that this crisis of lack of knowledge in chemistry is common, particularly among new teachers, since they do not have experience in teaching. Ryen et al. (2016) assertion was validated by the number of alternative conceptions found in their classrooms. Varma et al. (2017) hold that teachers should know their discipline in order to teach effectively in their classrooms. Bozbiyik, Lannoeye, De Vos, Baron, and Denayer (2016) assert that in order for teachers to understand the isomers of some of the organic compounds, for instance of alkanes, they should first understand the alkanes. They further clarify this with some examples of alkanes that pentane has a chemical formula C_5H_{12} and its structural formula would be:



The isomers for the above alkane would be as follows:



Pentane Isopentane Neopentane

The first structure is pentane, the second is an isomer 2-methylbutane, while the third one would be named 2, 2 dimethyl propane. In each case the straight chain represents the name of the alkane formed. From the above representation it is clear that without first understanding the basic structural formula for the type of alkane, it would be very difficult to understand isomerization within this alkane. In addition, Calder (2015) asserts that, most teachers who did not study tertiary chemistry prefer to explain concepts in their own way, which could lead to the information misleading the learners. He makes the example of a fatty acid chain and says the fatty acids have a carboxylic acid group that creates the acidity, which is represented as –COOH, with the structure shown as . The author continues to explain that this is the basic knowledge to understanding the concept of why these are called fatty acids. In Calder's view knowledge of the subject plays a role on how well the teacher will relate to his or her learners when teaching. In particular how well the teacher's presentation or facilitation would impact on learners' interest in the subject. Another example was made by Park and Oliver (2008) and Gurel, Eryılmaz, and McDermott (2015). PCK is well developed only when teachers are able to fully convert subject matter content into forms that are easily assimilated by learners. In the example of teaching proteins, it would be better if the teacher would first relate the topic to the food learners eat at home and the types of nutrients each food contains. They say this ability depends on what knowledge the teacher has on the topic, which in turn depends on the knowledge the teacher has from his previous institution. Therefore, from the above information the researcher views university content knowledge as the way in which teachers would best be able to explain to learners how each topic relates to their lives so as to keep the content alive.

Literature also shows that for teachers to teach effectively in their classrooms they need well-developed subject knowledge (Sun, Chan, & Chung, 2015). In the current study, out of three respondents, only one was trained from the university to teach chemistry. Mr. Eman and Mr. Sbu did not receive tertiary training to teach chemistry; only Mrs Deo did. This means that these two teachers are particularly vulnerable when it comes to irregularities or alternative conceptions in content presentation.

Theme 2: Teachers' lack of Pedagogical Content Knowledge (TLPCK)

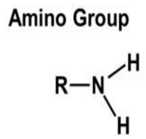
The scholars on the literature alluded to pedagogical content knowledge and cited this as the reason for students' accomplishment or lack of accomplishment in science. The idea of PCK, as referred to in the literature review, frames the premise of success in sciences since, when instructors knows the subject matter or content and in addition, the best instructional strategies to use, they will be better ready to change the such knowledge into structures that are simple for learners to assimilate. As reported in the interviews, it is clear that all three teachers lack the appropriate topic specific pedagogical knowledge (TS-PCK). When the researcher asked Mr. Eman: "what difficulties do you face when teaching organic compounds? Is it easy to explain Structural and chemical formulae of simple sugars (monosaccharides) to all your learners?" he reported that '*It is difficult to explain, to explain chemical formulas and Lewis structure to the learners in the classroom.'* This response shows that as such a teacher explains the concepts he would experience some difficulties, which prevent him from explaining concepts clearly to his learners. These concepts are not clear, even to the teacher. Furthermore, when the researcher asked Mr. Sbu: 'Since Agricultural Sciences include this chemistry section, how do you evaluate the inclusion of this section in CAPS Agricultural Sciences document, is it difficult but necessary for learners?' Then Mr. Sbu replied that '*Yes, this section is necessary for learners in order for them to be able to understand concepts. Agriculture very well and but it is difficult by the way....'* This response depicts such a teacher's lack of pedagogical content knowledge in teaching this chemistry section. This deficiency is caused by the lack of tertiary chemistry modules studied by these teachers. This normally results in some bad consequences that may impinge on learners' results.

Studies such as that of Rice and Kitchel (2015c) are of the view that PCK is the utmost persuasive knowledge base that determines teachers' instructional strategies' as such it is the blend of content knowledge and pedagogical knowledge to form knowledge for teaching. This means that PCK is way of instruction that tries to lighten the weight of big terminologies in science in order to deliver them in ways that learners could easily understand. All three participants in this study have shown lack of PCK in chemistry section.

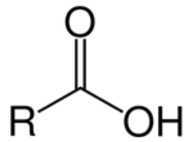
Teachers like Mr. Sbu use a lecturing method as shown when he responded in the interview: '*What I actually do, I make use of the chalkboard, and I lecture first…'* This means that his knowledge of teaching this chemistry section is limited to only the lecturing method. Bonding is also taught using lecturing method to learners and no models are used to supplement the textbook. As Mr. Sbu stated, the only resource he uses is the chalkboard when explaining to his learners whatever that they have to learn in this chemistry section. This shows that he lacks pedagogical content knowledge on how best he could supplement different teaching strategies so that learners would be more actively involved in the lessons in accordance with constructivist theories. Some of the alternative conceptions are revealed as the teacher teaches; for instance the teacher said that the chemistry section is difficult:

Mr. Sbu: ' *this section is necessary for learners in order for them to be able to understand Agriculture very well but it is difficult by the way more especial to us as teachers who did not do this chemistry section at University level. We even struggle to explain the content to learners as we ourselves do not have enough knowledge of the chapter…'*

Mr. Eman also said the chemistry section was difficult for him and the learners. This shows that even the teaching of this section is not perfect, but with some alternative conceptions that will later be seen to their learners. There is much literature related to the alternative conceptions that have found in chemistry, and their relation to teachers' PCK. Rollnick and Mavhunga (2016) state that many teachers in science lack PCK, which then needs to be developed. Torosantucci, Schöneich, and Jiskoot (2014) assert that most teachers who lack knowledge in their subjects deliver their content with many alternative conceptions. They cite the example on proteins and peptide bonds, stating that that most teachers do not first explain amino acids as the building blocks of proteins, which is the background of the topic. When Torosantucci et al. explain amino acids they show that they have an amino group which is structured as:

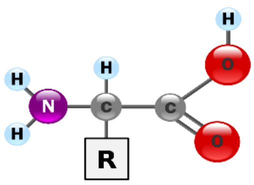


And this amino group is connected to the carboxylic group

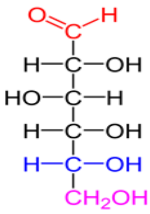


by the alpha carbon which is where the R group attaches itself. Torosantucci et al. further state that most teachers appear to have skipped this part and that leads to learners' rote learning the structure of each amino acid

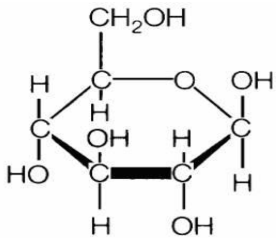
Which comes as



the peptide bond between each amino acid would then be easy to explain to learners after having explained the amino acid chain that forms the protein. This observation is similar to that found in my study, because the participants showed a considerable lack of PCK. As advocated by Gudmundsdottir and Shulman (1987), PCK is the foundation of any effective teaching and learning processes. Specifically, the teacher has to be grounded in the subject more than the learners. According to Kwak (2009), lack of PCK among teachers would have a direct impact on learners' achievement. Park and Oliver (2008) indicate that teachers are generally at the heart of learners' poor pass rates, which specifically emanates from teachers' lack of PCK. Furthermore, they discuss that when teachers explain some aspect such as carbohydrates being one of many organic compounds, they do not remind learners about properties; instead they explain carbohydrates in terms of things that do not exist in the learners' lives. Park and Olive also observe that when teachers lack PCK they memorise structures such as those for glucose, lactose and sucrose and simply draw the structure with no explanation, because they lack PCK. According to Wang, Blaszczyk, Xiao, and Tang (2018) glucose has the chemical formula $C_6H_{12}O_6$ and its straight chain structure is:



and when in a ring form, carbon number five would transfer its oxygen and hydrogen to carbon number one and with hydrogen combined with oxygen in carbon number one it will form hydroxyl (OH) and a ring will form from the straight structure of glucose thus:



.

In addition, these authors explicate that teachers will always affect the way learners learn, especially if there is no development in their PCK. According to Widodo (2017) it is necessary to support teachers continuously so as to enable them to teach effectively in their classrooms. He supports this contention by saying this support will encourage their confidence and enhance their teaching abilities, as they will now have improved PCK. From the findings of this study all the participants exhibited a lack of PCK and were therefore unable to fully explain chemistry concepts. The data also showed that these were not new teachers in Agricultural Sciences, yet their responses indicated many alternative conceptions.

Teachers' lack of PCK affects learners' understanding of chemistry concepts, directly or indirectly (Hill, Bicer, & Capraro, 2017). Rollnick et al. (2008) expound that teachers PCK is an important tool for them to teach effectively. Consequently developing PCK should be high on the list for professional development. This helps experienced and new teachers alike. Furthermore, the data showed that even though Mrs Deo had studied tertiary chemistry modules, she was still not able to explain some concepts. This could be attributed to her not having studied Agricultural Sciences at university. In the interview teachers reported that most of their understanding of concepts is from their high school experiences, and this hence there are so many alternative conceptions. Griffith and Brem (2004) point out that teachers exhibit a lack of PCK when it comes to teaching difficult science concepts. This was also seen in this study, where teachers were not able to explain properly some scientific processes.

Problem 3: Slow learners impede AGRSC educators from teaching the chemistry section effectively

The issue of slow learners was discussed in the literature review of this study. I as the researcher, would be out of line to not characterize what is meant by 'slow learner', being one myself. Accordingly, by slow learners the researcher means those learners who struggle in the chemistry section in Agricultural Sciences. Behind this battle is the issue that these learners have not been presented previously with any science, either in Physical Sciences or other subjects, which puts them at a disadvantage. Furthermore, the Grade 11 Agricultural Sciences chemistry is studied in the middle of Grade 12 year in Physical Sciences, when the Physical Sciences learners are taught about organic compounds such as alkanes. This means that even the Physical Sciences learners do experience some problems, but they are still better off than those who do not have any understanding of basic chemistry. In some schools there are learners who combine the subject of Mathematical Literacy with Agricultural Sciences. Many of these learners opt for this because they cannot cope with two demanding subjects such as Mathematics and Physical Sciences. At the start of their studies in Agricultural Sciences they normally think of basic ideas such as animals and crops, without realising the subject goes beyond that to study challenging topics such as atoms and glucose structure. The other problem is the large number of learners who study Agricultural Sciences, as has been my experience when teaching Agricultural Sciences. Furthermore, teachers are faced with slow learners in their different classrooms who misunderstand scientific concepts, and these learners may slow down the process of teaching and learning.

Entwistle and Ramsden (2015) state that learners need to be supported in their learning by teachers but for the slow learners, they need extra support from their teachers. This is in conjunction with the difficulty that their learners are likely to misunderstand scientific concepts and therefore misrepresent them. A study conducted by Kaur, Singh, and Josan (2015) revealed that most learners encounter some problems when they are required to explain scientific concepts, and so explain them in non-scientific ways. According to Education (2014), students did not understand the distinction between the concepts related to carbon and oxygen, and how the two are applicable for vegetation growth. They further explain that those students who cited copper as the oxidising agent instead of the reducing agent did now not seem to recognise or apprehend the distinction between the two intertwined principles of oxidising and reducing agents. They add that this could be because they did not know the molecular components for ammonium chloride or what the term hydrolysis means. The analysis of the examination reports shows that learners also lack sound knowledge of organic compounds. They suggested that a set of multiple choice questions about difficult topics, including chemical reactions and acids and bases should be prepared by teachers for their learners to use in revision. By doing that alternative conceptions may be diagnosed and then addressed. The Department of Education examination report stated that:

'*Many candidates could not identify the condensation polymer in Q2.1.2. Most selected the addition polymer (D). A condensation polymer was a challenge to many learners. This is a straight forward question but considering that polymer chemistry is new to most teachers, more activities on polymer chemistry are needed.*

This analysis by the DBE depicts the errors and alternative conceptions displayed by learners in organic compounds. It shows a big gap where learners lack understanding of the basic concepts of organic chemistry, such as nomenclature of organic compounds, as required by the CAPS Agricultural Sciences Grade 11 curriculum.

Chapter summery

This chapter presented data that was collected and include presentation of the data for research question one and discussions for research question one. The discussion was done on the problems that teachers face when teaching Agricultural Sciences organic chemistry section. Teachers outlined that: learners' lack of tertiary chemistry modules is one factor that needs to be solved. This is followed by slow learners who impede the teaching of Agricultural Sciences.

Chapter 5

Data Analysis, Presentation and Discussion for RQ2

In this chapter, firstly the study's data analysis is done for research question 2. Then data is presented and analysed to answer the second research question. This presentation takes the form of extracts from the post-PD interviews with the three selected teachers according to themes. From the analysis suggestions or solutions to the problems given from question one were discussed.

5.1 Data Analysis, Findings and Discussion for Research Question 2

Data gathered from the focus group post-PD interviews (Annexure B) were used to answer the second research question.

Research Question 2: What do Agricultural Sciences teachers' suggest in order to improve their topic specific pedagogical content knowledge (TS-PCK) in teaching organic compounds after engaging in a cycle of Action Research?

Data to answer this question was gathered when teachers were together having a workshop on the chemistry section for Agricultural Sciences. The workshop was planned with a view to addressing some of the problems they faced in teaching chemistry in their schools. The workshop helped teachers gain information on the concepts of Agricultural Sciences chemistry section and after that that they reflected on what they think this workshop would have been done better.

The discussion with teachers was seen as an aspect of the teachers' professional development because it was a reflective exercise. In the discussion, they raised issues around difficulties they had experienced, and diagnosed their problems through an active discourse. Several themes emerged and are discussed below.

5.1.1 Theme 1: Problem Diagnosis – Professional Support

Before the programme of professional development (PD) started, the researcher had first introduced the participant teachers so as to ease the process. Teachers were told how this process of PD would unfold and end. The researcher first explained that professional development was planned to help teachers to work together and identify and resolve some of the problems they experienced with organic chemistry. Thereafter, these teachers would ideally work on their own as a community of practice so as to develop each other in their context. The first process in the professional development was to discuss what problems they had been experiencing and the second involved a presentation with some solutions to some of the problems they had been experiencing.

Teachers were asked by the researcher about how PD could help them in developing their TS-PCK. Teachers commented in different ways concerning the ways in which researchers can use action research to help them. From the onset teachers had a common view that the PD needs to be continuously offered in their area and that it must be over a relatively long time to allow them to assimilate the information and find ways of using it.

From the three participants' responses, action research does play a big role as it helps even those who had not exposed to the chemistry content at an institution of higher learning. Therefore, they believed it would be best if the researcher would first diagnose where a problem lay and deal with that particular problem as it occurs to teachers. For instance, the researcher asked all the participants the following question: From the previous knowledge of workshops that was held by the subject advisors under the DOE, what can you say researchers can do to help teachers improve their topic specific pedagogical content knowledge? By that, I mean the ways in which knowledge/content is transferred to learners in relation to their capacity to grasp it.

Mr. Sbu: '*Researchers must interrogate exactly where the problem lies in this topic…this is because as teachers we do not have adequate knowledge to identify some problems or gaps we have as we do not have resources or extra-material to read and are far from resources areas and it takes a long time to reach certain areas as we are in rural areas*'

Two participants agreed that PD could provide them with one-on-one facilitation of chemistry concepts by action researchers, which would give them an opportunity to enhance their understanding of chemistry. They believed that action research is capable of building their content knowledge and effectiveness in their teaching.

When Mr. Sbu was asked what could have been done to improve the workshop to enhance his teaching; he responded thus:

Mr. Sbu: *The presenter must not be shy of us when it comes to addressing our problems because we are more than willing to commit ourselves in any way that would help us improve organic chemistry concepts.*

He suggests that action research would provide them with an opportunity to engage or rather listen to another person who is loud and knowledgeable when presenting.

When Mr. Eman responded to the same question, he agreed with Mr. Sbu.

Mr. Eman: *I think that teachers have to undergo some developmental training so that they can be equipped more about this topic.*

Mr. Eman then suggested that teachers should undergo one-on-one teaching of the content by the action research facilitators. This would therefore enhance their way of teaching. He elaborated by saying these workshops would keep them abreast in their PCK.

Mrs. Deo also agreed with other teachers that action research could help them, through facilitation of the chemistry content.

Mrs. Deo: *I think the teachers who teach Agriculture without the content of chemistry can be exposed to workshops and be taught in depth.*

Conclusion on Problem Diagnosis – Professional Support

From Mr. Sbu's comments, one could infer that teachers do need help. This could take the form where they would first be told where the problem lies in their TS-PCK and be offered help concerning that particular part of the researcher's diagnosis. This is in line with what Conners-Burrow, Patrick, Kyzer, and McKelvey (2017) confirm; that teachers enjoy being helped and supported in their work places as they get training from these workshops. Braga, Jones, Bulger, and Elliott (2017) further added that teachers feel empowered as they are exposed to these workshops. Moreover, these workshops also improve teachers' content knowledge, an important aspect of TS-PCK, and so improve their strategies for and ways of teaching. It has also been noted that after such workshops the learners' participation in classes may be enhanced (Ko, Wallhead, & Ward, 2006). Such workshops could not only address alternative conceptions but also produce quality teachers and subsequently learners who could become great thinkers of the country (Berger, Eylon, & Bagno, 2008; Vossen, Henze, De Vries, & Van Driel, 2019)

5.1.2 Theme 2: Professional development to support teachers in understanding their chemistry content

Mr. Sbu was asked: "From the previous knowledge of workshops, what can you say researchers can do to help teachers improve their topic specific pedagogical content knowledge. By that, I mean the ways in which knowledge/content is transferred to learners in relation to their capacity to grasp it." He replied:

Mr. Sbu: *You must recommend a best way for us as educators to learn the content and to be able to deliver it. It is best when it comes from you as an action researcher because as for us, we always await any help that comes from those who have got a better knowledge to assist us.*

When Mr. Eman was asked what interested him most about this topic specific professional development workshop, he replied:

I can say the way they are explaining it, the way they are unpacking it. It becomes brighter and lighter to me.

