INVESTIGATING PGCE PRE-SERVICE TEACHERS' LEVEL OF UNDERSTANDING OF LIFE SCIENCES AS A SCIENTIFIC DISCIPLINE

A research report submitted to the Faculty of Science, School of Education, University of the Witwatersrand, Johannesburg, South Africa, in partial fulfilment of the award of Master of Science (MSc.) in Science Education

Uchechi Agnes Ahanonye

Protocol Number: 2016ECE054M

Student Number: 1180216

1180216@students.wits.ac.za

Supervisor: Dr. Eunice Nyamupangedengu

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DECLARATION

I, Uchechi Agnes Ahanonye, declare that this dissertation entitled ‘Investigating PGCE pre-service teachers’ level of understanding of Life science as a scientific discipline’ is my own unaided work; and that the information quoted from other sources has been duly acknowledged. It is being submitted for the degree of Masters in Science Education at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

Uchechi Agnes Ahanonye

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Signature of Candidate

24th of March 2017

DEDICATION

This research work is dedicated to God Almighty for his Love, Goodness, Mercy, Greatness, Protection and Provision throughout this journey of achievement. Without Him I am just an empty vessel.

Also to my Late parents, Mr & Mrs Emmanuel Ahanonye and to my Late dear brother and friend, Isioma Aniemeke, May God's perpetual light shine upon them, Amen.

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And to me I say; Congratulations and God bless you

Table of content

Contents **Page**

LIST OF TABLES

LIST OF FIGURES

List of Acronyms

SMK	Subject matter knowledge
PCK	Pedagogical content knowledge
NOS	Nature of Science
PGCE	Postgraduate certificate of Education
LCT	Legitimation code theory
GCK	General content knowledge
CK	Curricular knowledge
PSTs	Pre-service teachers
FET	Further Education training
GET	General education training
ER	Epistemic relation
SR	Social relations
TO	Temporal orientation
TP	Temporal positioning
MaD	Material density
MoD	Moral density

Abstract

The aim of this study was to investigate PGCE pre-service teachers' level of understanding of life sciences as a scientific discipline. The investigation was carried out at a Higher Education institution where Life science is studied. A questionnaire containing a Likert scale section with twenty two items, and open ended section with two statements was administered for this study. The participants were sixteen Postgraduate certificate in Education (PGCE) Life science pre-service teachers at a South African Higher Educational institute. Also, an interview was conducted with the participating students and two teacher educators who teach in the PGCE program. The theoretical framework adopted for this research is built on Bernstein's legitimation code theory (LCT). The data was deductively analysed qualitatively by using the legitimation code theory (LCT) dimensions to answer the research questions posed for this study. The findings of this study revealed that PGCE Life science pre-service teachers show an understanding of their disciplinary knowledge in terms of its important knowledge content (specialization), diversified nature of the disciplinary knowledge (density) and the emergent and existence of the accumulated knowledge (Temporality). Also in their responses, it was evident that they recognize the place of Nature of science (NOS) as part of their disciplinary knowledge, that is, they have a better gaze of the need for SMK, inquiry based skills, and history of science (HoS). The educational implications as well as recommendations of this study were explained. The recommendation for this study is that, the nature of Life science as a discipline of knowing should be made explicit to students.

Chapter One

1.0 Introduction

There is general awareness that teachers need to first comprehend the concepts they teach before going into the classroom to enhance learning. Research studies in science education have been able to indicate that teachers' level of understanding of their subject is of utmost importance in relation to the quality of classroom teaching (Ekberg, 2005; Kind, 2009). In this line of thought, the authors found out that science teachers need to know more science so as to be able to teach the concepts better. Similarly, CaSE opinion forum (2007) argues that "children need to be taught by specialist [science] teachers" (p.2). So the place of teachers' understanding of their subjects cannot be overlooked in effective teaching and learning process. Teachers' understanding of a subject influences the manner in which they teach each concept in their discipline and this understanding is dependent on various factors such as: the teachers' subject matter knowledge (SMK); pedagogical knowledge (PK); understanding of the nature of science (NOS); and teacher beliefs (Ekborg, 2005). These factors form part of the disciplinary knowledge structure or nature of a discipline (Ekborg, 2005) like Life Science. For instance, both the subject matter and the nature of science form the structure/nature of Life sciences.

Considering the importance of these factors, research by Myers (2016) reported that an understanding of a discipline's knowledge structures is a precursor to effective teaching. While tertiary institutions make efforts in developing and evaluating subject matter knowledge (SMK), little is known about how deep they go in testing students' understanding of the structure of the knowledge acquired. With this in mind, this study investigated the Postgraduate Certificate in Education (PGCE) Life science Pre-service teachers' understanding of disciplinary structures or nature of Life Sciences at the end of their program in a tertiary institution in Gauteng province. Questionnaires as well as focus group interviews were administered to collect data on pre-service teachers' (PSTs') viewpoints about the nature of Life Science. The captured viewpoints were conceptualised as showing how participants understand the nature of Life Science subject as a discipline

1.1 Background/context of the study

My study was set to investigate PGCE pre-service teachers' level of understanding of the nature of Life Science subject at the end of their program. Various teacher training institutions have their aims, goals and objectives which they set in their course outlines, syllabuses, and curriculum to ensure adequate training of their student-teachers (Ekborg, 2005). However, the Pre-service teacher training programmes differ from one institution to another within the South African context and also from one country to another around the world (Nyamupagedengu, 2015). According to Nyamupangedengu (2015) two main models of teacher preparation programmes can be used to train pre-service teachers and they are described as 'the concurrent model and the consecutive model' (pg. 2). According to her the models (concurrent and consecutive models) are made up of **general component** which enables students to study one or more academic teaching subjects and also, the **professional component** which enables them to study the theory and practical skills required for teaching and learning and also to practice their teaching skills within a period of time (Nyamupagedengu, 2015).

The **concurrent model** involves the students studying concurrently, both the general and professional component. While in the **consecutive model study**, student teachers obtain the general component first, that is, the undergraduate bachelor's degree (B.Sc.) or post graduate degree (M.Sc.) in content subject which could be one or more before they undertake further studies for the professional component. The University under study practice both the concurrent and consecutive model. For instance, the B.Ed. students studying in the school of Education campus undergo a concurrent programme by learning both the general and professional component (content and pedagogy), while the PGCE **pure science** students undergo the consecutive model, whereby they obtain the general content knowledge at B.Sc. or M.Sc. level and then proceed to obtain the professional knowledge in education (PGCE). For my study, the PGCE training fall under the consecutive model because they already have acquired the general component, that is, content knowledge during their B.Sc. undergraduate program and now embarking on the professional component which is more about pedagogy.

The PGCE program in my study prepares high school teachers who intend to teach in the senior phase (grades 8-9) and Further Education and Training phase (FET, grades 10-12) of schooling. Evidence can be drawn from the content of the curriculum used for the PGCE program in the tertiary institution under study, specifically for Life science. The program is as follows;

Theory of education

One major FET subject methodology (which is the life science subject)

Teaching experience in the major FET subject (Life science)

One general education training (GET) subject methodology e.g. teaching skills (+ an optional 2nd GET subject methodology)

Teaching experience in the GET subject/s, and

Endorsement courses (where necessary) in computer literacy and language proficiency (PGCE Life sciences, 2016). Please refer to appendix 9

The information given above is contained in the curriculum used in teaching the PGCE Life science pre-service teachers during their program, and it is expected that at the end of the program, they should be able to understand the structures and nature of life science for effective classroom teaching. The curriculum shows that the PGCE Life science pre-service teachers are trained to understand their subject matter as well as the methods of disseminating the knowledge. The teacher knowledge expected of them is grounded in the life sciences and therefore requires adequate training to acquire such skills.