Here Mr. Eman shows his belief that action researcher helped them get clear information about the chemistry concepts. He believes that every time the researchers were involved they made the content clearer to them and the load became lighter as they are involved.

When Mr. Sbu was asked: “What interest you most about this Topic Specific development workshop?” he replied that:

Yes, actually it was enlightening to me because some of the concepts I did not know and even how to deliver lessons of that nature.

Both Mr. Sbu and Mr. Eman believe the workshop was enlightening and enhanced their content knowledge. They believe that the aim of the action research should be based on helping them gain understanding, and so make organic compounds seem lighter or perhaps easier.

Discussion

Mr. Sbu believes that action researchers should also point out ways that teachers could possibly use to teach more effectively in their classrooms. According to Guzey, Tank, Wang, Roehrig, and Moore (2014), professional development workshops help inform teachers of their educational role and guide their actions in ways that would make the content easy for their learners to understand.

Teachers believe that action research would help them enhance their TS-PCK in the chemistry section. Jao and McDougall (2015) elucidate that teachers coming from professional development workshops show a great ability to improve classroom practice. This view was supported by Kiemer, Gröschner, Pehmer, and Seidel (2015), who added that workshops create an opportunity for teachers who do not have sufficient content knowledge to improve this aspect of their teaching.

5.1.3 Theme 3: Opportunities for reflection

Mr. Sbu alluded to the notion that this action research would open opportunities to them for reflection. We hear him in his response to the researcher.

Researcher: What could have been done to improve the workshop to enhance your teaching?

Mr. Sbu: *We could have been given a chance to actually present what we have learnt. If the professional development can be done at least at the beginning of each year this can help a lot of new teachers who just came into the field. These teachers lack experience and do not even understand the importance of identification of alternative conceptions in learners as they themselves have got their own alternative conceptions*.

When the same question was posed to Mr. Eman, he answered: '*the researchers should have given us an opportunity to try and present our new knowledge so as to see if we can do well'*.

Mrs. Deo was also asked the same question, and she replied: '*Researchers should try to include even other teachers who may have the same problems in organic compounds'.*

A PD workshop can make teachers aware of what knowledge they have and what they need to learn. They, thus, help teachers realize how far they have gone in teaching and how they can excel best after learning (Brookfield, 2017; Canning, 1991; Zeichner & Liston, 1987). Mr Sbu believes the use of this PD should be accompanied by the provisions of resources such as extra-textbooks and some pamphlets, which would help them to solve their problems as a community of practice of teachers. The teachers also suggested that once they had more information through those textbooks, they would use that information to help their colleagues that teach near their schools.

5.1.4 Theme 4: Lack of resources

Teachers believe that a PD workshop should also help them with some resources that they could use even after the workshop. This comes after having an interest in the way the workshop was presented to them, but no resources were presented. Mr. Sbu was asked: "What could have been done to improve the workshop to enhance your teaching?" and he responded thus:

Mr. Sbu: *We were not given resources, enough resources so that we can take back and read on our own. I think if we can be provided with more textbooks or pamphlets in this section we can at least have a reference to work on while trying to improve the situation in our community. We want to use those resources to help one another.*

Mr. Sbu alluded to the idea that the resources should come with the researcher so that they leave teachers with something to rely on during their teaching time. He believes that if the professional development workshops can provide them with extra-material, this could help them learn more, and so have a deeper knowledge, which can then be used to help even new coming teachers.

5.1.5 Theme 5: Make workshops available for rural teachers

Lastly, the participant teachers believed that more action research workshops should be provided, especially in the rural areas where there is not much development support.

Mr. Eman: *I can say the way they are explaining it, the way they are unpacking it. It becomes brighter and lighter to me.*

Researcher: What could have been done to improve the workshop to enhance your teaching?

Mr. Eman: *I am not sure but what I can say, if they can always go to the teachers who teach in rural areas. These teachers always struggle when it comes to information/ As a result learners fail science simply because even we as teacher do not get enough support from professional.*

The only information we rely on as the information from our textbooks mostly. Teachers who came this year did not even receive a workshop in the neighbouring schools but we always try find ways to mentor some who seeks help with the knowledge that we have.

The three teachers exhibited a great joy and belief in action research, as it meets their need for help. They believe that provision of resources would enhance the workshops, especially in the rural context. The participants elucidate that their attempts to help novice staff extend only as far as their own limited knowledge from their higher education. They believe that their knowledge is not enough but they use it anyway, simply because they do not have anyone else to help.

5.2.1 Emerging Themes

The previous section has identified five themes from the data recorded from the PD workshops.

The previous section has identified five themes from the data recorded from the PD workshops. Teachers submitted a number of suggestions towards the improvement of teachers' topic specific pedagogical content knowledge. Teachers indicated that for any action researcher to help them successfully, identification of the problem must be a priority. You cannot help anyone without first knowing their problem. They believe that if professional developers would also allow teachers to be practically involved in their own professional development, as in solving their TS-PCK problem, this would make it easier for them to identify and change their alternative conceptions.

The teachers also believe that when they are allowed to reflect on their own work they would understand better what they have gained and can now do better after the workshop. They further say that PD should assist through provision of teaching and learning resources, which would help them to continue reading and improving their situation even when professional developers have departed. Lastly, teachers hold the notion that workshops of this nature are needed, particularly in the rural schools that are so often neglected by even the Department of Education, to the extent that they seem to have been abandoned by education stakeholders. According to Avraamidou (2014), professional development often shapes the mind of the developed professionals and leaves them in better condition to take action. They further note that PD also provides teachers with the basis for improved confidence in their professional day-to-day duties.

5.2.2 Data, Analysis and Findings for Research Question 2b

Research Question 2b: How can Action Research to help Grade 11 Agricultural Sciences teachers improve their topic specific pedagogical content knowledge (TS-PCK) in teaching organic compounds?

After a week the researcher came back to his participants for another session of action research. The phases of the cycle were discussed with the participants, according to what will happen when, and we agreed that the research should continue.

During the cycles of action that the professional development went through, and taking into account the suggestions that arose from Research Question 1 (Appendix D). All the activities that took place from day one are shown below in Figure 5.3.1. As stipulated above the research cycles for this study were as shown.

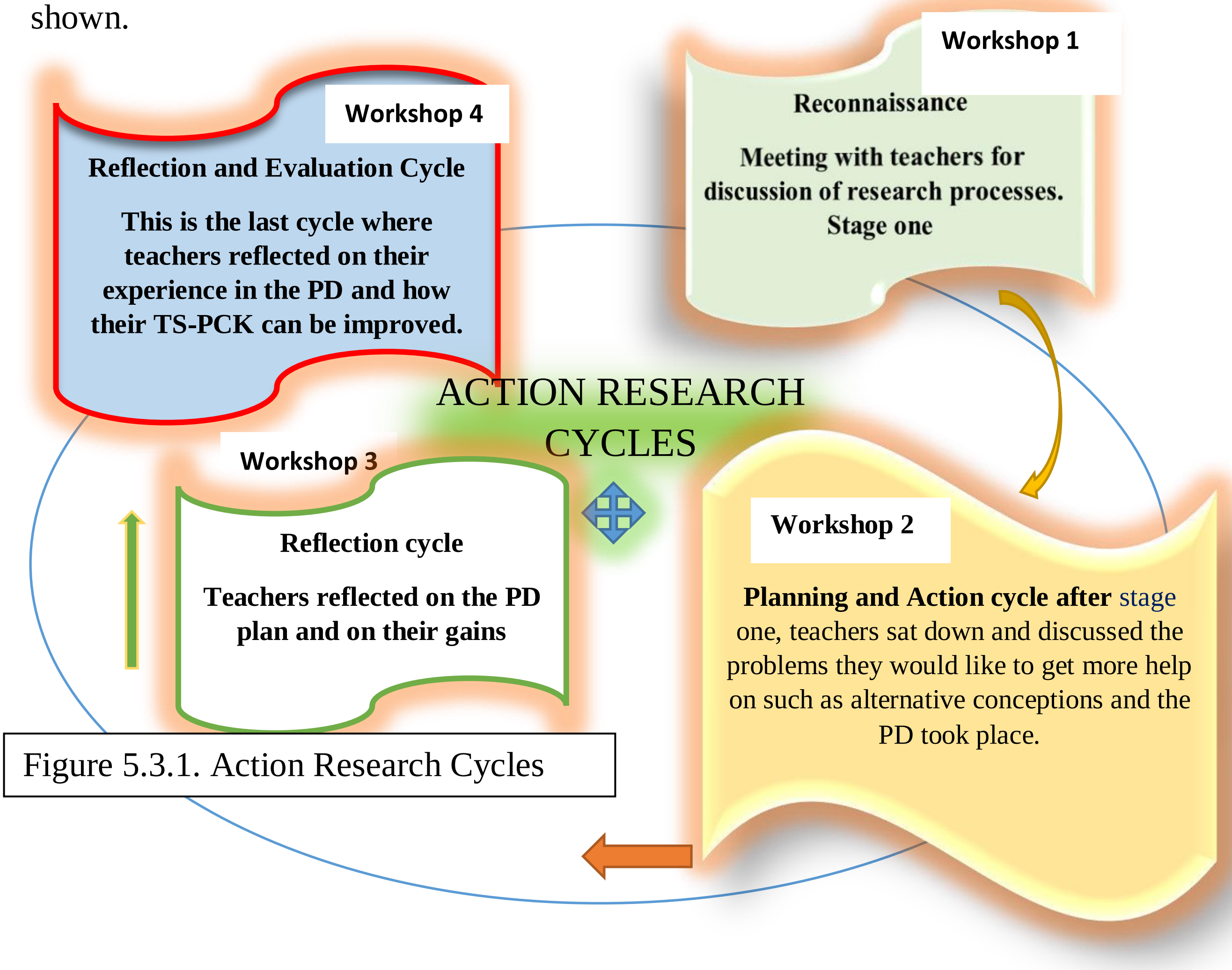


Figure 5.3.1. Action Research Cycles

Stage 1: In the first stage, the researcher met with the participants and presented the cycles of the research study and in our dialogue and all participants in the investigation consented to take part in all dimensions of this study. Each participant in the study was given the same instrument for the exploration of organic compounds TS-PCK in Agricultural Sciences. This was a test based on a previous matriculation examination paper in Agricultural Sciences. (Appendix B). The participants examined the research processes step-by-step before the research could begin. Participants were given consent form and it was read and explain to them and they agreed to continue participating in this study (Appendix A). The research processes was explained by the researcher to the participants step by step.

Stage 2: This stage extended from February to June. In this stage the participants gathered together for the PD workshop on TS-PCK related to organic chemistry. There would be an attempt to resolve their alternative conceptions and to discuss other matters around organic chemistry, since two participants they did not study it at their institution of higher education. The researcher and a chemistry specialist were present on these days for the presentation of the chemistry concepts.

The workshops began with the participants sharing a meal. This is a common social practice in the rural areas as people travel from far and get to know each other during this introductory time. The researcher took the opportunity to introduce the chemistry specialist as the main speaker for the workshop days. In addition, the chemistry specialist had prepared some material to assist the participants, which they could then read through before the presentation. During the presentation, the specialist explained the concepts that were included in the pamphlet given to them (Appendix E). As the presentation continued teachers asked some questions; they discussed these questions amongst themselves, facilitated by the presenter. For example, teachers asked about the differences between carbonic acid and humic acid. Then, after a discussion it was understood that humic acid was a group of molecules that bind to, and help plant roots receive, water and nutrients. It was also noted that high humic acid levels can dramatically increase yields of farmers, but a humic acid deficiency could prevent farmers and gardeners from growing crops with maximum yield.

After presentation of the chemistry concepts, such as covalent bonding, all participants were happy or potentially euphoric about the newly explained and clarified concepts in organic chemistry. They were prepared to be interviewed about the significance of the PD workshop in the action research process. Reflections took place after the presentation of chemistry concepts and teachers were excited about the PD, and expressed their wishes to have more of such PDs year after year. These reflections were not recorded as they were not part of the main data collection methods but are, instead, part of the action research.

Stage 3: The third day was used to answer research question 2b of this study. As the participants of this study gathered again for this last cycle of the research, the researchers interviewed them using the post-PD interview questions (see Appendix C).

The discussion below indicates the responses of participants to questions that were designed specifically to answer Research Question 2b.

Issues emerging from Stage 3

- **Problem diagnosis in TS-PCK**

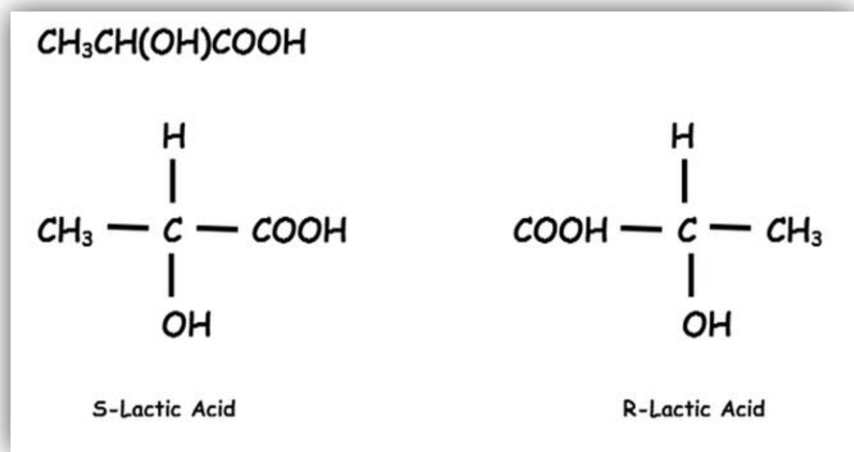
Teachers hold a perspective that they can best be helped by first revealing to the researcher their problems in TS-PCK. Mr. Sbu said: *'Researchers must investigate exactly where the problem lies in this topic…and the action researchers can use teachers who participate in the professional development to train even others after this. The reason why we say teachers must investigate teachers' problems first is that, we as teacher sometimes we think we are teaching correctly until someone who knows better come and identifies a problem or gaps in our content knowledge*'.

After that, action researchers must work on the observed or identified alternative conceptions to help the teachers understand this basic chemistry section.

According to Poehner, Zhang, and Lu (2015), diagnosis of a problem or misconception means to check first what the problem is and implement what you think can be the resolution to rectify that situation. Teachers work better when they get full support to understand their content knowledge. However, without first indicating their TS-PCK needs, teachers will not fully supported (Good & Lavigne, 2017). Klingner, Vaughn, and Boardman (2015) add that for teachers to help their learners to learn successfully, they need to be well versed in their content and learn how they can best identify their own or learners' alternative conceptions, which the authors believe applies even to teachers who can get help from colleagues, research studies or outside institutions. The participants of their study believed that first diagnosed any errors in their content knowledge, means they could then prepare something in line with what they actually need. I therefore, adopt the view that our teachers would be best supported by developing their TS-PCK through proper identification of their alternative conceptions and by engaging in a community of practice.

The process of action research includes ideas like engaging participants to be involved in their own learning. In this regard, the researcher would provide the best support by understanding their difficulties deeply (Carr & Kemmis, 2003; Robson & McCartan, 2016). This means that whenever research of this nature is conducted, the views of participants must be noted and those who want to help will help best according to the teachers' needs. From the findings, it is evident that educators can be best helped through their own diagnosis, initially; after that researchers may continue to find the best possible ways to improve teachers' TS-PCK. Martínez and Mellado (2016) suggested that any successful PD programme depends on how much information the researchers have about the problem to be solved. This will also help those in charge of the improvement plan, to decide on what resources could be helpful for participants. According to Dell, Newton, and Petroff (2016), diagnosis of the problem gives those who plan an opportunity to know why and what to prepare for an upcoming workshop. The reason why some PDs do not work in South Africa is therefore possibly because teachers are not asked what type of PD they prefer. In addition such programmes are not updated as the needs of teachers change; knowledge is dynamic. According to Brookfield (2017), if teachers are helped in a chemistry section, they are enabled to work better with a fuller understanding of what and how they can explain more difficult concepts to their learners. He further says identification of alternative conceptions is needed so as to make teachers aware of their own pre-existing alternative conceptions, and to help them move beyond such erroneous ideas.

In support of this perspective, Fantilli and McDougall (2009) found that most teachers would have a problem with regards to the formation of an acid. They believe that if teachers believe that the carboxyl group –COOH is not significant in the formation of acidity, then teachers lack TS-PCK in this section. They further add that the nature of a carboxylic acid is mainly due to the presence of the carboxyl acid group COOH, which is the attached to the carbon chain. Two examples of carboxylic acid chemical structures are:



Here, it is clear that the presence of this COOH group is visible in both R- and S- lactic acids. As the researcher found, teachers also pass on these alternative conceptions to learners as some of them do not grasp the fact that this is the reason why these compounds are classified as acids.

- **Supporting Teachers in Understanding Chemistry Content**

It is evident from Stage 3 of the action research cycle, after diagnosis of the problem, that the teachers request help in the form of setting up a community of practice. A community of practice is a situation where people, teachers in this case, continue to work together, more especially after a professional development programme (Lave & Wenger, 1991). In this study, the researcher found that teachers trust that regular visits by action researchers would improve their areas of need in TS-PCK. Warrican (2006) reports that educators who have attended proficient advancement workshops are likely to have capacity to enhance classroom performance. This was upheld by Kiemer et al. (2015) who argued that workshops support teachers who do not have adequate PCK, by enhancing it. According to the findings of this study, teachers need to be taught the necessary deep chemistry content and through that, those who teach them (the action researchers), would be improving the teachers' effectiveness. The research participants of this study reported that they believe workshops can assist them in improving their TS-PCK, which should have a subsequent spin-off improvement in their classroom practice. Teachers believed that action researchers would assist them in improving their TS-PCK. This means that action researchers can only assist teachers when they are fully capacitated themselves in PCK. They also view the workshops as enlightening in their lives and daily school duties.