However, it is becoming evident that the complex nature of science (NOS) teaching calls for more research studies which investigate teacher knowledge which influences classroom teaching and learning process (Nilson, 2013). With regards to the idea of teacher knowledge Nilsson (2013) argued that "*the complexity of teaching brings into sharp focus the need for more extensive research into the relationship between the different elements that constitute teacher knowledge, and how these are developed and further assessed during pre-service teacher education*" (p. 188). Nilsson's research about teacher knowledge shows the importance of examining pre-service teachers' development of knowledge for teaching. Linked to the statement above about teacher knowledge, Shulman (1986) theorized pedagogical content knowledge (PCK) as a unique kind of knowledge teachers need to make concepts understandable to students. As described by Shulman (1986), PCK is produced as a teacher unifies content knowledge of a subject (SMK) with pedagogical strategies in enhancing students' conceptual understanding. Mthethwa-Kunene, Onwu and de Villiers (2015) added that "*through that combination of knowledge, teachers gain a perspective that enhances their abilities to present specific topics in a specific subject area*" (p. 1141).

Therefore, there is need for proper training of student teachers both in the subject matter and their disciplinary knowledge at different levels. This teacher education training, according to Ekborg (2005) is very crucial because the teacher plays a very important role in decision making based on sound science. The PGCE is an education training program whereby graduates are trained to become teachers in various specializations. Therefore the participants in my study were PGCE pre-service teachers who are trained in the field of Life science subject area. Their expected subject matter knowledge is in Life Science, which is why there is need to investigate the PGCE pre-service teachers' understanding of the disciplinary structure/nature of Life Science subject at the end of their program.

1.2 Knowledge

Knowledge in general means to know something and it could happen at any time, space or place. The constructivists believe that knowledge is constructed by an individual through experience and learning, that is, construction of the knower (Moore and Muller, 2010) which results from the interaction and interests within social groups. As individuals interact within their environment, they gain knowledge within that context through experience and culture, and it is this knowledge that Rata (2011) termed as 'social knowledge'. Young (2007) differentiated knowledge into two types as; 'school knowledge' and 'non-school knowledge'. Non-school knowledge also known as 'social knowledge' (Rata, 2011) is everyday knowledge of an individual which emanates from their experience within a social group. Social knowledge is 'context-dependent knowledge' (Young, 2010) and it is developed in the process of tackling everyday life issues. This kind of knowledge is acquired outside the school, but it plays a vital role in education by enabling teachers to relate sensitively with their students (Rata, 2011) which motivate learners to learn when they find themselves in the school environment. Having said this, one can only say that school knowledge is acquired in schools and Young (2007) termed it as "powerful knowledge" (pg. 13). He distinguished knowledge into two ideas; "knowledge of the powerful" and "powerful knowledge". But I will be emphasizing on 'powerful knowledge' which is disciplinary knowledge since it is my focus for this study. Young view powerful knowledge as the knowledge that is "context-independent", which is developed in order to provide generalisations and which is potentially acquired in school.

Kelly, Luke and Green (2008) view educational knowledge as that which is constructed and involves concepts and practices that acts as a tool for learning and problem solving. With this idea in mind, I view knowledge of Life Science as powerful knowledge because it is a special kind of knowledge acquired in the discipline of science (disciplinary knowledge) as a body of knowledge. Life Science is context-independent as Young (2007) defines it and it empowers' individuals (Beck, 2014) within its field and enable them to apply their knowledge in every other context. Generally, knowledge can be said to play a vital role because of its influence on students, and it can be viewed in various forms such as; situational knowledge; conceptual knowledge; procedural knowledge; and strategic knowledge (de Jong & Ferguson-Hessler, 1996). In Life science, *conceptual knowledge* is viewed as the teachers' understanding of theories, laws and concepts which unite to explain the nature of life science; it is knowledge of what makes up the content (Windschitl, 2004). This is basically what teachers know about their subject of specialization. For example, concepts such as ecology, biodiversity, conservation, are found under a particular specialization of Life sciences.

In this study the content knowledge is referred to as subject matter knowledge (SMK). Content knowledge and SMK will be used interchangeably in this study because some researchers such as Shulman categorized SMK, curricular knowledge and pedagogical content knowledge as 'content knowledge' (Ball, Thames & Phelps, 2008). In Life science *Procedural knowledge* is also knowledge of the content and the methods adopted for teaching the concepts. Procedural knowledge encompasses teacher knowledge of possible ways and strategies of making concepts understandable to the learners (Shulman, 1986). Procedural knowledge deals with valid manipulations in certain domain such as the Life sciences (de Jong & Ferguson-Hessler, 1996). While in Life science *strategic knowledge* deals with knowing how to interpret and organize the content, and giving illustrations or the use of models to explain a particular concept or topic (de Jong & Ferguson-Hessler, 1996). These knowledge forms were produced through the introduction of two dimensions that were used in describing it which are; type of knowledge and quality of knowledge respectively (de Jong & Ferguson-Hessler, 1996). For instance, in the Life Science domain, the subject matter involves various concepts and structures, therefore these different concepts require different procedures and strategies in which a teacher is expected to make knowledge of the subject matter accessible to students.