During the interviews, teachers reported that action research helps them understand chemistry or scientific concepts better. Archer, Heikkinen, and Lester (2015) believe that once a problem has been identified then help can be provided to rectify the problem. Organic chemistry has long been problematic for leaners, as described by Gosser et al. (1996), who view it as a conceptually difficult topic. Consequently, this topic needs the attention of researchers to help teachers improve their chemistry content and pedagogy. Rollnick et al. (2008) believe that without teachers having in-depth subject matter knowledge (SMK), it will be difficult for learners to fully grasp the same content that the teacher would want them to acquire. They say that PCK should be focused on a specific topic when wanting to help teachers for example it can focus on organic compounds. Topics like organic compounds is such an example, as it has largely been only recently into the Agricultural Sciences curriculum, and so is seen as the most challenging topic for both learners and teachers.

- **Availability of Workshops for Rural Teachers**

Teachers also alluded to the notion that they needed to be provided with some resources, such as reading materials that would leave them with a better content, it could help reduce some of the problems. According to these teachers more workshops such as the one they experienced are needed more, especially in the rural areas. So often these areas are ignored and these workshops could make a lot of difference. Whitworth and Chiu (2015) state that professional development workshops are a central factor for previously disadvantaged learners to excel in their studies. In turn, Glover et al. (2016) maintain that workshops in a rural context should be a priority as those science teachers seem to be neglected. This means that in the rural context, teachers should be given a chance to develop their TS-PCK, which would improve their subject matter knowledge. Similarly, Ary, Jacobs, Irvine, and Walker (2018) maintain that if researchers would focus on the far disadvantaged areas, it would contribute deeply to such teachers' professional development. Albion, Tondeur, Forkosh-Baruch, and Peeraer (2015) explain that professional development as required especially by science teachers, so it is crucial for researchers to know where and why the research would be conducted in a particular area. In most cases, teachers in rural areas are not often exposed to a high standard of resources that should help them develop their TS-PCK. According to Sheehan et al. (2011), *"For an improvement in science education to occur teachers must be able to apply the findings of research into chemistry alternative conceptions, yet many pre-service chemistry teachers have numerous alternative conceptions themselves"* (p. 1). This means that even when these pre-service teachers qualify, they still need professional development to help them rectify their own alternative conceptions and so identify alternative conceptions among their learners.

My view as a researcher is that this study is different in a way that it is focused more on basic Agricultural Science chemistry, especially in the topic organic compounds. Such an aspect has not been studied in depth among teachers, more especially not in the province of the Eastern Cape in South Africa. Some studies have been conducted on chemistry in this region, but not on Agricultural Sciences organic compounds. I think that action researchers should base their research on deeper engagement with teachers so to enhance their TS-PCK in difficult topics, one of which is organic chemistry.

Chapter summery

This chapter was about data analysis, presentation and discussion for research question 2. The participants of the study in answering research question 2 they suggested that they should be assisted in identifying their weaknesses or lack of PCK. They also said that researchers should provide them with some workshops. They also suggested that books talking about chemistry should be given to them more especially in the rural areas.

Chapter 6

Summary of Findings and Conclusion

6.1 Overview of Findings

The intention of the researcher in this study was to explore Grade 11 Agricultural Science teachers' topic specific pedagogical content knowledge in teaching organic compounds. Two critical research questions informed my study. The findings of the study gave rise to themes, which are based on the answers given by the participants of this study.

6.2 Summary of the Research Process

This was a qualitative action research study with three participating Agricultural Science teachers, conducted using a critical research paradigm. A critical paradigm was used because the researcher had to interact with the participants in understanding their problems in teaching organic compounds. The researcher had to also conduct the developmental workshop on the chosen topic of organic compounds. Accordingly the critical research paradigm was chosen as being in line with action research and the researcher was actively involved in the research process as well as the professional development of the Agricultural Sciences teachers. The research data for this study was collected through semi-structured interviews: both pre-professional development and post-professional development. The pre-PD interviews were focused on answering the first research question of this study, which was 'What problems do Grade 11 Agricultural Sciences teachers encounter in teaching the topic organic compounds? The second question, which the interviews answered was 'How can we use Action

Research to help Grade 11 Agricultural Sciences teachers' to improve their topic specific pedagogical content knowledge (TS-PCK) in teaching organic compounds?' This question was answered using the post-developmental interviews.

The researcher used a purposive sampling method to select the participants. The reason behind the use of this sample stems from the notion that only teachers who teach Agricultural Sciences would have opinions that were relevant in the research, as they are the ones who are involved in the teaching of organic compounds in the subject. The other reason for the choice was the teachers' working in reasonably close proximity to each other, which was necessary for the continuity of working together in a community of practice after the professional development workshop was over.

The data was collected from three Agricultural Sciences teachers in Libode district. The instruments were first piloted and the questions were readjusted for the purpose of the main study. The second stage was to collect data from the three chosen teachers and this data was used to answer the research questions of this study. The data was analysed and themes emerged and this data was also coded and findings were presented in Chapters 4 and 5 of this study.

6.3 Summary of the Findings for Research Question 1

The first research question was: What problems do Grade 11 Agricultural Sciences teachers encounter in teaching the topic organic compounds identified through action research?

Four key themes emerged in answering this research question, as follows:

- Lack of tertiary module/s (LOTM) in chemistry which impedes Agricultural Sciences educators in teaching the chemistry section,
- Learner's cramming or rote learning science concepts,
- Teachers' significant lack of content knowledge (CK) needed to teach organic chemistry for Agricultural Sciences non-science learners impedes AGRSC educators from teaching the chemistry section effectively,
- Learners hold alternative conceptions in basic organic chemistry (LGMOC)

From these themes, it was evident that teachers faced problems such as a lack of exposure to tertiary modules in organic chemistry. This was said to be the main reason why teachers exhibited a number of alternative conceptions in organic chemistry in Agricultural Sciences. The problems associated with this issue were that of not knowing the deep explanation behind organic chemistry concepts. It can be said that the teachers were not able to teach it effectively as they had little or weak foundational knowledge in chemistry. Teacher's ideas also reflected that learners hold alternative conceptions in basic organic chemistry section and this becomes a burden for teachers as they have to first identify the alternative conceptions and later correct their learners' ideas. Many non-science learners that enrolled for Agricultural Sciences directly impeded the teaching and learning of organic chemistry section as they do not have any knowledge of basic chemistry. This means that teachers have to explain starting from a Grade 8 or 9 level, when they explained certain concepts in chemistry in FET Agricultural Sciences.

6.4 Conclusion to Research Question 1

The findings of my study concerning the problems teachers face when teaching organic compounds include learner's alternative conceptions, teachers' lack of tertiary chemistry modules, slow learners' alternative conceptions and poor understanding, and learners cramming. These challenges, amongst others, are significant problems that teachers face. This study confirms findings from other studies that teachers cannot teach effectively when they lack deep content knowledge. This affects their pedagogy and learners acquisition of chemistry knowledge.

6.5 Findings for Research Question 2

Research question 2 was 'How can Grade 11 Agricultural Sciences teachers' improve their topic specific pedagogical content knowledge (TS-PCK) in teaching organic compounds through action research?'

For this research question, the key issues that emerged were:

- ❖ Problem diagnosis,
- ❖ Help teachers in understanding chemistry content,
- ❖ Availability of workshops for rural teachers.

Teachers required professional support to identify problems regarding their own alternative conceptions. They further stated that it would be beneficial if more developmental workshops could focus on rural schools, as they are too often ignored due to their location away from urban areas.

6.6 Conclusion for Research Question 2

Agricultural Science teachers in these rural areas reported that they require support from professional development teams (subject specialist, experienced teachers, and researchers) to identify TS-PCK problems they have might have. Teachers' alternative conceptions in the content of organic chemistry automatically require action to improve the situation through organizing sustainable professional development workshops. The rural school sciences teachers requested more professional development workshops, as they have limited resources such as the internet, libraries and textbooks.

6.7 Recommendations

The purpose of the study was to explore Agricultural Science teacher's knowledge about learners' alternative conceptions and their learning challenges in a specific topic in Agricultural Science, namely, *organic compounds* and to identify the kind of professional support they needed. In this section, the researcher presents recommendations based on the findings of this study.

From the findings and conclusion of the study and working with teacher's needs, the study recommends the following:

1. Lack of tertiary module/s (LOTM) in chemistry which impedes Agricultural Sciences educators to teach the chemistry section (from conclusion 1).

Higher education institutes such as universities and colleges should offer organic chemistry for all science teachers who teach Agricultural Sciences, either in pre-service education or as extended in-service courses. These institutions should also take into account the development of teachers, more specifically those from and who go to teach in rural schools.

2. Support teachers in understanding chemistry content

Teachers need to be taught or re-taught content by professional developers, such as subject advisors or lecturers. Teachers should also be given a chance to develop one another by working as a community of practice in their own context.

3. Make workshops available for rural teachers

Professional development teachers or action researchers should be more visible in rural areas, where there is the greatest need for professional support. Teachers in the rural areas are not often taken care of by the Department of Education as they are seldom given refresher seminars or workshops in the content areas.

6.8 Limitations of the study

This study was an action research study and was limited to only the Libode district and to teachers from three schools. The participants of this study were also limited to three and so results reflects opinions of only a small sample. Hence, they are not necessarily generalizable. However there are valuable findings emerging from the study concerning teacher support in Agricultural Sciences, where research has been sparse. Time and access to teachers and their working on their own are also limitations, as I could not spend as much time in the field as I would have liked.

In terms of research design, one drawback is the study's subjectivity. One of the main criticisms of action research is that when left unchecked, results are loaded with subjectivity (Kock, 2005) because the researcher is too close to the participants. I have encountered that sometimes being an action researcher means I was a bit too close to the participants.

This study was also time consuming. Participating in meetings and being a part of a change process takes a lot of time, and as an action researcher I needed to find a good balance between these aspects and the writing and analysis of data. Some have blamed practical action research as drifting away from the sole spirit of action research because it has been fuelled by practices and inputs of ‘outsiders’ (Pine, 2008). In effect, it ran the risk of research questions being ‘externally formulated’ and delving into issues which were not reflective of real sentiments and problems of practitioners (Kemmis, 2009).

References

Adedokun, O. A., & Balschweid, M. A. (2008). Investigating Community Factors as Predictors of Rural 11th-Grade Agricultural Science Students' Choice of Careers in Agriculture. *Journal of Agricultural Education, 49*(4), 1-10.

Agten, S. M., Dawson, P. E., & Hackeng, T. M. (2016). Oxime conjugation in protein chemistry: From carbonyl incorporation to nucleophilic catalysis. *Journal of Peptide Science, 22*(5), 271-279.

Ahmad, S. S., Shaari, M. F., Hashim, R., & Kariminia, S. (2015). Conducive attributes of physical learning environment at preschool level for slow learners. *Procedia-Social and Behavioral Sciences, 201*, 110-120.

Akaygun, S., & Aslan-Tutak, F. (2016). STEM images revealing stem conceptions of pre-service chemistry and mathematics teachers. *International Journal of Education in Mathematics, Science and Technology, 4*(1), 56-71.

Akkuzu, N., & Uyulgan, M. A. (2016a). An epistemological inquiry into organic chemistry education: exploration of undergraduate students' conceptual understanding of functional groups. *Chemistry Education Research and Practice, 17*(1), 36-57.

Akkuzu, N., & Uyulgan, M. A. (2016b). How to Improve Students' Comprehension Concerning the Major Terms of Functional Groups?--In the Experiment of OrCheTaboo Game. *International Journal of Higher Education, 5*(2), 196-212.

Albion, P. R., Tondeur, J., Forkosh-Baruch, A., & Peeraer, J. (2015). Teachers' professional development for ICT integration: Towards a reciprocal relationship between research and practice. *Education and Information Technologies, 20*(4), 655-673.

Angell, C., Ryder, J., & Scott, P. (2005). Becoming an expert teacher: Novice physics teachers' development of conceptual and pedagogical knowledge. *Working Document*. https://www.google.com/search?client=firefox-b d&q=Angell%2C+C.%2C+Ryder%2C+J.%2C+%26+Scott%2C+P.+%282005%29.+Becoming+an+expert+teacher%3A+Novice+physics+teachers%E2%80%99+development+of+conceptual+and+pedagogical+knowledge.+Working+Document.+.

Anne. Marie, H. (2017). Why Do Atoms Bond? *Difference Between Stability and Neutral Electrical Charge.* https://www.thoughtco.com/why-do-atoms-bond-603992.

Archer, R. D., Heikkinen, H. W., & Lester, M. K. (2015). ACS's Role in Improving Chemistry Education—Synergism among Governance, Chemistry Teachers, and Staff *Sputnik to Smartphones: A Half-Century of Chemistry Education* (pp. 277-298): ACS Publications.

Ary, D., Jacobs, L. C., Irvine, C. K. S., & Walker, D. (2018). *Introduction to Research in Education* (10 ed. Vol. 5). New York, San Francisco: Cengage Learning.

Atherton, J. (2011). Learning and teaching: Constructivism in learning. http://www.learningandteaching.info/*learning*/experience.htm.

Atkins, P., & De Paula, J. (2011). *Physical Chemistry for the Life Sciences*: Oxford University Press, USA.

Avraamidou, L. (2014). Studying science teacher identity: Current insights and future research directions. *Studies in Science Education, 50*(2), 145-179.

Babbie. V.D., (2007). Ethical consideration *The Practice of Social Research*. United States of America: Belmont, CA: Thomson Wadsworth.

Bachsmann, S., Wolf, K., & Waitz, T. (2015). *Learning Strategies in a Blended Learning Environment.* Paper presented at the *Conference Proceedings. New Perspectives in Science Education*.

Baraniuk, R. G., Foucart, S., Needell, D., Plan, Y., & Wootters, M. (2017). Exponential decay of reconstruction error from binary measurements of sparse signals. *IEEE Transactions on Information Theory, 63*(6), 3368-3385.

Barrows, S. E., & Eberlein, T. H. (2004). Cis and trans isomerization in cyclic alkenes: A topic for discovery using the results of molecular modeling. *Journal of Chemical Education, 81*(10), 1529.

Bartlett, M. K., Klein, T., Jansen, S., Choat, B., & Sack, L. (2016). The correlations and sequence of plant stomatal, hydraulic, and wilting responses to drought. *Proceedings of the National Academy of Sciences, 113*(46), 13098-13103.

Bartos, S. A., & Lederman, N. G. (2014). Teachers' knowledge structures for nature of science and scientific inquiry: Conceptions and classroom practice. *Journal of Research in Science Teaching, 51*(9), 1150-1184.

Bartos, S. A., Lederman, N. G., & Lederman, J. S. (2014). Teachers' reflections on their subject matter knowledge structures and their influence on classroom practice. *School Science and Mathematics, 114*(3), 125-138.

Bensley, D. A., & Lilienfeld, S. O. (2015). What is a psychological misconception? Moving toward an empirical answer. *Teaching of Psychology, 42*(4), 282-292.

Berger, H., Eylon, B.-S., & Bagno, E. (2008). Professional development of physics teachers in an evidence-based blended learning program. *Journal of Science Education and Technology, 17*(4), 399-409.

Beaudry, J. (1991). Book Reviews: Renata Tesch. Qualitative Research:. Analysis Types and Software Tools. New York: The Falmer Press, 1990, 329 pp. *American Journal Of Evaluation, 12*(1), 79-82.

Bhattacharyya, G., & Bodner, G. M. (2005). " It gets me to the product": How students propose organic mechanisms. *Journal of Chemical Education, 82*(9), 1402.

Binu, P., & Nair, P. (2015). Affective teaching: An effective way to deal with slow learners in ESL classroom. *International Journal of English Language, Literature and Humanities, 2*(10)*, p. 504-511*.

Blömeke, S., Suhl, U., & Kaiser, G. (2014). Teacher education effectiveness: Quality and equity of future primary teachers' mathematics and mathematics pedagogical content knowledge *International Perspectives on Teacher Knowledge, Beliefs and Opportunities to Learn* (pp. 91-114): Springer.

Bodner, G., & Orgill, M. (2007). Theoretical frameworks for research in chemistry/science education. *Journal of Science Education, 5*(1), 5-22.

Bozbiyik, B., Lannoeye, J., De Vos, D. E., Baron, G. V., & Denayer, J. F. (2016). Shape selective properties of the Al-fumarate metal–organic framework in the adsorption and separation of n-alkanes, iso-alkanes, cyclo-alkanes and aromatic hydrocarbons. *Physical Chemistry Chemical Physics, 18*(4), 3294-3301.

Braga, L., Jones, E., Bulger, S., & Elliott, E. (2017). Empowering teachers to implement innovative content in physical education through continuous professional development. *Teacher Development, 21*(2), 288-306.

Brookfield, S. (2017). *Becoming a critically reflective teacher*. London: John Wiley & Sons.

Brown, R. I. (2017). *Psychology and Education of Slow Learners*. London: Routledge.

Bryan, L. C. H. (2007). Identifying students' misconceptions in 'a-level'organic chemistry. Journal of Chemical Education. http://conference.crpp.nie.edu.sg/2007/paper/papers/SCI352.pdf.

Bucat, R. (2004). Pedagogical content knowledge as a way forward: Applied research in chemistry education. *Chemistry Education Research and Practice, 5*(3), 215-228.

Bucat, R. (2014). Pedagogical content knowledge as a way forward: Applied research in chemistry education. *Chemistry Education: Research and Practice, 5*(3), 215-228.

Burke, M., & Lobell, D. B. (2017). Satellite-based assessment of yield variation and its determinants in smallholder African systems. *Proceedings of the National Academy of Sciences, 114*(9), 2189-2194.

Calder, P. C. (2015). Marine omega-3 fatty acids and inflammatory processes: effects, mechanisms and clinical relevance. *Biochimica et Biophysica Acta (BBA)-Molecular and Cell Biology of Lipids, 1851*(4), 469-484.