These knowledge forms according to the authors were illustrated based on their individual functions regarding a specific task targeted (describing epistemological perspective). They are forms of knowledge which emanates during the classroom teaching and learning process, and are used to describe different situations and tasks. However, different classifications of forms of knowledge are fixed for different tasks respectively, and in a particular knowledge domain, similar components of a subject matter can be categorized by different "ontological typologies" depending on their functioning tasks (de Jong & Ferguson-Hessler, 1996). The nature of Life science comprises of SMK (content) and the NOS (procedures and inquiry) as its disciplinary knowledge, therefore, in my view, Life science involves procedural, conceptual, situational and strategic types of knowledge, as mentioned by researchers (de Jong & Ferguson-Hessler, 1996).

1.3 Nature of Life Science as a scientific discipline.

Life science is a sub-discipline or scientific discipline. Life science is the scientific study of organisms from molecular level to their interactions with one another and their environments (DBE, 2011). Life science is a scientific discipline with a distinct nature because of the nature of its area of investigation (NOS), research method and epistemology (content) (Cohen & Lloyd, 2014). Life science consists of the nature of science (NOS) and the knowledge of the subject matter which together form its disciplinary knowledge. NOS refer to the epistemological underpinnings of the activities of science (i.e. scientific theories, history of science) and the characteristics of the resulting knowledge such as scientific skills and investigations (Lederman, 2007). While the subject matter deals with the knowledge of the concepts that make up the subject specialization (Shulman, 1986). The main purpose of studying Life science in schools is for students to develop scientific skills (investigations) and understand the role of science in the society (DBE, 2011). The skills acquired while learning Life science equip the students in solving everyday issues. All of these purposes relate to the subject specific aims of Life science as a scientific discipline. The subject specific aims relates to understanding the content, doing practical works and investigations in biology, understanding the history and nature of science and being able to apply the acquired knowledge of Life science in everyday life (DBE, 2011). The PGCE Life science pre-service teachers specialize in the field of Life science where they have acquired their content knowledge (SMK) and NOS, which forms part of their disciplinary knowledge. In line with this, Evens, Elen and Depaepe (2015) described disciplinary knowledge as all the 'activities and courses' that emphasizes on content knowledge of Life science. In my view, disciplinary knowledge in Life science deals with understanding the nature and structures of Life science in terms of its SMK and NOS.

1.3.1 Disciplinary knowledge

The acquisition of knowledge is a target in the academic context. People get to increase and expand their knowledge as they engage in a particular academic discipline. While describing an academic discipline, Cohen and Lloyd (2014) view it as a 'branch of knowledge' (p. 1). The authors posit that a discipline comprises of academic studies (specializations) that focus on "self-imposed limited field of knowledge" (p. 1). Different types of disciplines are found in the academic context. Examples include: Science, Humanities, Arts etc. Disciplines differ and each has distinct nature. The distinct nature of discipline can be traced to the nature of the area of investigations (context), research methods and epistemologies, and their way of knowing (otherwise known as the disciplinary knowledge (Cohen & Lloyd, 2014). For example, the discipline of science is a body of knowledge which has other sub disciplines such as, Life science and Physical science (physics and chemistry) and each of these sub disciplines have their specializations and NOS within its field.