Cambron-McCabe, N., Lucas, T., Smith, B., & Dutton, J. (2012). *Schools that learn: A fifth discipline fieldbook for educators, parents, and everyone who cares about education* (5 ed.). Penguin Rndom House: Broadway Business.
Canada, & Alberta. (2002). Health and Life Skills Guide to Implementation (K–9) Instructional Strategies: What are instructional strategies? *Health Education, 1*(2), 67.
Canning, C. (1991). What teachers say about reflection. *Educational Leadership, 48*(6), 18-21.
Cannon, R. D. (2016). *Electron transfer reactions*. London: Butterworth-Heinemann.
Carnduff, J., & Reid, N. (2003). *Enhancing undergraduate chemistry laboratories: pre-laboratory and post-laboratory exercises*. Royal Society of Chemistry: London.
Carneiro, G., Parulekar, T., Shridhar, G., & Ladage, S. (2016). Experimenting with the teaching of organic chemistry–the process-oriented guided inquiry learning way. *CURRENT SCIENCE, 111*(7), 1152-1155.
Carr, W., & Kemmis, S. (2003). *Becoming critical: education knowledge and action research*: Routledge.
Cebrián-Robles, D., Franco-Mariscal, A.-J., & Blanco-López, Á. (2018). Preservice elementary science teachers' argumentation competence: impact of a training programme. *Instructional Science, 3*(1), 1-29.
Chan, K. K. H., & Yung, B. H. W. (2018). Developing pedagogical content knowledge for teaching a new topic: more than teaching experience and subject matter knowledge. *Research in Science Education, 48*(2), 233-265.
Chapoo, S., Thathong, K., & Halim, L. (2014). Biology Teacher's Pedagogical Content Knowledge in Thailand: Understanding & Practice. *Procedia-Social and Behavioral Sciences, 116*, 442-447.
Cobern, W. W., & Tobin, K. (2003). *Chemical Education: Towards Research-based Practice* (Vol. 17). United States of America: Kluwer Academic Publishers.
Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (8 ed.). London: Prentice Hall.
Cohen, L., Manion, L., & Morrison, M. (2018). *Research Methods in Education*. *Milton Park: Routledge, 7*(2), 25.
Conners-Burrow, N. A., Patrick, T., Kyzer, A., & McKelvey, L. (2017). A preliminary evaluation of REACH: Training early childhood teachers to support children's social and emotional development. *Early Childhood Education Journal, 45*(2), 187-199.
Cope, D. G. (2014). *Methods and meanings: credibility and trustworthiness of qualitative research.* Paper presented at the Oncology nursing forum.
Costa, N., Marques, L., & Kempa, R. (2009). Science teachers' awareness of findings from education research. *Research in Science & Technological Education, 18*(1), 37-44.
Creswell, J. W. (2013). *Qualitative Inquiry & Research Design* (3 ed.). United States of America: SAGE Publications.
Curtiss, S. L., Pearson, J. N., Akamoglu, Y., Fisher, K. W., Snodgrass, M. R., Meyer, L. E., . . . Halle, J. W. (2016). Bringing instructional strategies home: Reaching families online. *Teaching Exceptional Children, 48*(3), 159-167.
Cuttance, P. (2013). *School innovation: Pathway to the knowledge society*: Department of Education, Training and Youth Affairs.
Dammak, A. (2015). Research Paradigms: Methodologies And Compatible Methods. *Veritas, 6*(2), 1-5.
Darling-Hammond, L. (2006). Assessing teacher education: The usefulness of multiple measures for assessing program outcomes. *Journal of Teacher Education, 57*(2), 120-138.
Dauzvardis, F., Knapp, A., Shein, K. N. D., & Lisensky, G. (2019). Quick and Easy Electroless Deposition and Alkanethiol Treatment To Form a Superhydrophobic Surface. *Journal of Chemical Education*. https://pubs.acs.org/doi/10.1021/acs.jchemed.9b00639.
Davidowitz, & Rollnick, M. (2011). What lies at the heart of good undergraduate teaching? A case study in organic chemistry. *Chemistry Education Research and Practice, 12*(3), 355-366.

Davidowitz, G., McCue, M., & Levin, E. (2017). Sex Differences in the Utilization of Essential and Non-Essential Amino Acids in Lepidoptera. *The FASEB Journal, 31*(1 Supplement), 889.810-889.810.

De Quadros, A. L., Carvalho Da-Silva, D., Silva, F. C., Pereira de Andrade, F., Aleme, H. G., Tristão, J. C., . . . DeFreitas-Silva, G. (2011). The knowledge of chemistry in secondary education: difficulties from the teachers' viewpoint. *Educación química, 22*(3), 232-239.

De Souza, R. J., Mente, A., Maroleanu, A., Cozma, A. I., Ha, V., Kishibe, T., . . . Beyene, J. (2015). Intake of saturated and trans unsaturated fatty acids and risk of all cause mortality, cardiovascular disease, and type 2 diabetes: systematic review and meta-analysis of observational studies. *Bmj, 351*, h3978. https://doi.org/10.1136/bmj.h3978.

Dell, A. G., Newton, D. A., & Petroff, J. G. (2016). *Assistive technology in the classroom: Enhancing the school experiences of students with disabilities*. London: Pearson.

Demirdöğen, B., Hanuscin, D. L., Uzuntiryaki-Kondakci, E., & Köseoğlu, F. (2016). Development and nature of preservice chemistry teachers' pedagogical content knowledge for nature of science. *Research in Science Education, 46*(4), 575-612.

Dickson, H., Thompson, C. D., & O'Toole, P. (2016). A picture is worth a thousand words: Investigating first year chemistry students' ability to visually express their understanding of chemistry concepts. *International Journal of Innovation in Science and Mathematics Education, 24*(1), 2-23.

Dong, Y., Chai, C. S., Guo-Yuan, S., Koh, J. H. L., & Chin-Chung, T. (2015). Exploring the profiles and interplays of pre-service and in-service teachers' technological pedagogical content knowledge (TPACK) in China. *Journal of Educational Technology & Society, 18*(1), 158.

Driel, v., Berry, & Meirink. (2014). Research on science teacher knowledge *Handbook of Research on Science Education, Volume II* (pp. 862-884). New jersey: Prentice hall: Routledge.

Dube, T., & Lubben, F. (2011). Swazi teachers' views on the use of cultural knowledge for integrating education for sustainable development into science teaching. *African Journal of Research in Mathematics, Science and Technology Education, 15*(3), 68-83.

Dugdale, J. S. (2016). *The electrical properties of metals and alloys*. London: Courier Dover Publications.

Duis, J. M. (2011). Organic chemistry educators' perspectives on fundamental concepts and misconceptions: An exploratory study. *Journal of Chemical Education, 88*(3), 346-350.

Ebbutt, D. (1985). Educational action research: Some general concerns and specific quibbles. *Issues in educational research: Qualitative methods, 7*(2), 152-174.

Education, D. o. B. (2014). *National Curriculum Statement Grades 10-12 (GENERAL) Learning Programme Guidelines Agricultural Sciences. Pretoria: Department of Education.* Pretoria: Department of Education.

Education, D. o. B. (2015). *Curriculum and Assessment Policy Statement Grades 10-12 Agricultural Sciences*. Pretoria Soth Africa: Department of Education.

Entwistle, N., & Ramsden, P. (2015). *Understanding student learning (Routledge revivals)*. London: Routledge.

Erman, E. (2017). Factors contributing to students' misconceptions in learning covalent bonds. *Journal of research in Science Teaching, 54*(4), 520-537.

Espinosa, A. A., Nueva España, R. C., & Marasigan, A. C. (2016). Investigating Pre-Service Chemistry Teachers' Problem Solving Strategies: Towards Developing a Framework in Teaching Stoichiometry. *Journal of Education in Science, Environment and Health, 2*(2), 104-124.

Esselman, B. J., & Hill, N. J. (2016). Integration of computational chemistry into the undergraduate organic chemistry laboratory curriculum. *Journal of Chemical Education, 93*(5), 932-936.

Fantilli, R. D., & McDougall, D. E. (2009). A study of novice teachers: Challenges and supports in the first years. *Teaching and teacher education, 25*(6), 814-825.

Farrell, J. B. (2003). Empowering Beginning Teachers through Action Research. paper presesented at AERAC conference, Illinois, Chicago.

Feistritzer, C. E., Griffin, S., & Linnajarvi, A. (2011). *Profile of teachers in the US, 2011*: National Center for Education Information Washington, DC.

Flynn, A. (2016). The" EcoTardis": Charting the Early Stages of a Secondary School Participatory Action Research (PAR) Project in Post-Colonial Eco-Place Pedagogies. *Australian Association for Research in Education, 3*(2), 1-36.

Friedrichsen, P. J., Abell, S. K., Pareja, E. M., Brown, P. L., Lankford, D. M., & Volkmann, M. J. (2009). Does teaching experience matter? Examining biology teachers' prior knowledge for teaching in an alternative certification program. *Journal of Research in Science Teaching, 46*(4), 357-383.

Fulton, R. L. (1993). Sharing of electrons in molecules. *The Journal of Physical Chemistry, 97*(29), 7516-7529.

Gafoor, K. A., & Shilna, V. (2014). *Gender Fair Efficacy of Concept Mapping Tests in Identifying Students' Difficulties in High School Organic Chemistry*. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED545404&site=ehost-live

Garrett, R., & Grisham, C. (2005). Biochemistry Belmont CA. *CA: Thomson Brooks/Cole, 32005*.

Geddis, A. N. (1993). Transforming subject-matter knowledge: the role of pedagogical content knowledge in learning to reflect on teaching. *International journal of science education, 15*(6), 673-683.

Geyer, R., Kuczenski, B., Zink, T., & Henderson, A. (2016). Common misconceptions about recycling. *Journal of Industrial Ecology, 20*(5), 1010-1017.

Gilbert, J. K., Bulte, A. M., & Pilot, A. (2011). Concept development and transfer in context-based science education. *International Journal of Science Education, 33*(6), 817-837.

Gilbert, J. K., de Jong, O., Justi, R., Treagust, D. F., & van Driel, J. H. (2002). *Chemical education: towards research-based practice*: Springer.

Gilbert, J. K., De Jong, O., Justi, R., Treagust, D. F., & Van Driel, J. H. (2006). *Chemical education: Towards research-based practice* (Vol. 17). Berlin: Springer Science & Business Media.

Gilbert, J. K., & Justi, R. (2016). Educating Teachers to Facilitate Modelling-Based Teaching *Modelling-based Teaching in Science Education* (pp. 223-251). New York: Springer.

Gilbert, J. K., & Treagust, D. F. (2009). *Multiple representations in chemical education* (Vol. 2): New York: Springer.

Glover, T. A., Nugent, G. C., Chumney, F. L., Ihlo, T., Shapiro, E. S., Guard, K., . . . Bovaird, J. (2016). Investigating rural teachers' professional development, instructional knowledge, and classroom practice. *Journal of Research in Rural Education (Online), 31*(3), 1-16.

Gonen, S., & Kocakaya, S. (2010). A Physics Lesson Designed According to 7E Model with the Help of Instructional Technology (Lesson Plan). *Turkish Online Journal of Distance Education, 11*(1), 98-113.

Good, T. L., & Lavigne, A. L. (2017). *Looking in classrooms*. London: Routledge.

Goodnough, K. (2016). Professional Learning of K-6 Teachers in Science Through Collaborative Action Research: An Activity Theory Analysis. *Journal of Science Teacher Education, 27*(7), 747-767.

Gosser, D., Roth, V., Gafney, L., Kampmeier, J., Strozak, V., Varma-Nelson, P., . . . Weiner, M. (1996). Workshop chemistry: Overcoming the barriers to student success. *The Chemical Educator, 1*(1), 1-17.

Govender, N. (2015). Developing pre-service teachers’ Subject Matter Knowledge of electromagnetism by integrating concept maps and collaborative learning. *African Journal of Research in Mathematics, Science and Technology Education, 19*(3), 306-318.

Gregory, G. H., & Chapman, C. (2012). *Differentiated instructional strategies: One size doesn't fit all* (2 ed.). California: Corwin Press.

Griffith, J. A., & Brem, S. K. (2004). Teaching evolutionary biology: Pressures, stress, and coping. *Journal of Research in Science Teaching, 41*(8), 791-809.

Grosslight, L., Unger, C., Jay, E., & Smith, C. L. (1991). Understanding models and their use in science: Conceptions of middle and high school students and experts. *Journal of research in Science Teaching, 28*(9), 799-822.

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*: Teachers College Press, Teachers College, Columbia University.

Großschedl, J., Harms, U., Kleickmann, T., & Glowinski, I. (2015). Preservice biology teachers' professional knowledge: Structure and learning opportunities. *Journal of Science Teacher Education*, *26*(3), 291-318.

Guarte, J. M., & Barrios, E. B. (2006). Estimation under purposive sampling. *Communications in Statistics—Simulation and Computation®, 35*(2), 277-284.

Gudmundsdottir, S., & Shulman, L. (1987). Pedagogical content knowledge in social studies. *Scandinavian Journal of Educationl Research, 31*(2), 59-70.

Gudyanga, E., & Madambi, T. (2014a). Pedagogics of chemical bonding in Chemistry; perspectives and potential for progress: The case of Zimbabwe secondary education. *International Journal of Secondary Education, 2*(1), 11-19.

Gudyanga, E., & Madambi, T. (2014b). Students' misconceptions about bonding and chemical structure in chemistry. Midlands State University.

Gulyas, A., Pfefferle, J., Wolf, K., & Waitz, T. (2015). A Model for CLIL in School Chemistry Classes: Combining the Aims of CLIL and Chemistry Teaching. *Eurasian Journal of Physics & Chemistry Education, 7*(2), 75-82

Gurel, D. K., Eryılmaz, A., & McDermott, L. C. (2015). A Review and Comparison of Diagnostic Instruments to Identify Students' Misconceptions in Science. *Eurasia Journal of Mathematics, Science & Technology Education, 11*(5), 989-1008.

Gurses, A., Dogar, C., & Gunes, K. (2015). A New Approach for Learning: Interactive Direct Teaching Based Constructivist Learning (IDTBCL). *Procedia-Social and Behavioral Sciences, 197*, 2384-2389.

Guzey, S. S., Tank, K., Wang, H. H., Roehrig, G., & Moore, T. (2014). A high-quality professional development for teachers of grades 3–6 for implementing engineering into classrooms. *School Science and Mathematics, 114*(3), 139-149.

Hahm, H. S., Schlegel, M. K., Hurevich, M., Eller, S., Schuhmacher, F., Hofmann, J., . . . Seeberger, P. H. (2017). Automated glycan assembly using the Glyconeer 2.1 synthesizer. *Proceedings of the National Academy of Sciences*, *114*(17), E3385-E3389.

Halim, L., Abdullah, S. I. S. S., & Meerah, T. S. M. (2014). Students' perceptions of their science teachers' pedagogical content knowledge. *Journal of Science Education and Technology, 23*(2), 227-237.

Harasim, L. (2017). *Learning theory and online technologies*. London: Taylor & Francis.

Harrison, A. G., & Treagust, D. F. (2010). A typology of school science models. *International Journal of Science Education, 22*(9), 1011-1026.

Harvey, R. (2013). The Peper Perspective. *Journal of Science Education, 2*(1), 2-33.

Hassan, A., & Mahmud, M. (2015). Tablet Technology and Apps to Enhance Slow Learners Motivation in Learning. *Advanced Science Letters*, *21*(10), 3165-3169.

Hayek, D. (2015). Why is iodine a solid at room temperature?

Hanson, R. (2017). "Unearthing conceptions about types of chemical bonding through the use of tiered worksheets: A case study." International Journal for Cross-Disciplinary Subjects in Education **8**(2): 3112-3122.

https://www.mytutor.co.uk/answers/37744/GCSE/Chemistry/Why-is-iodine-a-solid-at-room-temperature-and-chlorine-a-gas-despite-being-in-the-same-group/.

Henning, E., Van Rensburg, W., & Smit, B. (2004). *Finding your way in qualitative research*: Pretoria: Van Schaik.

Hill, Bicer, A., & Capraro, R. M. (2017). Effect of Teachers' Professional Development from MathForward™ on Students' Math Achievement. *International Journal of Research in Education and Science, 3*(1), 67-74.
Hill, Nixon, & Luft. (2017). Secondary science teachers' subject matter knowledge development across the first five years. *Journal of Science Teacher Education.*, 1-34.
Hofmann, J., Hahm, H. S., Seeberger, P. H., & Pagel, K. (2017). Method for Determining Carbohydrates Structure. https://pure.mpg.de/pubman/faces/ViewItemOverviewPage.jsp?itemId=item_2407890
Hunt, P. A., Ashworth, C. R., & Matthews, R. P. (2015). Hydrogen bonding in ionic liquids. *Chemical Society Reviews, 44*(5), 1257-1288.
Hwa, T. H., & Karpudewan, M. (2017). Green Chemistry-Based Dual-Situated Learning Model: An Approach that Reduces Students' Misconceptions on Acids and Bases *Overcoming Students' Misconceptions in Science* (pp. 133-155). London: Springer.
Ifenthaler, D., Masduki, I., & Seel, N. M. (2011). The mystery of cognitive structure and how we can detect it: tracking the development of cognitive structures over time. *Instructional Science, 39*(1), 41-61.
Izci, K., & Siegel, M. A. (2019). Investigation of an Alternatively Certified New High School Chemistry Teacher's Assessment Literacy. *International Journal of Education in Mathematics, Science and Technology, 7*(1), 1-19.
Jaafarpour, M., Aazami, S., & Mozafari, M. (2016). Does concept mapping enhance learning outcome of nursing students? *Nurse Education Today, 36*, 129-132.
Jain, S., Wheeler, J. R., Walters, R. W., Agrawal, A., Barsic, A., & Parker, R. (2016). ATPase-modulated stress granules contain a diverse proteome and substructure. *Cell, 164*(3), 487-498.
Jao, L., & McDougall, D. (2015). The collaborative teacher inquiry project: A purposeful professional development initiative. *Canadian Journal of Education, 38*(1), 1-22.
Jeffrey, J. L., Terrett, J. A., & MacMillan, D. W. (2015). O–H hydrogen bonding promotes H-atom transfer from α C–H bonds for C-alkylation of alcohols. *Science, 349*(6255), 1532-1536.
Jones, J. W., Antle, J. M., Basso, B., Boote, K. J., Conant, R. T., Foster, I., . . . Janssen, S. (2017). Toward a new generation of agricultural system data, models, and knowledge products: State of agricultural systems science. *Agricultural Systems, 155*(2), 269-288.
Kamen, M. (1996). A teacher's implementation of authentic assessment in an elementary science classroom. *Journal of Research in Science Teaching, 33*(8), 859-877.
Kanyane, C. (2005). Informing Approaches in Establishing Stand Alone Community Literacy Programmes in South Africa. *Africa Development, 29*(3), 33-68.
Karpudewan, M., Roth, W. M., & Sinniah, D. (2016). The role of green chemistry activities in fostering secondary school students' understanding of acid–base concepts and argumentation skills. *Chemistry Education Research and Practice, 17*(4), 893-901.
Kaur, P., Singh, M., & Josan, G. S. (2015). Classification and prediction based data mining algorithms to predict slow learners in education sector. *Procedia Computer Science, 57*, 500-508.
Kaya, M. (2016). Recovery of metals and nonmetals from electronic waste by physical and chemical recycling processes. *Waste Management, 57*, 64-90.
Kazeni, M., & Onwu, G. (2013). Comparative effectiveness of context-based and traditional approaches in teaching genetics: Student views and achievement. *African Journal of Research in Mathematics, Science and Technology Education, 17*(1-2), 50-62.
Khursheed, M. Q., & Mahammad, M. Q. (2015). Effect of Different Nitrogen Fertilizers on Growth and Yield of Wheat. *ZANCO Journal of Pure and Applied Sciences, 27*(5), 19-28.
Kiemer, K., Gröschner, A., Pehmer, A.-K., & Seidel, T. (2015). Effects of a classroom discourse intervention on teachers' practice and students' motivation to learn mathematics and science. *Learning and Instruction, 35*, 94-103.
Kind, V. (2009). Pedagogical content knowledge in science education: perspectives and potential for progress. *Studies in Science Education, 45*(2), 169-204.