Life science comprises of cell Biology, Anatomy, zoology, Botany specializations, to mention a few. The nature of Life science is made up of its subject matter and NOS. Therefore, Life science is viewed as a scientific discipline because of its affiliation to science. The disciplinary knowledge of Life science deals with the epistemological (knowledge) and ontological (nature) perspective of the science discipline and it is organized according to its components such as; ‘procedures, systems, principles and codes’ (Moore & Young, 2001, 2010). For instance, the epistemological perspective deals with the theory of knowledge, its methods, justified beliefs and opinion of Life science, while the ontological perspective entails the nature, that is, how things are in Life science. Life science therefore has a distinct body of knowledge and distinct procedures and ways of validating that body of knowledge. Life science is known for its distinct way of acquiring knowledge through inquiry and conducting experiment objectively and it is made up of various concepts, methods and procedures, which are termed as the legitimate way of knowing in the field. Life science involves mostly, knowledge of the discipline of science (NOS) and knowledge of the subject matter in that domain, which was what Shulman in his study described as the knowledge of the content (Shulman, 1986).

The disciplinary knowledge of Life science comprises of SMK because it deals with the understanding of subject matter, procedures and scientific skills embedded in a discipline and how to make it accessible to students. Subject matter knowledge involves the understanding of concepts and its structures in the Life sciences field, and it can be transformed with the use of PCK. The university assesses students’ SMK and PK/PCK but not their understanding of the nature of Life Science knowledge which is important for the development of other forms of knowledge. Students are taught various concepts and procedures to enable them to be knowledgeable in Life Science, but most times the structures of these particular concepts, that is, how knowledge is accumulated and taught according to its importance are not emphasized upon during learning. This is why I have decided to investigate the PGCE Life Science pre-service teachers understanding of the disciplinary structure of Life Science in the institution under study.

1.4 Rationale

The major topic which has been persistently discussed in international debate is the issue concerning the means through which ‘teacher education’ institutions make sure that the training given to the science teachers, is adequate enough to prepare them for efficient work in their science classroom at the secondary school level (Abell, 2007). One of the issues from the debate is; how best can the trainee science teachers be equipped with scientific subject matter knowledge (SMK) which is required for teaching? Also, there have been arguments on whether the reason for student teachers' subject matter inadequacy is as a result of poor content and structuring of the tertiary school syllabus and course outline in various disciplines, teaching method or learners' need to acquire a certificate but lack of interest of being a teacher (Ekborg, 2005). While all of these issues concerning teacher training programs are debated, little is known about what pre-service teachers learn while undertaking the courses which have been designed to equip them with the understanding of the subject matter (Abell, 2007). Therefore, my study focused on the PGCE pre-service teachers' understanding of their disciplinary structure In Life science, that is, what they take from the courses they are being taught.

In Life science, the disciplinary structure includes what the epistemological (theories, methods, beliefs) and its ontological (nature) perspectives entails and how they are sequenced. Therefore, Life science deals with teacher knowledge of the purposes and methods of inquiry as well as understanding the existing kinds of connections, models and data that validate the knowledge (Windschitl, 2004). The understanding of Life science structure is known to influence the methods adopted in teaching its concepts, and it depends on a number of factors such as, teachers' understanding of the nature of science (NOS), subject matter knowledge (SMK), pedagogical knowledge (PK) and teacher beliefs (Ekborg, 2005). This is why there is need to review the PGCE Life Science pre-service teachers' understanding of the disciplinary structure of Life Science at the end of their postgraduate program in the university under study.

1.5 Statement of the problem

There have been concerns about the inadequate students' conceptual understanding of sciences particularly in the South African schools (Rollnick & Mavhunga, 2014). Some of the difficulties students encountered in understanding science concepts have been associated with inefficient and inexplicit science teachers' teaching strategies (Planinic, Milin-Sipus, Katic, Susac, & Ivanjek, 2012). Other conceptual problems have been reported to be as a result of the teachers' poor preparation and hence poor understanding of the required content concepts (Rollnick & Mavhunga, 2014). Also, there have been indications of inadequate content knowledge by South African science teachers (Spaull, 2013) and poor pedagogical content knowledge (Rollnick & Mavhunga, 2014) in making the concepts accessible to students. For instance, with the just released Diagnostic Report of the 2015 Grade 12 students who wrote matriculation examination, the performances have not been very encouraging in Life Sciences with the percentage achieved at 40% and above as shown in the Figure 1.1 below.