Kind, V. (2014). Exploring Mathematics and Science Teachers' Knowledge Editors: Hamsa Venkat, Marissa Rollnick, John Loughran and Mike Askew. London: Routledge.

Klingner, J. K., Vaughn, S., & Boardman, A. (2015). *Teaching reading comprehension to students with learning difficulties, 2/E*. New York: Guilford Publications.

Ko, B., Wallhead, T., & Ward, P. (2006). Chapter 4: Professional development workshops—what do teachers learn and use? *Journal of Teaching in Physical Education, 25*(4), 397-412.

Kohn, C. (2019). The development of a bioenergy-based green chemistry curriculum for high schools. *Physical Sciences Reviews, 4*(1). DOI: https://doi.org/10.1515/psr-2018-0080.

Kwak, Y.-S. (2009). Research on the effects of Subject Matter Knowledge (SMK) on Pedagogical Content Knowledge (PCK) of secondary beginning science teachers in classroom teaching. *Journal of the Korean Association for Science Education, 29*(6), 611-625.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press.

Lee, Burstyn, I., Lai, A., Grundy, A., Friesen, M., Aronson, K., & Spinelli, J. (2019). Women's occupational exposure to polycyclic aromatic hydrocarbons and risk of breast cancer. *Occup Environ Med, 76*(1), 22-29.

Lee, & Prausnitz, J. M. (2010). Polarity and hydrogen-bond-donor strength for some ionic liquids: effect of alkyl chain length on the pyrrolidinium cation. *Chemical Physics Letters, 492*(1-3), 55-59.

Levy Nahum, T., Mamlok-Naaman, R., Hofstein, A., & Taber, K. S. (2010). Teaching and learning the concept of chemical bonding. *Studies in Science Education, 46*(2), 179-207.

Li, M., & Cong, X. (2017). Chemical changes and the mechanisms in the sintering process of sea silt. *BULGARIAN CHEMICAL COMMUNICATIONS, 49*(1), 250-255.

Lucenario, J. L. S., Yangco, R. T., Punzalan, A. E., & Espinosa, A. A. (2016). Pedagogical Content Knowledge-Guided Lesson Study: Effects on Teacher Competence and Students' Achievement in Chemistry. *Education Research International*,1-9. http://dx.doi.org/10.1155/2016/6068930.

Luft, J. A., Dubois, S. L., Nixon, R. S., & Campbell, B. K. (2015). Supporting newly hired teachers of science: Attaining teacher professional standards. *Studies in Science Education, 51*(1), 1-48.

Luft, J. A., Firestone, J. B., Wong, S. S., Ortega, I., Adams, K., & Bang, E. (2011). Beginning secondary science teacher induction: A two-year mixed methods study. *Journal of research in Science Teaching, 48*(10), 1199-1224.

Luft, J. A., & Zhang, C. (2014). The pedagogical content knowledge and beliefs of newly hired secondary science teachers: the first three years. *Educación química, 25*(3), 325-331.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching *Examining pedagogical content knowledge* (pp. 95-132). London: Springer.

Malcolm, S. A. (2015). The design and validation of an instrument to measure topic-specific pedagogical content knowledge in stoichiometry of physical sciences teachers. Unpublished *Master of Science Thesis, University of the Witwatersrand, South Africa.*

Martínez, G., & Mellado, V. (2016). The importance of pck in the education of secondary school physics teachers: Acase studyon teaching electric fields. *Secondary Education: Perspectives, global issues and challenges*, 133.

Martins, P. N. (2017). Organic Chemistry in Portugal from 1900 to 1970: A Contribution to the History of Science. *Orbital: The Electronic Journal of Chemistry, 9*(5).

Mauksch, M., & Tsogoeva, S. B. (2017). 4 N electron aromatic cycles in polycyclic hydrocarbons. *Physical Chemistry Chemical Physics, 19*(21), 14066-14072.

Mavhunga. (2014). *Explicit inclusion of topic specific knowledge for teaching and the development of PCK in pre-service science teachers.*

Mavhunga, & Rollnick, M. (2013). Improving PCK of chemical equilibrium in pre-service teachers. *African Journal of Research in Mathematics, Science and Technology Education, 17*(1-2), 113-125.

Mavhunga, & Rollnick, M. (2016). Teacher-or Learner-Centred? Science Teacher Beliefs Related to Topic Specific Pedagogical Content Knowledge: A South African Case Study. *Research in Science Education, 46*(6), 831-855.

McKernan, J. (2013). Curriculum Action Research. A Handbook of Methods and Resources for the Reflective Practitioner. London: Kogan Publishers

McNiff, J. (2013) Action research: Principles and practice. London: Routledge

Morrison, G. R., Ross, S. J., Morrison, J. R., & Kalman, H. K. (2019). *Designing effective instruction*. Hoboken: Wiley.

Mphathiwa, L. (2016). *An investigation into the topic specific pedagogical content knowledge of Botswana social studies teachers: the case of'water resources and their management'.*

Mthethwa-Kunene, E., Onwu, G. O., & de Villiers, R. (2015). Exploring biology teachers' pedagogical content knowledge in the teaching of genetics in Swaziland science classrooms. *International Journal of Science Education, 37*(7), 1140-1165.

Muijs, D., & Reynolds, D. (2017). *Effective teaching: Evidence and practice*. London:Paul Chapman

Nahum, T. L., Hofstein, A., Mamlok-Naaman, R., & Ziva, B.-D. (2004). Can final examinations amplify students'misconceptions in chemistry? *Chemistry Education Research and Practice, 5*(3), 301-325.

Nesrullajev, A. (2016). Thermotropic, refracting and birefringent properties in homogeneous mixtures of 4-n-alkyl-4′-cyanobiphenyl mesogens. *Journal of Molecular Liquids, 215*, 503-511.

Neville, H. A. D., & Newman, L. F. (2000). *Science Progress*. Retrieved from London:

Nezamzadeh-Ejhieh, A., & Zabihi-Mobarakeh, H. (2014). Heterogeneous photodecolorization of mixture of methylene blue and bromophenol blue using CuO-nano-clinoptilolite. *Journal of Industrial and Engineering Chemistry, 20*(4), 1421-1431.

Nichols, J. (2019). Investigating the Effects of Agricultural Education on Student Achievement among Students in Tift County High School: A Quantitative Study. *Journal of Agricultural Education, 7*(3), 22-55.

Nicoll, G. (2010). A report of undergraduates' bonding misconceptions. *International Journal of Science Education, 23*(7), 707-730.

Nikolić, G., & Marković, D. (2015). Misconceptions about nutritional supplements and modern diseases. *HRANA U ZDRAVLJU I BOLESTI, 4*(1), 34-47.

Nixon. (2015). *Knowing Science Like a Teacher: An exploration of the Content knowledge of new science teachers.* University of Georgia, Georgia.

Nixon, Campbell, B. K., & Luft, J. A. (2016). Effects of subject-area degree and classroom experience on new chemistry teachers' subject matter knowledge. *International Journal of Science Education, 38*(10), 1636-1654.

Njoku, Z. (2004). *Fostering the application of science education research findings in Nigerian classrooms; strategies and need for teachers' professional development.* Paper presented at the STAN proceedings of the 45th Annual Conference.

Nortvedt, G. A., & Buchholtz, N. (2018). Assessment in mathematics education: responding to issues regarding methodology, policy, and equity. *ZDM, 7*(1), 1-16.

O'Dwyer, A., & Childs, P. (2011). *Second level Irish pupils' and teachers' view of difficulties in organic chemistry.* Paper presented at the IOSTE Mini-Symposium.

O'Dwyer, A., & Childs, P. (2014). Organic Chemistry in Action! Developing an Intervention Program for Introductory Organic Chemistry To Improve Learners' Understanding, Interest, and Attitudes. *Journal of Chemical Education, 91*(7), 987-993.

Oberem, P. T., Adu-Damoah, E., & Mbatha, P. (2011). *Via Afrika Agricultural Sciences*.

Olaleye, B. O. (2012). Enhancing teachers' knowledge for using multiple representations in teaching chemistry in Nigerian senior secondary schools. *Journal of Science Education, 7*(1), 2-55.

Oliveira, C., Lopes, J., & Spear-Swerling, L. (2019). Teachers' academic training for literacy instruction. *European Journal of Teacher Education, 6*(2), 1-20.

Combinatorial Chemistry Online Volume 10, Issue 12, December 2008. (2008). *Combinatorial Chemistry - An Online Journal*, *10*(12), 47-50. doi: 10.1016/j.comche.2008.11.001

Özmen, H. (2004). Some student misconceptions in chemistry: A literature review of chemical bonding. *Journal of Science Education and Technology, 13*(2), 147-159.

Özmen, H. (2014). Some student misconceptions in chemistry: A literature review of chemical bonding. *Journal of Science Education and Technology, 13*(2), 147-159.

Pabuçcu, A., & Geban, Ö. (2013). Remediating misconceptions concerning chemical bonding throuh conceptual change text. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 30*(30), 184-192.

Padsalgikar, A. (2017). *Plastics in Medical Devices for Cardiovascular Applications*: William Andrew.

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education*, *38*(3), 261-284.

Patel, D., & Chakraborty, N. (2016). Effects of fuel Lewis number on localised forced ignition of turbulent homogeneous mixtures: A numerical investigation. *International Journal of Spray and Combustion Dynamics, 8*(3), 183-196.

Pathiraja, D., Kim, K. H., & Choi, I.-G. (2017). Rapid and robust enzymatic sensing and quantitation of 3, 6-Anhydro-L-galactose in a heterogeneous sugar mixture. *Carbohydrate Research, 446*, 13-18.

Pendur, G. (2012). Prospective Science Teachers' Misconceptions in Organic Chemistry: The Case of Alkenes. *Journal of Turkish Science Education, 9*(3).

Pérez, Pérez, Calatayud, García-Lopera, & Sabater. (2017). Student’s Misconceptions on Chemical Bonding: a Comparative Study Between High School and First Year University Students. *Asian Journal of Education and e-Learning (ISSN: 2321–2454)*, *5*(1), 1-16.

Perry, D. L. (2016). *Handbook of inorganic compounds*: CRC press.

Peters, K. E., Walters, C. C., & Moldowan, J. M. (2005). *The biomarker guide* (Vol. 1): Cambridge University Press. Cambridge

Poehner, M. E., Zhang, J., & Lu, X. (2015). Computerized dynamic assessment (C-DA): Diagnosing L2 development according to learner responsiveness to mediation. *Language Testing, 32*(3), 337-357.

Polikanov, Y. S., Steitz, T. A., & Innis, C. A. (2014). A proton wire to couple aminoacyl-tRNA accommodation and peptide-bond formation on the ribosome. *Nature structural & Molecular Biology, 21*(9), 787-793.

Prain, V., & Waldrip, B. (2006). An exploratory study of teachers’ and students’ use of multi-modal representations of concepts in primary science. *International Journal of Science Education, 28*(15), 1843-1866.

Raker J. R., (2011), *Connecting scientific research and classroom instruction: developing authentic problem sets for the undergraduate organic chemistry curriculum,* Doctoral dissertation, Purdue University, West Lafayette, Indiana

Rehman, R., Ahmed, K., Rehan, R., Hassan, F., & Syed, F. (2016). Learning approaches and performance of medical students. *J Pak Med Assoc, 66*(2), 198-202.

Retnawati, H., Hadi, S., & Nugraha, A. C. (2016). Vocational High School Teachers' Difficulties in Implementing the Assessment in Curriculum 2013 in Yogyakarta Province of Indonesia. *International Journal of Instruction, 9*(1), 33-48.

Rice, A. H., & Kitchel, T. (2015a). Preservice Agricultural Education Teachers' Experiences in and Anticipation of Content Knowledge Preparation. *Journal of Agricultural Education, 56*(3), 90-104.

Rice, A. H., & Kitchel, T. (2015b). The Relationship between Agriculture Knowledge Bases for Teaching and Sources of Knowledge. *Journal of Agricultural Education, 56*(4), 154-169.

Rice, A. H., & Kitchel, T. (2015c). The Relationship between Agriculture Knowledge Bases for Teaching and Sources of Knowledge. *Journal of Agricultural Education, 56*(4), 153-168.

Robson, C, & McCartan, K. (2016). Real world research: a resource for users of social research methods in applied settings. Chichester: Wiley.
Roche, A. (2013). *Evaluation of a targeted intervention method for concept formation in chemical bonding.* MSc Dissertation, University of Pretoria, Pretoria, South Africa.
Rollnick, M., Bennett, J., Rhemtula, M., Dharsey, N., & Ndlovu, T. (2008). The place of subject matter knowledge in pedagogical content knowledge: A case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education, 30*(10), 1365-1387.
Rollnick, M., & Mavhunga, E. (2014). PCK of teaching electrochemistry in chemistry teachers: A case in Johannesburg, Gauteng Province, South Africa. *Educación Química, 25*(3), 354-362.
Rollnick, M., & Mavhunga, E. (2016). Can the principles of topic-specific PCK be applied across science topics? Teaching PCK in a pre-service programme *Insights from research in science teaching and learning* (pp. 59-72): Springer.
Roundhill, D. M., & Fackler Jr, J. P. (2013). *Optoelectronic properties of inorganic compounds*: Springer Science & Business Media.
Rowles, C. J., & Brigham, C. (2005). Strategies to promote critical thinking and active learning. *Teaching in Nursing: A guide for faculty, 2*, 283-315.
Rule, P., & John, V. (2011). *Case Study Research* (J. Read Ed. 1 ed.). Hatfield, Pretoria: Van Schaik Publishers
Russo, E. B. (2017). Cannabidiol claims and misconceptions. *Trends in pharmacological sciences, 38*(3), 198-201.
Ryan, N., Campbell, B. K., & Luft, J. A. (2016). Effects of subject-area degree and classroom experience on new chemistry teachers' subject matter knowledge. *International Journal of Science Education, 38*(10), 1636-1654.
Sağır, Ş. U., & Küçükaydın, M. A. (2016). Loughran, J., Berry, A. and Mulhall, P.(2012). Understanding and Developing Science Teachers' Pedagogical Content Knowledge. *İlköğretim Online, 15*(1).
Sani, S. M., Bichi, A. B., & Ayuba, S. (2016). Artificial Intelligence Approaches in Student Modeling: Half Decade Review (2010-2015). *IJCSN-International Journal of Computer Science and Network, 5*(5).
Santrock JW (2007) Biological beginnings. In: Santrock JW, ed.A Topical Approach to Life-Span Development, pp. 69–70.
Sarma, S. K. (2015). Qualitative research: Examining the misconceptions. *South Asian Journal of Management, 22*(3), 176.
Scanlon, V. C., & Sanders, T. (2014). *Essentials of anatomy and physiology*: FA Davis.
Schaefer, D., Spiess, H., Suter, U., & Fleming, W. (1990). Two-dimensional solid-state NMR studies of ultraslow chain motion: glass transition in atactic poly (propylene) versus helical jumps in isotactic poly (propylene). *Macromolecules, 23*(14), 3431-3439.
Schwarzenbach, R. P., Gschwend, P. M., & Imboden, D. M. (2016). *Environmental Organic Chemistry* (2 ed.). New Jersey: John Wiley & Sons.
ŞEndur, G. g. s. d. e. t., & Toprak, M. (2013). Öğretmen Adaylarının Organik Kimya Konularındaki Anlama Düzeylerinin ve Kavram Yanılgılarının Bir Analizi: Alkoller Örneği. (Turkish). *An Analysis of Prospective Teachers' Understanding Levels and Misconceptions in The Subjects of Organic Chemistry: The Case of Alcohols. (English), 7*(1), 264-301. doi:10.12973/nefmed162
Seven, E., Horoz, U., Sarı, E., Özakpınar, H. R., Sandıkcı, M. M., İnözü, E., & Tellioğlu, A. T. (2017). A rare type of burn injury due to butane gas inhalation. *Ulus Travma Acil Cerrahi Derg, 23*(3), 212-216.
Sharp, R. and Green, A. (2017), Education and Social Control: A Study in Progressive Primary Education. London: Routledge & Kegan Paul.

Sheehan, M., Childs, P. E., & Hayes, S. (2011). *Pre-service irish science teachers'misconceptions of chemistry.* Paper presented at the ESERA Conference Proceedings.
Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for information, 22*(2), 63-75.
Shin, J.-Y., Lee, T., & Ouarda, T. B. (2015). Heterogeneous mixture distributions for modeling multisource extreme rainfalls. *Journal of Hydrometeorology, 16*(6), 2639-2657.
Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational researcher, 15*(2), 4-14.
Sibanda, D. (2013). *How Teachers Construct Teaching-learning Sequences in Chemistry Education in the Further Education and Training Phase.* Unpublished PhD, University of KwaZulu-Natal, Durban.
Siemens, G. (2014). Connectivism: A learning theory for the digital age. e-Learning Library. Retrieved from htt://er.dut.ac.za/handle/123456789/69
Silverman, L. K., Leviton, L. P., & Haas, S. C. (2015). Engaging Different Types of Gifted Learners *Applied Practice for Educators of Gifted and Able Learners* (pp. 25-41). London: Springer.
Sime-Ngando, T., Gerphagnon, M., Colombet, J., Jobard, M., Lefevre, E., Monchy, S., . . . Amblard, C. (2016). Molecular Diversity Studies in Lake Pavin Reveal the Ecological Importance of Parasitic True Fungi in the Plankton *Lake Pavin* (pp. 329-343). London: Springer.
Simkins, P. C. (2010). Maths and Science Performance of South Africa's public schools.
Somers, J. L. (2013). *Using concept maps to explore preservice teachers' perceptions of science content knowledge, teaching practices, and reflective processes*: Florida Atlantic University.
Stevenson, M. P., Hartmeyer, R., & Bentsen, P. (2017). Systematically reviewing the potential of concept mapping technologies to promote self-regulated learning in primary and secondary science education. Educational Research Review, 21,1e16.http://dx.doi.org/10.1016/j.edurev.2017.02.002.
Stringer, E. (2013). Action Research in Education (2nd ed.). Upper Saddle River, NJ: Pearson/Merrill/Prentice Hall.
Sun, S.-P., Chan, S.-Y., & Chung, T.-S. (2015). A slow–fast phase separation (SFPS) process to fabricate dual-layer hollow fiber substrates for thin-film composite (TFC) organic solvent nanofiltration (OSN) membranes. *Chemical Engineering Science, 129*, 232-242.
Suskie, L. (2018). *Assessing student learning: A common sense guide* (4 ed.). New Jersey: John Wiley & Sons.
Taber, K. S. (2009). Student understanding of ionic bonding: molecular versus electrostatic framework? *School Science Review, 78*(285), 85-95.
Tan, C. (2015). Beyond rote-memorisation: Confucius' concept of thinking. *Educational Philosophy and Theory, 47*(5), 428-439.
Tan, P. L. (2011). Towards a culturally sensitive and deeper understanding of "rote learning" and memorisation of adult learners. *Journal of Studies in International Education, 15*(2), 124-145.
Tingas, E. A., Kyritsis, D. C., & Goussis, D. A. (2015). Autoignition dynamics of DME/air and EtOH/air homogeneous mixtures. *Combustion and Flame, 162*(9), 3263-3276.
Torosantucci, R., Schöneich, C., & Jiskoot, W. (2014). Oxidation of therapeutic proteins and peptides: structural and biological consequences. *Pharmaceutical Research, 31*(3), 541-553.
Tsaparlis, G., Pappa, E. T., & Byers, B. (2018). Teaching and learning chemical bonding: research-based evidence for misconceptions and conceptual difficulties experienced by students in upper secondary schools and the effect of an enriched text. *Chemistry Education Research and Practice, 19*(4), 1253-1269.
Turi, J. A., Ghani, M. F. A., Javid, Y., & Sorooshian, S. (2017). Teacher's instructional strategies to support slow learners in selected schools, the islamic republic of pakistan. *O-JIE: Online Journal of Islamic Education, 5*(2).

Omwirhiren, E.M., & Ubanwa, A. O. (2016). An analysis of misconceptions in organic chemistry among selected senior secondary school students in Zaria local government area of Kaduna state, Nigeria. *International Journal of Education and Research, 4*(7), 247-266.
Uce, M. (2015). Constructing models in teaching of chemical bonds: Ionic bond, covalent bond, double and triple bonds, hydrogen bond and molecular geometry. *Educational Research and Reviews, 10*(4), 491.
Van Driel, Berry, & Meirink. (2014). Research on science teacher knowledge *Handbook of Research on Science Education, Volume II* (4 ed., pp. 862-884). Prentice Hall, Routledge.
Van Driel, Jong, O. D., & Verloop, N. (2002). The development of preservice chemistry teachers' pedagogical content knowledge. *Science Education, 86*(4), 572-590.
Van Driel, Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching, 35*(6), 673-695.
Varma, S., Bhasker, S., Manhas, L., Grover, U., & Phalachandra, B. (2017). Unit-7 Understanding the Problems of Slow Learners: IGNOU.
Vavrus, F., Thomas, M., & Bartlett, L. (2011). *Ensuring quality by attending to inquiry: Learner-centered pedagogy in sub-Saharan Africa*: UNESCO-IICBA Addis Ababa, Éthiopie.
Vosloo, J. J. (2015). Research Design And Methodology (pp. 299-353). Western Cape: University of Western Cape.
Vossen, T., Henze, I., De Vries, M., & Van Driel, J. (2019). Finding the connection between research and design: the knowledge development of STEM teachers in a professional learning community. *International Journal of Technology and Design Education*, 1-26.
Wael, A., Asnur, M. N. A., & Ibrahim, I. (2018). Exploring students'learning strategies in speaking performance. *International Journal of Language Education, 2*(1), 65-71.
Wang, H., Blaszczyk, S., Xiao, G., & Tang, W. (2018). Chiral reagents in glycosylation and modification of carbohydrates. *Chemical Society Reviews*, *47*(3), 681-701.
Warrican, S. J. (2006). Action research: A viable option for effecting change. *Journal of Curriculum Studies, 38*(1), 1-14.
Weimer, M. (2002) Learner-centred Teaching: Five Key Changes to Practice, San Francisco, CA: Jossey-Bass
Whitworth, B. A., & Chiu, J. L. (2015). Professional development and teacher change: The missing leadership link. *Journal of Science Teacher Education, 26*(2), 121-137.
Widodo, A. (2017). *Teacher Pedagogical Content Knowledge (PCK) and Students' Reasoning and Wellbeing.* Paper presented at the Journal of Physics: Conference Series.
Wu G (2013) Amino acids: biochemistry and nutrition. CRC Press, Boca Raton, Florida
Yang, K., & Xing, B. (2010). Adsorption of organic compounds by carbon nanomaterials in aqueous phase: Polanyi theory and its application. *Chemical Reviews, 110*(10), 5989-6008.
Yue, W., Sun, W., Rao, R. S. P., Ye, N., Yang, Z., & Chen, M. (2019). Non-targeted metabolomics reveals distinct chemical compositions among different grades of Bai Mudan white tea. *Food Chemistry*, *277*(2), 289-297.
Zeichner, K., & Liston, D. (1987). Teaching student teachers to reflect. *Harvard Educational Review, 57*(1), 23-49.

APPENDICES

APPENDIX A

Dear Principal

INFORMED CONSENT LETTER FOR PRINCIPAL

I am Pasika Patrick Mbono, a Masters student studying at the University of KwaZulu-Natal, South Africa. I am fascinated in Exploring grade 11 Agricultural Science Teacher's Topic-Specific Pedagogical Content Knowledge in Teaching Organic Compounds a special topic in Basic Agricultural Chemistry. This research is significant as it will provide information about the way content knowledge is transferred, I would like to kindly request to work with 1 Agricultural science teacher in your school for the purpose of this research which will benefit your school and the community. The interview should be 40 minutes long and we can hold the interview session in a conducive environment and cannot disturb the teacher-daily duties.

Please note that:

- In this study, your teachers' confidentiality is my first priority and their input will be used in this study and for the purpose of this study only.
- The interview is estimated to take about 40 minutes of your time
- Any information given by them cannot be used against them and the school, and the collected data will be used for purposes of this research only.
- The collected data will be combined and be stored in a locked container for 5 years and be destroyed completely.
- During the interview, your teachers will be allowed to proceed participating, may withdraw, or not participate, for such they will not be charged of any trespass.
- Their involvement is purely for academic purposes only, and there are no financial benefits involved.

I can be contacted at:

Email: mbonocomprehensive@gmail.com

Cell: 0787124887/ 063 6229246

My supervisor is Dr. N. Govender who is located at the School of education, at the University of KwaZulu-Natal. You can contact him at:

Email: Govendern37@ukzn

Phone: 031 2603469

You may also contact the Research Office through:

P. Mohun

HSSREC Research Office,

Tel: 031 260 4557 E-mail: mohunp@ukzn.ac.za

Thank you for your participation in this research.

DECLARATION

I……………………………………………………………………………… (Full names of principal) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent Mr/Miss/Mrs to participate in the research project.

PRINCIPALS' SIGNATURE DATE

………………………………………… ………/……………/……………

APPENDIX B

Dear Teacher

INFORMED CONSENT LETTER FOR TEACHERS

My name is Pasika Patrick Mbono a Masters student studying at the University of KwaZulu-Natal, South Africa. I am interested in Exploring grade 11 Agricultural Science Teacher's Topic-Specific Pedagogical Content Knowledge in Teaching Organic Compounds a special topic in Basic Agricultural Chemistry. This research is significant as it will provide information about the way content knowledge is transferred, I would like to ask you some questions, by interviewing you. The interview should be 45 minutes long and we can hold the interview session in a conducive environment.

Please note that:

- In this study, your confidentiality is my first priority and your input will be used in this study and for the purpose of this study only.
- The interview is estimated to take about 40 minutes of your time
- Any information given by you cannot be used against you, and the collected data will be used for purposes of this research only.
- The collected data will be combined and be stored in a locked for 5 years and be destroyed completely.
- In this study you may proceed participating, you may withdraw or not participate, for such you will not be charged of any trespass.
- Your involvement is purely for academic purposes only, and there are no financial benefits involved.
- If you are willing to be interviewed, please indicate (by ticking as applicable) whether or not you are willing to allow the interview to be recorded by the following equipment:

	Willing	Not willing
Audio equipment		
Photographic equipment		
Video equipment		

I can be contacted at:

Email: mbonocomprehensive@gmail.com

Cell: 0787124887/ 063 6229246

My supervisor is Dr. N. Govender who is located at the School of education, at the University of KwaZulu-Natal. You can contact him at:

Email: Govendern37@ukzn

Phone: 031 2603469

You may also contact the Research Office through:

P. Mohun

HSSREC Research Office,

Tel: 031 260 4557 E-mail: mohunp@ukzn.ac.za

Thank you for your participation in this research.

DECLARATION

I………………………………………………………………………… (Full names of participant) hereby confirm that I understand the contents of this

document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire. I give/ do not give (delete that which is not applicable) permission for the interview to be digitally recorded.

SIGNATURE OF PARTICIPANT DATE

……………………………………… …………………………………

APPENDIX C

Yellowwood

Flat: 2: room Y72

University of KwaZulu Natal

Edgewood Campus

3605

Department of education

Eastern Cape

Steve Vukile Tshwethe

Biosho

Zone 6

Zwelitsha

Dear HOD

INFORMED CONSENT LETTER FOR EC DEPARTMENT OF EDUCATION

I am Pasika Patrick Mbono, a Masters student studying at the University of KwaZulu-Natal, South Africa. I am fascinated in Exploring grade 11 Agricultural Science Teacher's Topic-Specific Pedagogical Content Knowledge in Teaching Organic Compounds a special topic in Basic Agricultural Chemistry. This research is significant as it will provide information about the way content knowledge is transferred, I would like to kindly request your permission to conduct my study at Libode district and work with 3 Agricultural science teachers in 3 schools for the purpose of this research which may also benefit your schools and the country in the long run. The interview should be 40 minutes long and we can hold the interview session in a conducive environment and cannot disturb the teacher-daily duties.

Please note that:

- In this study, your teachers' confidentiality is my first priority and their input will be used in this study and for the purpose of this study only.
- The interview is estimated to take about 40 minutes of your time
- Any information given by them cannot be used against them and the school, and the collected data will be used for purposes of this research only.
- The collected data will be combined and be stored in a locked container for 5 years and be destroyed completely.
- During the interview, your teachers will be allowed to proceed participating, may withdraw, or not participate, for such they will not be charged of any trespass.
- Their involvement is purely for academic purposes only, and there are no financial benefits involved.

I can be contacted at:

Email: mbonocomprehensive@gmail.com

Cell: 0787124887/ 063 6229246

My supervisor is Dr. N. Govender who is located at the School of education, at the University of KwaZulu-Natal. You can contact him at:

Email: Govendern37@ukzn

Phone: 031 2603469

You may also contact the Research Office through:

P. Mohun

HSSREC Research Office,

Tel: 031 260 4557 E-mail: mohunp@ukzn.ac.za

Thank you for your participation in this research.

DECLARATION

I……………………………………………………………………… (Full names of Head of Department) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent this study must be carried out.

DEPARTMENTAL SIGNATURE DATE

……………………………………… ………/……………/……………

APPENDIX D: Interview Guide for a Teacher

What is your educational qualification?

- Meaning: Bachelors' degree or diploma or higher certificate?

Which major subjects did you do at the higher institution, And up to what level?

Did you do any content in chemistry either at high school level or higher institution?

- If yes, does it help you in teaching Agricultural science chemistry section? And

Since Agricultural sciences has got this chemistry section, how do you feel about the inclusion of this section?

Are there any problems you face in teaching this section? For example, there are alternative conceptions that:

- Organic compounds are soluble in water and can melt and boil faster
- Chemical bonding is bonding through physical means etc.

Are you aware of any other alternative conceptions that your learners exhibit in organic compounds? If yes, what examples of alternative conceptions do your learners have on this topic?

- ➢ If any alternative conceptions in this chemistry section, how do you come about solving them?
- ➢ Are your effort of any success? And how do you see that they were successful in addressing learners' misconception?

- **Learners' prior knowledge**

What alternative conceptions do your learners normally hold in basic agricultural chemistry?

For example: They normally confuse organic and inorganic compounds

Normally confuse the structural formula of an organic compound shows every bond between every atom in the molecule. Each bond is represented by a line.

What misconception do they normally hold in organic compounds?

- **Curriculum saliency**

In teaching basic agricultural chemistry organic compounds, what are the big ideas about this topic (how is it structured?)

What is your purpose for learners to know about this topic?

Why is it important for learners to know this?

In the curriculum, what is the arrangement of this section, in terms of the concepts taught?

What concepts for this section needs to be taught before teaching this topic

Is there any information you have about this topic that you do not want your learners to know as yet?

- **What is easy or difficulty to teaching this topic**

What do you consider as easy or difficult in teaching this section? And why do you think so?

What difficulties do you face when teaching this topic?

For instance: is it easy to represent chemical formula of a compound or difficult

- **Learner's pre-and misconception**

What are distinctive learner's misconception in this topic? For example:

- Basically, a common mistake is to assume that the difference between inorganic and organic compounds is whether or not a substance contains carbon. Diamond is pure carbon, yet is inorganic. Carbon dioxide contains carbon and oxygen, both elements associated with life, yet it is an inorganic compound. Why is this a misconception?
- In one group of organic compounds called the hydrocarbons, the single, double and triple bonds of the alkanes, alkenes and alkynes are not examples of functional groups

- **Conceptual teaching strategies**

What effective teaching strategies do you use to teaching this chemistry section?

Are there any types of questions you consider important when teaching this section?

- **Representations**

What representations do you use in supplementing the teaching strategies? For example:

Any objects or taking of learners through videos or pictures?

Appendix E

Province of the
EASTERN CAPE
EDUCATION

STRATEGIC PLANNING POLICY RESEARCH AND SECRETARIAT SERVICES
Steve Vukile Tshwete Complex • Zone 6 • Zwelitsha • Eastern Cape
Private Bag X0032 • Bhisho • 5605 • REPUBLIC OF SOUTH AFRICA
Tel: +27 (0)40 608 4773/4035/4537 • Fax: +27 (0)40 608 4574 • Website: www.ecdoe.gov.za

Enquiries: B Pamla   Email: babalwa.pamla@ecdoe.gov.za   Date: 08 May 2017

Mr. Pasika Patrick Mbono

Flat 2 Room Y72

University of Kwa-Zulu Natal

Edgewood Campus

Dear Mr. Mbono

PERMISSION TO UNDERTAKE A MASTERS THESIS: EXPLORING GRADE 11 AGRICULTURAL SCIENCE TEACHERS' TOPIC SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE IN TEACHING ORGANIC COMPOUNDS – ACTION RESEARCH OF SELECTED SCHOOLS IN LIBODE

1. Thank you for your application to conduct research.

2. Your application to conduct the above mentioned research in three selected Secondary Schools under the jurisdiction of OR Tambo Coastal Education District of the Eastern Cape Department of Education (ECDoE) is hereby approved based on the following conditions:

   a. there will be no financial implications for the Department;

   b. institutions and respondents must not be identifiable in any way from the results of the investigation;

   c. you present a copy of the written approval letter of the Eastern Cape Department of Education (ECDoE) to the Cluster and District Directors before any research is undertaken at any institutions within that particular district;

   d. you will make all the arrangements concerning your research;

   e. the research may not be conducted during official contact time;

   f. should you wish to extend the period of research after approval has been granted, an application to do this must be directed to Chief Director: Strategic Management Monitoring and Evaluation;

building blocks for growth

PGDP EASTERN CAPE

Ilumro elupuedinyo!

g. your research will be limited to those institutions for which approval has been granted, should changes be effected written permission must be obtained from the Chief Director: Strategic Management Monitoring and Evaluation;

h. you present the Department with a copy of your final paper/report/dissertation/thesis free of charge in hard copy and electronic format. This must be accompanied by a separate synopsis (maximum 2 – 3 typed pages) of the most important findings and recommendations if it does not already contain a synopsis.

i. you present the findings to the Research Committee and/or Senior Management of the Department when and/or where necessary.

j. you are requested to provide the above to the Chief Director: Strategic Management Monitoring and Evaluation upon completion of your research.

k. you comply with all the requirements as completed in the Terms and Conditions to conduct Research in the ECDoE document duly completed by you.

l. you comply with your ethical undertaking (commitment form).

m. You submit on a six monthly basis, from the date of permission of the research, concise reports to the Chief Director: Strategic Management Monitoring and Evaluation

3. The Department reserves a right to withdraw the permission should there not be compliance to the approval letter and contract signed in the Terms and Conditions to conduct Research in the ECDoE.