Table 9.1 Overall achievement rates in Life Sciences

Year	No. wrote	No. achieved at 30% and above	% achieved at 30% and above	No. achieved at 40% and above	% achieved at 40% and above
2012	278 412	193 593	69.5	120 734	43.4
2013	301 718	222 374	73.7	144 355	47.8
2014	284 298	209 783	73.8	139 109	48.9
2015	348 076	245 164	70.4	160 204	46.0

Table 1.1: An extract of the Diagnostic report for 2015

While the Minister of Education was commenting on the results generally, she stated that "the 2015 diagnostic report for the 11 subjects covered in this publication indicate that the pass rate has decreased at varying degrees in these subjects. These were also fewer distinctions achieved in 2015 than 2014" (Department of Basic Education, 2016, p. 6). Consequently, it would not be of any good impact if high school students' poor conceptual understanding (concepts and subject matter), associated with the teachers' inefficient teaching continues without being addressed (Rollnick & Mavhunga, 2015). This calls for rigorous effort in adequately training of pre-service teachers. Because, we do not know whether the PGCE Life science pre-service teachers understand the Life science structure, therefore in addressing some of these difficulties, it is important to establish the understanding of Life Science disciplinary structures acquired by the PGCE Life science pre-service teachers (PGCE) at the institution under study.

1.6 Purpose of the study

The purpose of this study was to investigate PGCE pre-service teachers' level of understanding of the nature of Life Science at the end of their postgraduate program (PGCE) and to what extent the knowledge they acquired equip them for future practice as teachers.

1.7 Research questions

1. What level of understanding of the nature of Life sciences as a scientific discipline is demonstrated by PGCE Life science PSTs?

2. To what extent do PSTs develop the required gaze about Life science from their PGCE program?

1.8 Structure of the study report

The study report comprises of five chapters. Chapter one introduces the problem that motivated the study; two and three provide the reader with the understanding of the theoretical underpinnings this study. Chapter four focused in presentation and analysis of data, and interpretation of findings. Chapter five presents the conclusion to this study and relevant recommendations were stated. This study is presented chapter by chapter below.

Chapter one gives a general overview of this study. The chapter dealt with the focus on specific problem of the understanding the participants of this study have concerning their disciplinary structure in Life science. The chapter also formulates the rationale and purpose of this study as well as the research questions posed for this study.

Chapter two gives a review of the literature in line with the title of the study. The background of the study was given laying emphasis on knowledge and nature of Life science. The theoretical framework of this study was presented, laying emphases on the legitimation code theory (LCT) in a discipline. The chapter also emphasized on various knowledge base and implications of disciplinary knowledge on learning in secondary schools.

Chapter three focused on the methodology that was used to investigate the understanding that the PGCE pre-service teachers have concerning the disciplinary structure of Life science. As explained in this chapter, a triangulation method was adopted. The chapter revealed the use of both qualitative and quantitative approach, as well as a case study method as the appropriate approach in this study. Participants were mentioned and also the sampling method used (purposeful sampling). The chapter also revealed the methods adopted in collecting, analysing and interpreting data, as well as the instruments.

Chapter four presents the results of data analysis and discussion of findings.

Chapter five presents a general conclusion on PGCE pre-service teachers' level of understanding of Life sciences in the institution under study. The chapter provides conclusion on the previous chapters as well as presenting a recommendation to the policy makers regarding the need to make explicit, the structures of a discipline.

1.9 Conclusion

In this chapter, a general introduction is provided. The chapter introduced and gave the background of the study. The chapter described the nature of Life science as a scientific discipline and focused on the specific problem of the disciplinary knowledge (NOS & SMK) of Life science in terms of its structures. Knowledge and its forms and the various programs held for the PGCE pre-service teachers were also explained in details. The rationale, purpose of the study as well as the research questions guiding the study are explained in this chapter.

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[1] In this study, 'Gaze' means glance, perception of the knower (PGCE pre-service teachers)

Chapter Two

Literature review and conceptual framework

2.0 Introduction

In this chapter, I review the literature on disciplinary knowledge SMK and NOS. In addition, various forms of knowledge which make up the disciplinary knowledge will be discussed in detail, as well as its educational implications. The theoretical framework for this research is built on Bernstein's legitimation code theory (LCT). Also, the conceptual framework guiding this literature is adopted from Young and Muller's (2013) concept of 'powerful knowledge'.