4. The Department will publish the completed Research on its website.

5. The Department wishes you well in your undertaking. You can contact the Director, Ms. NY Kanjana on the numbers indicated in the letterhead or email babalwa.pamla@ecdoe.gov.za should you need any assistance.

NY KANJANA
DIRECTOR: STRATEGIC PLANNING POLICY RESEARCH & SECRETARIAT SERVICES

FOR SUPERINTENDENT-GENERAL: EDUCATION

Appendix F

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

INFORMED CONSENT LETTER FOR TEACHER

Dear Teacher

My name is Pasika Patrick Mbono a Masters student studying at the University of KwaZulu-Natal, South Africa. I am interested in Exploring grade 11 Agricultural Science Teacher's Topic-Specific Pedagogical Content Knowledge in Teaching Organic Compounds a special topic in Basic Agricultural Chemistry. This research is significant as it will provide information about the way content knowledge is transferred, I would like to ask you some questions, by interviewing you. The interview should be 45 minutes long and we can hold the interview session in a conducive environment.

Please note that:

- In this study, your confidentiality is my first priority and your input will be used in this study and for the purpose of this study only.
- The interview is estimated to take about 40 minutes of your time
- Any information given by you cannot be used against you, and the collected data will be used for purposes of this research only.
- The collected data will be combined and be stored in a locked for 5 years and be destroyed completely.
- In this study you may proceed participating, you may withdraw or not participate, for such you will not be charged of any trespass.
- Your involvement is purely for academic purposes only, and there are no financial benefits involved.
- If you are willing to be interviewed, please indicate (by ticking as applicable) whether or not you are willing to allow the interview to be recorded by the following equipment:

	Willing	Not willing
Audio equipment		✓
Photographic equipment	✓	
Video equipment		✓

I can be contacted at: Email: mbonocomprehensive@gmail.com Cell: 0787124887/ 063 6229246

My supervisor is Dr. N. Govender who is located at the School of Education, at the University of KwaZulu-Natal. You can contact him at: Email: Govendern37@ukzn Phone: 031 2603469

You may also contact the Research Office through:

P. Mohun
HSSREC Research Office,

Tel: 031 260 4557 E-mail: mohunp@ukzn.ac.za

Thank you for your participation in this research.

DECLARATION

I...JAMI JAM GCINIBANDLA H...(full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire. I give/ do not give (delete that which is not applicable) permission for the interview to be digitally recorded.

SIGNATURE OF PARTICIPANT **DATE**

.... 07 - 06 - 2017..........................

BHEKIZULU SEN. SEC. SCHOOL
P.O. Box 243 - LIBODE
Principal:..........................
Date: 07 - 06 - 2017

APPENDIX 2

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

INFORMED CONSENT LETTER FOR TEACHER

Dear Teacher

My name is Pasika Patrick Mbono a Masters student studying at the University of KwaZulu-Natal, South Africa. I am interested in Exploring grade 11 Agricultural Science Teacher's Topic-Specific Pedagogical Content Knowledge in Teaching Organic Compounds a special topic in Basic Agricultural Chemistry. This research is significant as it will provide information about the way content knowledge is transferred, I would like to ask you some questions, by interviewing you. The interview should be 45 minutes long and we can hold the interview session in a conducive environment.

Please note that:

- In this study, your confidentiality is my first priority and your input will be used in this study and for the purpose of this study only.
- The interview is estimated to take about 40 minutes of your time
- Any information given by you cannot be used against you, and the collected data will be used for purposes of this research only.
- The collected data will be combined and be stored in a locked for 5 years and be destroyed completely.
- In this study you may proceed participating, you may withdraw or not participate, for such you will not be charged of any trespass.
- Your involvement is purely for academic purposes only, and there are no financial benefits involved.
- If you are willing to be interviewed, please indicate (by ticking as applicable) whether or not you are willing to allow the interview to be recorded by the following equipment:

	Willing	Not willing
Audio equipment	✓	
Photographic equipment	✓	
Video equipment	✓	

I can be contacted at: Email: mbonocomprehensive@gmail.com Cell: 0787124887/ 063 6229246

My supervisor is Dr. N. Govender who is located at the School of Education, at the University of KwaZulu-Natal. You can contact him at: Email: Govendern37@ukzn Phone: 031 2603469

You may also contact the Research Office through:

P. Mohun
HSSREC Research Office,
Tel: 031 260 4557 E-mail: mohunp@ukzn.ac.za

Thank you for your participation in this research.

DECLARATION

I KATISO Mosimoa .... (full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any time, should I so desire. I give/ do not give (delete that which is not applicable) permission for the interview to be digitally recorded.

SIGNATURE OF PARTICIPANT	DATE
[signature]	07/06/2017

DEPARTMENT OF EDUCATION
CHIEF HENRY BOKLENI S.S.S
DATE : 07/06/2017
SIGNATURE : [signature]

APPENDIX 2

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

INFORMED CONSENT LETTER FOR TEACHER

Dear Teacher

My name is Pasika Patrick Mbono a Masters student studying at the University of KwaZulu-Natal, South Africa. I am interested in Exploring grade 11 Agricultural Science Teacher's Topic-Specific Pedagogical Content Knowledge in Teaching Organic Compounds a special topic in Basic Agricultural Chemistry. This research is significant as it will provide information about the way content knowledge is transferred, I would like to ask you some questions, by interviewing you. The interview should be 45 minutes long and we can hold the interview session in a conducive environment.

Please note that:

- In this study, your confidentiality is my first priority and your input will be used in this study and for the purpose of this study only.
- The interview is estimated to take about 40 minutes of your time
- Any information given by you cannot be used against you, and the collected data will be used for purposes of this research only.
- The collected data will be combined and be stored in a locked for 5 years and be destroyed completely.
- In this study you may proceed participating, you may withdraw or not participate, for such you will not be charged of any trespass.
- Your involvement is purely for academic purposes only, and there are no financial benefits involved.
- If you are willing to be interviewed, please indicate (by ticking as applicable) whether or not you are willing to allow the interview to be recorded by the following equipment:

	Willing	Not willing
Audio equipment	✓	
Photographic equipment	✓	
Video equipment	✓	

I can be contacted at: Email: mbonocomprehensive@gmail.com Cell: 0787124887/ 063 6229246

My supervisor is Dr. N. Govender who is located at the School of Education, at the University of KwaZulu-Natal. You can contact him at: Email: Govendern37@ukzn Phone: 031 2603469

You may also contact the Research Office through:

P. Mohun
HSSREC Research Office,
Tel: 031 260 4557 E-mail: mohunp@ukzn.ac.za

You may also contact the Research Office through:

P. Mohun
HSSREC Research Office,
Tel: 031 260 4557 E-mail: mohunp@ukzn.ac.za

Thank you for your participation in this research.

DECLARATION

I.....SINDILE MAHAMBEHLALA..... **(full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.**

I understand that I am at liberty to withdraw from the project at any time, should I so desire. I give/ do not give (delete that which is not applicable) permission for the interview to be digitally recorded.

SIGNATURE OF PARTICIPANT ....

DATE ....

DEPARTMENT OF EDUCATION
SANDI S.S
POSTNET X 5013
EXECUTIVE SUITE 506, MTHATHA, 5099
DATE: 06/06/2017
HOD'S SIGN: ....

DEPARTMENT OF EDUCATION
SANDI S.S
POSTNET X 5013
EXECUTIVE SUITE 506, MTHATHA, 5099
DATE: 06/06/2017
HOD'S SIGN: ....

Appendix G

Province of the
EASTERN CAPE
EDUCATION

STRATEGIC PLANNING POLICY RESEARCH AND SECRETARIAT SERVICES
Steve Vukile Tshwete Complex • Zone 6 • Zwelitsha • Eastern Cape
Private Bag X0032 • Bhisho • 5605 • REPUBLIC OF SOUTH AFRICA
Tel: +27 (0)40 608 4773/4035/4537 • Fax: +27 (0)40 608 4574 • Website: www.ecdoe.gov.za

Enquiries: B Pamla Email: babalwa.pamla@ecdoe.gov.za Date: 08 May 2017

Mr. Pasika Patrick Mbono

Flat 2 Room Y72

University of Kwa-Zulu Natal

Edgewood Campus

Dear Mr. Mbono

PERMISSION TO UNDERTAKE A MASTERS THESIS: EXPLORING GRADE 11 AGRICULTURAL SCIENCE TEACHERS' TOPIC SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE IN TEACHING ORGANIC COMPOUNDS – ACTION RESEARCH OF SELECTED SCHOOLS IN LIBODE

1. Thank you for your application to conduct research.

2. Your application to conduct the above mentioned research in three selected Secondary Schools under the jurisdiction of OR Tambo Coastal Education District of the Eastern Cape Department of Education (ECDoE) is hereby approved based on the following conditions:

   a. there will be no financial implications for the Department;

   b. institutions and respondents must not be identifiable in any way from the results of the investigation;

   c. you present a copy of the written approval letter of the Eastern Cape Department of Education (ECDoE) to the Cluster and District Directors before any research is undertaken at any institutions within that particular district;

   d. you will make all the arrangements concerning your research;

   e. the research may not be conducted during official contact time;

   f. should you wish to extend the period of research after approval has been granted, an application to do this must be directed to Chief Director: Strategic Management Monitoring and Evaluation;

PGDP EASTERN CAPE 2004 - 2014

building blocks for growth

Ikamva eliqaqambileyo!

g. your research will be limited to those institutions for which approval has been granted, should changes be effected written permission must be obtained from the Chief Director: Strategic Management Monitoring and Evaluation;

h. you present the Department with a copy of your final paper/report/dissertation/thesis free of charge in hard copy and electronic format. This must be accompanied by a separate synopsis (maximum 2 – 3 typed pages) of the most important findings and recommendations if it does not already contain a synopsis.

i. you present the findings to the Research Committee and/or Senior Management of the Department when and/or where necessary.

j. you are requested to provide the above to the Chief Director: Strategic Management Monitoring and Evaluation upon completion of your research.

k. you comply with all the requirements as completed in the Terms and Conditions to conduct Research in the ECDoE document duly completed by you.

l. you comply with your ethical undertaking (commitment form).

m. You submit on a six monthly basis, from the date of permission of the research, concise reports to the Chief Director: Strategic Management Monitoring and Evaluation

3. The Department reserves a right to withdraw the permission should there not be compliance to the approval letter and contract signed in the Terms and Conditions to conduct Research in the ECDoE.

4. The Department will publish the completed Research on its website.

5. The Department wishes you well in your undertaking. You can contact the Director, Ms. NY Kanjana on the numbers indicated in the letterhead or email babalwa.pamla@ecdoe.gov.za should you need any assistance.

NY KANJANA
DIRECTOR: STRATEGIC PLANNING POLICY RESEARCH & SECRETARIAT SERVICES

FOR SUPERINTENDENT-GENERAL: EDUCATION

Appendix H

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

HIGHER DEGREES DISSERTATION/THESIS PROPOSAL REPORT FOR RESEARCH MASTERS AND PhD STUDENTS

(This report is to be completed by the appointed scribe or Postgraduate Administrator after the proposal panel has met and thereafter submitted to the Supervisor)

DATE OF ORAL PRESENTATION: 10 February 2017

NAMES OF CHAIRPERSON AND PANEL MEMBERS PRESENT:

Dr B Alant (Chairperson)
Dr A Singh-Pillay
Mr T Chirikure

In attendance administrator: **Philisiwe Ncayiyana**

STUDENT NAME: Mr Pasika Patrick Mbono

STUDENT NUMBER: 216057817

DEGREE: MED

DISCIPLINE: Curriculum Studies

SHORT DESCRIPTIVE TITLE. Exploring Grade 11 Agricultural Science Teachers' Topic-Specific Pedagogical Content Knowledge in Teaching Organic Compounds: An *Action*-Research Study of Selected Schools in Libode District

---

SUPERVISOR/S: Dr N Govender

ETHICAL CLEARANCE CODE:

GREEN: *No human subjects*

ORANGE: *Human subjects but research not of a sensitive nature*

RED: *Human subjects and research of a sensitive nature:*

Appendix I

Province of the
EASTERN CAPE
EDUCATION

GRADE 11

NOVEMBER 2016

AGRICULTURAL SCIENCES P1

MARKS: **150**

TIME: **2½ hours**

IAGRSE1

This question paper consists of pages.

INSTRUCTIONS AND INFORMATION

1. This question paper consists of TWO sections, namely SECTION A and SECTION B.

2. Answer ALL the questions in the ANSWER BOOK.

3. Start EACH question on a NEW page.

4. Read ALL the questions correctly and answer only what is asked.

5. Number the answers correctly according to the numbering system used in this question paper.

6. A non-programmable calculator may be used.

7. Show ALL your calculations, including formulae, where applicable and round off the answers to TWO decimal places.

8. Write neatly and legibly.

SECTION A

QUESTION 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A–D) next to the Question number (1.1.1–1.1.10) in the ANSWER BOOK, for example 1.1.11 A.

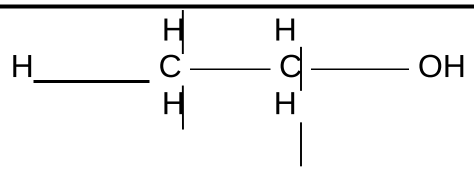
1.1.1 ... is a building block of a fat molecule.

A Glucose
B Amino acid
C Glycerol
D Lactose

1.1.2 The chemical substance consisting of one type of atom and cannot be broken down is a/an ...

A compound.
B mixture.
C atom.
D element.

1.1.3 The structure below represents the structural formula of an organic compound.



(i) It turns into vapour easily.
(ii) It is an excellent solvent in many industries.
(iii) It is used as a preservative.
(iv) It can be used as an alternative to petrol.

Choose the correct combination.

A (i), (iii) and (iv)
B (ii), (iii) and (iv)
C (i), (ii) and (iv)
D (i), (ii) and (iii)

1.1.4 The yellow colour in soil is an indication of … A signs of reduction in soil. B the presence of organic matter. C the presence of enough air and less water.

D signs of oxidation.

1.1.5 Horizons in the soil develop over time through the action of parent material and climate. The following statement characterises the E-horizon. A It has plenty of decayed organic matter. B It is a zone of leaching.

C It is sticky due to permanent waterlogging.

D It has unweathered material.

1.1.6 The illustration below shows an example of an inorganic colloid.

Silica sheet
Alumina sheet
Silica sheet

(i) It is sticky and expand quickly when exposed to water. (ii) It is an end product of weathering. (iii) It is grouped under spectates.

(iv) It has a higher absorption surface area.

Choose the correct combination.

A (i), (ii) and (iii)
B (i), (iii) and (iv)
C (ii), (iii) and (iv)
D (i), (ii) and (iv)

1.1.7 The reason for alkalinity in soil is the accumulation of ... ions in the soil.

A calcium and hydrogen
B sodium and aluminium
C magnesium and calcium
D potassium and sodium

1.1.8 The fungi that help plant roots to absorb more phosphorus through a symbiotic relationship is ... A mycorrhiza. B rhizobium. C azotobacter.

D clostridium.

1.1.9 The following is NOT influenced by soil temperature.

A Seed germination.
B Soil formation.
C Microbial action.
D Soil colour

1.1.10 The agricultural practice below lead to the destruction of structure.
A Introduction of pasture crop into crop rotation system. B Avoiding soil disturbances when it is wet.
C Continuous soil cultivation.
D Minimum tillage to preserve organic content of soil. (10 x 2) (20)

1.2 Indicate whether each of the following statements/items in COLUMN B applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the statements/ items in COLUMN A. Write **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** next to the question number (1.2.1–1.2.5) in the ANSWER BOOK, for example 1.2.6 B only.

COLUMN A			COLUMN B
1.2.1	A:	Anion	Atoms with more electrons
	B:	Cation	
1.2.2	A:	Valence electron	An outermost energy level of an atom
	B:	Valence shell	
1.2.3	A:	Adhesion	The attraction between molecules of the same kind
	B:	Cohesion	
1.2.4	A:	Soil horizon	Arrangement of soils into groups based on features
	B:	Soil profile	
1.2.5	A:	Salinity	Excess of chlorides and sulphates of sodium
	B:	White brack	

(5 x 2) (10)

1.3 Give ONE word/term for each of the following descriptions. Write only the word/term next to the question number (1.3.1–1.3.5) in the ANSWER BOOK.

1.3.1 The disaccharide formed when glucose bonds with fructose

1.3.2 The arrangement of elements according to their atomic number

1.3.3 A comparison between mass and volume of dried soil

1.3.4 The colour of soil with a number of flecks due to seasonal waterlogging

1.3.5 A condition of a substance having a higher concentration of hydroxyl than hydrogen ions (5 x 2) (10)

1.4 Change the UNDERLINED WORD(S) in each of the following statements to make them TRUE. Write only the answer next to the question number (1.4.1–1.4.5) in the ANSWER BOOK.

1.4.1 Polarity is the sharing of electrons by atoms.

1.4.2 The amount of water held in a well-drained soil is the wilting point.

1.4.3 B-horizon occurs in poorly aerated soil conditions.

1.4.4 Mineralisation is the conversion of nutrients from inorganic to organic in the bodies of micro-organisms.

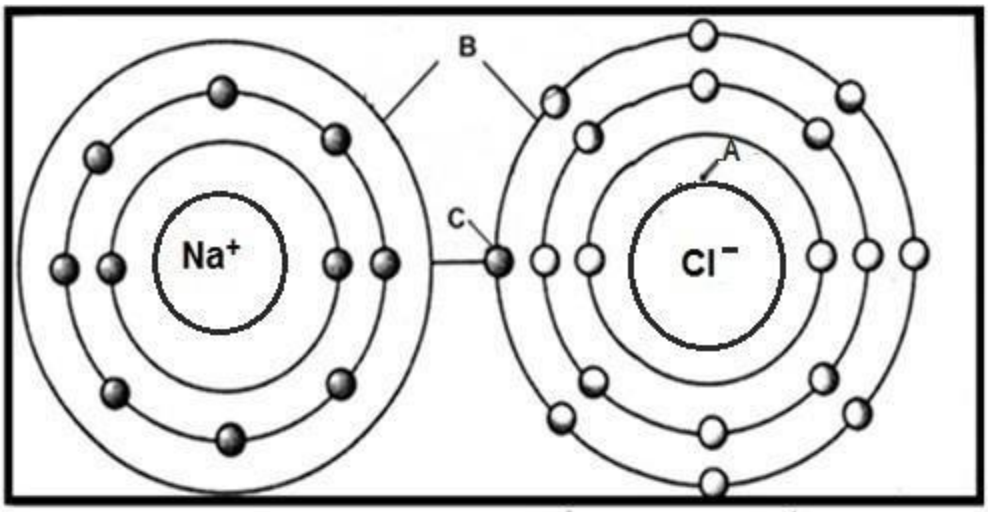
1.4.5 The exchangeable aluminium and hydrogen ions on the surface of soil colloids is sodicity. (5 x 1) (5)

TOTAL SECTION A: 45 SECTION B

Start this question on a NEW page.

QUESTION 2: BASIC AGRICULTURAL CHEMISTRY

2.1 The diagram below illustrates atoms responsible for the formation of a compound.



2.1.1 Identify the compound formed by the atoms in the diagram above. (1)

2.1.2 Indicate the health benefit of the above compound in food. (1)

2.1.3 Name the parts labelled **A**, **B** and **C**. (3)

2.1.4 Elements in the periodic table are grouped according to similar chemical characteristics. Indicate the group to which each of the elements illustrated in QUESTION 2.1 belong. (2)

2.1.5 Name TWO common characteristics of the elements in a group where Cl belong. (2)

2.2 Disaccharides are formed when two monosaccharide molecules join to form one molecule which can be broken down during hydrolysis process.
Name a disaccharide formed when the following monosaccharide's are joined together:

2.2.1 A glucose and a fructose (1)

2.2.2 A glucose and a galactose (1)

2.2.3 Write a chemical formula of the molecules mentioned in QUESTION 2.2.1 and QUESTION 2.2.2 above. (2)

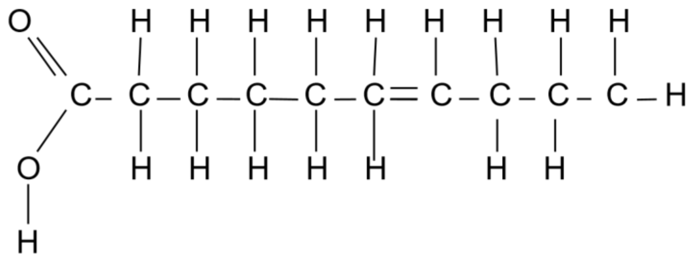
2.2.4 Mention the importance of starch in animals prepared for the following functions:

(a) Racing (1)

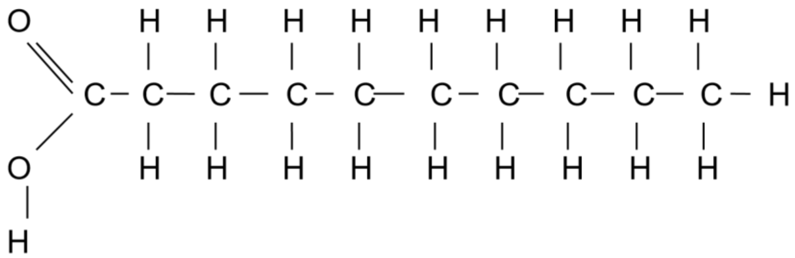
(b) Selling at a market (1)

2.3 The following structures illustrate the compounds playing a role in agriculture.

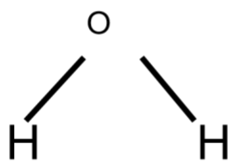
A.



B.



C.



2.3.1 Classify the compounds labelled **A** and **C**. (2)

2.3.2 Indicate the name of the fatty acids labelled **A** and **B**. (2)

2.3.3 Write only the letter representing a fatty acid to which each of the following statement applies:

(a) It is of animal origin (1)

(b) Has a low melting point (1)

2.3.4 The compound labelled **C** plays an important role in agriculture. Justify this statement with TWO important roles of this compound. (2)

2.4 HCl and NaOH are chemical formulae of substances used in agriculture.

2.4.1 Identify the chemical formula representing the following:

(a) Alkali (1)

(b) Acid (1)

2.4.2 Show the chemical reaction when HCl dissolves in water. (3)

2.5 The products below are displayed in a retail shop. Carefully analyse the products and answer questions that follow.

PRODUCT A	**PRODUCT B**
	

2.5.1 Indicate the functional group of products **A** and **B**. (1)

2.5.2 Give the scientific name of both products **A** and **B**. (2)

2.5.3 Identify the product (A or B) which is ideal to be used for heating. (1)

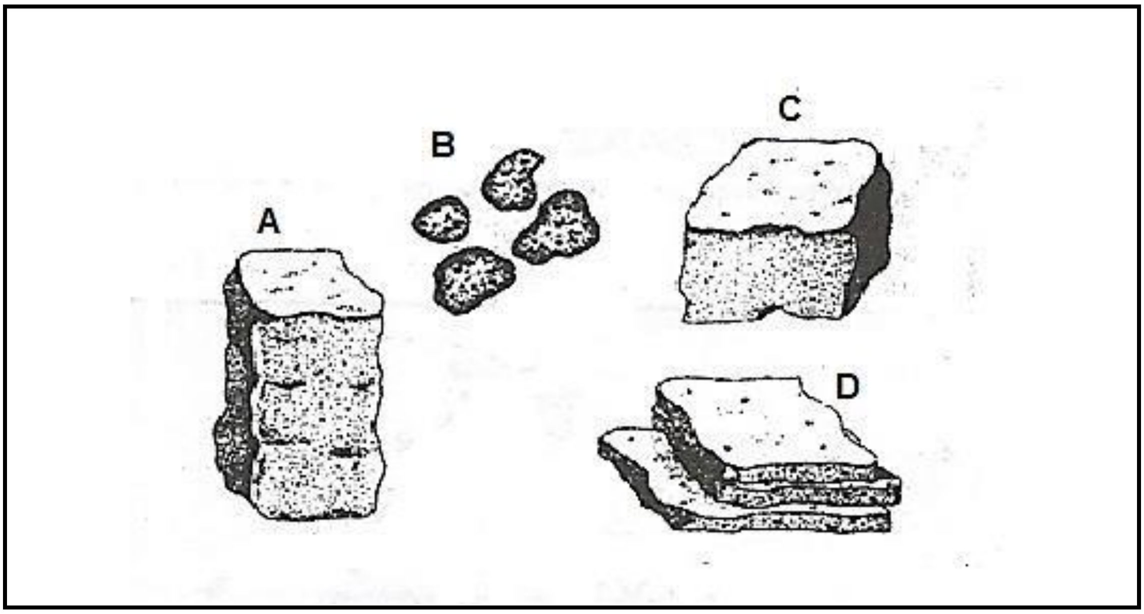
2.5.4 Write the structural formula of product **B**. (2)

2.5.5 Product **A** can be oxidised to form another product. Give the
scientific name of that product. (1)

[35] QUESTION 3: SOIL SCIENCE

Start this question on a NEW page.

3.1 Soil particles are grouped together to form aggregates or peds. These peds are classified on the basis of shape. The diagrams below show different structures based on shape.



3.1.1 Identify the structure types labelled **A** and **D**. (2)

3.1.2 Indicate the letter representing a structure to which each of the following statements applies:

(a) It is found in compacted soil. (1)

(b) Develops in soils with a high concentration of kaolinite. (1)

3.1.3 Indicate the letter of the structure you would recommend to the farmer for crop production. (1)

3.1.4 Give THREE reasons for the recommendation in QUESTION 3.1.3. (3)

3.2 A soil analyst conducted a research to establish the correlation between the particle size, pore space and water behaviour of a soil sample. The scientist used the following indicators:

- Macro-pores 0 0
- Micro-pores + +
- Percolation ^ ^
- Drainage - -

Sample A	Sample B	Sample C
0 0 0 0 ++ ^ ^ ^ ^ - - - -	0 0 ++ ^^ - -	0 + + + +

3.2.1 Identify the soil texture represented by soil samples **A** and **C**. (2)

3.2.2 Give ONE reason for each of the identifications in QUESTION 3.2.1. (2)

3.2.3 Texture has a great influence on the behaviour and characteristics of soil. Indicate the letter representing the soil sample with the following influence on soil:

(a) Larger surface area for chemical reactions (1)

(b) Lower degree of cohesion between soil particles (1)

(c) Particles increases the angle of diffraction because of size (1)

(d) High permeability (1)

3.3 The table below shows the mass, volume, bulk density and the percentage pore space of different soil samples.

SOIL SAMPLE	MASS (g)	VOLUME (cm^3)	BULK DENSITY (g/cm^3)	PORE SPACE (%)
A	450	600	0,75	62,7
B	620	550	1,13	56,2
C	880	500	--------	52,5

D	680	80	8,5	30,8

3.3.1 Use the information in the table to draw a bar graph showing the mass and the volume of the soil sample. (6)

3.3.2 Identify the soil that has not been disturbed by heavy implements. (1)

3.3.3 Deduce TWO reasons from the data in the table above for your answer in QUESTION 3.3.2. (2)

3.3.4 Calculate the bulk density of soil sample **C**. (3)

3.4 Name the gas that is responsible for each of the functions below:

3.4.1 Inaccessible compounds become accessible to plant roots (1)

3.4.2 Slows down oxidation process in soil (1)

3.4.3 Improves the formation of humus in soil (1)

3.5 The availability of water for plants is influenced by the presence of accessible soil water. The plants can either wither, die or grow optimally depending on soil moisture conditions.

Indicate the plant's response to the following soil conditions:

3.5.1 Water is held at a point equal to permanent wilting (1)

3.5.2 Field water capacity (1)

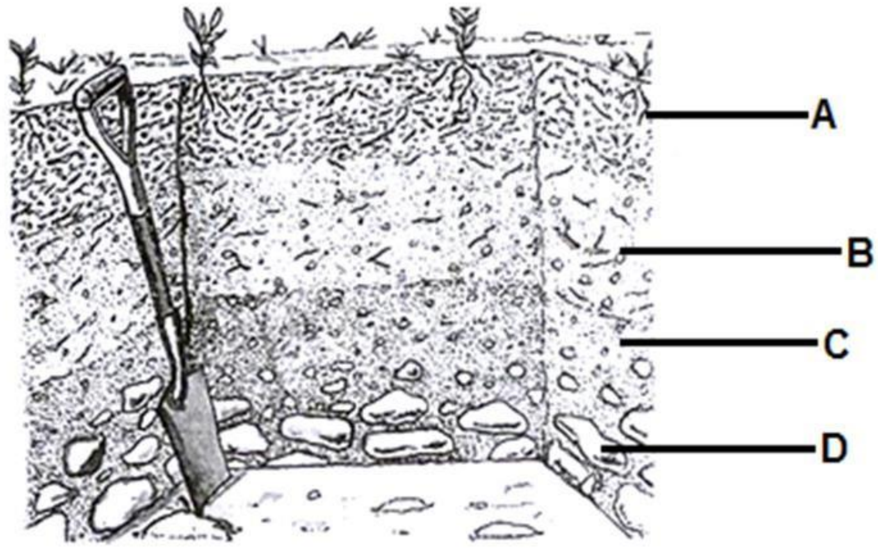
3.5.3 Temporal wilting point (1)

3.5.4 Saturation point (1)

[35] QUESTION 4: SOIL SCIENCE

Start this question on a NEW page.

4.1 The schematic representation below shows different horizons visible after digging through the soil.



4.1.1 Determine the age of the soil above. (1)

4.1.2 Give a reason for the answer in QUESTION 4.1.1 above. (2)

4.1.3 Sketch the profile of the above soil. (2)

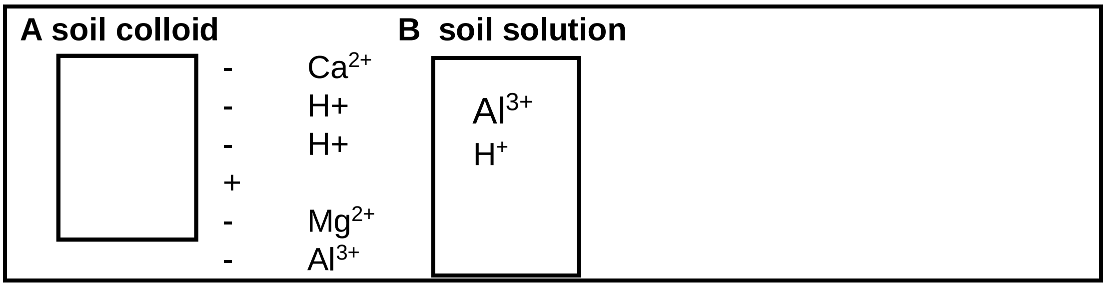
4.1.4 Indicate the letter representing a horizon with the following characteristics:

(a) Enriched with eluviated material. (1)

(b) Inorganic material mixed with organic matter. (1)

4.1.5 Name TWO diagnostic horizons of the horizon labelled **B**. (2)

4.2 Cation absorbed on the surface of the colloid can be exchanged with cation predominant in the soil solution. The diagrams below show cations adsorbed on the colloid and in the soil solution.



4.2.1 Identify the form of acidity labelled **A** and **B**. (2)

4.2.2 Justify the answer in QUESTION 4.2.1 above. (2)

4.2.3 Indicate the letter representing acidity that will have an effect on plant growth. (1)

4.2.4 Suggest a reason for the answer in QUESTION 4.2.3 above. (1)

4.2.5 Give an appropriate term for the ability of soil to exchange cations with the soil solution. (1)

4.3 Compare in a table form saline and sodic soils with regard to the following:

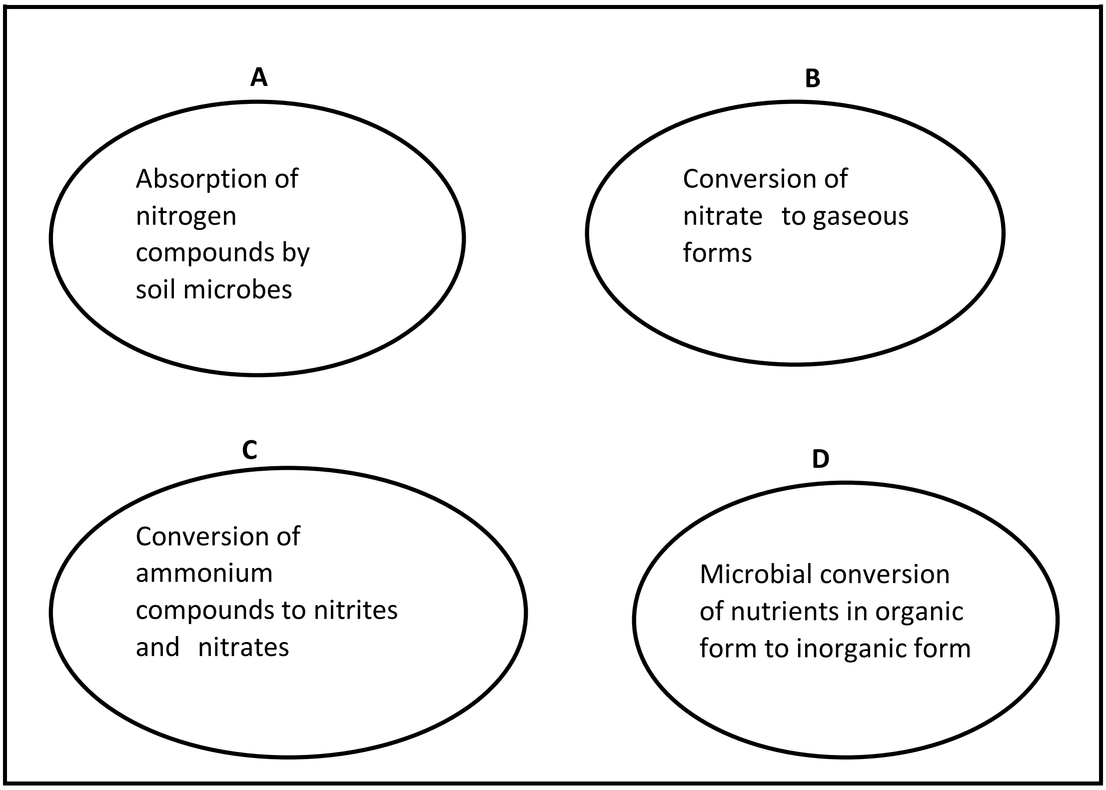
4.3.1 (a) Dominant salts (2)

(b) Colour (2)

4.3.2 The farmer can correct sodicity through the application of gypsum. Show the exchange reaction during the reclamation process when gypsum is added to soil. (3)

4.4 Soil micro-organisms have a specific functions in soil and without them, soil will not be able to support plants.
Explain TWO ways in which the soil can benefit from the breaking of plant and animal residue by soil microbes. (4)

4.5 The illustrations below shows the processes during nitrogen cycle.



4.5.1 Identify the processes labelled **A**, **B**, **C** and **D**. (4)

4.5.2 Name the soil conditions favouring the process in **B**. (1)

4.6 Organic matter contributes to plant growth through its effect on the physical, chemical and biological properties of soil.

Name THREE practices that may lead to the decline in the organic matter Content of the soil. (3)
[35]

TOTAL SECTION B: 105 GRAND TOTAL