2.1 Disciplinary knowledge

2.1.1 Disciplinary knowledge is powerful knowledge

According to Young (2007) powerful knowledge is viewed as the knowledge acquired in school to empower individuals (Beck, 2014) and prepare them for the future. Disciplinary knowledge is powerful knowledge. Science is a discipline which is taught in school, therefore what makes up disciplinary knowledge in terms of its content and skills should be emphasized on according to its categories and qualities. "Content knowledge generally refers to the facts, concepts, theories, and principles that are taught and learned in specific academic courses" such as Life Science (Hidden curriculum, 2016, p. 1). Shulman (1986) termed content knowledge as "the amount and organization of knowledge per se in the mind of the teacher" (p. 9), which is classified into three different types such as, curricular knowledge, pedagogical content knowledge and subject matter content knowledge (SMK). The SMK is knowledge of the nature of a subject and its structures which can be found in a discipline (Science). Therefore, content knowledge or SMK is specific to each sub discipline of science (e.g. Life science, Physical science).

According to Rata (2011) disciplines are distinguished by their methods of learning and theories which reveals its disciplinary nature, and therefore termed disciplinary knowledge. For instance, the SMK for physical sciences is different from the SMK for Life sciences, but their method of inquiry is same because they are both scientific disciplines.

General content knowledge forms part of the disciplinary knowledge (NOS & SMK) of Life science because it goes way beyond knowledge of concepts or facts of a domain. It also deals with the disciplinary structure which could be syntactic and substantive in nature. Each of the disciplines has its own GCK and it is different in different aspect of science as a discipline, that is, it is specific to individual sub discipline, such as Life science, physics and chemistry. Also, the sub disciplines of science differ in their subject matter knowledge. As discussed in the previous chapter, this study focused on the PGCE Life science pre-service teachers' level of understanding of Life science at the end of their program.

2.1.2 Disciplinary Knowledge of Life science

According to Rata (2011) disciplinary knowledge is 'future oriented' with the purpose of providing foresight which requires the 'faculties of reasoning and judgement'. Disciplinary knowledge deals with the epistemological and ontological perspective of a discipline and it is organized according to its components such as; 'procedures, systems, principles and codes' (Moore & Young, 2001, 2010) which separates it from social knowledge through its contributions of giving knowledge its own 'epistemological structure'. Disciplinary knowledge can also be acquired at the academic/institutional level. Disciplinary knowledge involves more than the acquisition of basic skills or bits of received knowledge (Kelly, Luke & Green, 2008) and individuals in a specific discipline have identities. For instance, science is a discipline with a distinct way of acquiring knowledge, and in its community, various specializations are found such as the Life science and physical science, which makes it a whole body of knowledge.

Therefore, Life science form part of the science community of practice (Lave, 1991). As individuals are enculturated into its community they form an identity and are seen as scientist or specialist in the field. Science as a discipline is seen to be among those "Communities whose knowledge practices are embedded within distinct socio-cultural contexts" and they are identified by what they do, they are a community with certain beliefs, practices, values and language (Harvey, 2011, p. 30). It is within the disciplinary knowledge of science that various sub-disciplines such as Life Science, Physical Science, Chemistry, Geography and Mathematics, are found (Harvey, 2011).

Also, found within the sub-disciplines are specialisations, for example, Life science has various specialisations such as zoology, Microbiology, Botany, etc. Therefore, individuals specialize in any of the specializations mentioned, and such can be found in other sub-disciplines. Disciplinary knowledge is also specialised knowledge because of its uniqueness to a discipline. The special nature of disciplinary knowledge confirms that within a discipline or sub-discipline, there are branches of knowledge which forms the specialisms and they all share same laws and beliefs because they are Science oriented. Specialist knowledge involves developing **identity and affiliation** which is as a result of learners' participation in a discourse (discourse means power of the language between people and the use of language to express power) and actions of a collective social field.

Rata (2011) posit that specialization is not all about how many parts that can be held in a complex whole, but rather how they are related into orders and their relationship. For example, at the tertiary institution, students find themselves doing all courses at the first level of their study, this is done to enculture them into the body of knowledge and way of life of that discipline (science discipline) and then at the second, third and fourth year they choose their specialism (Microbiology, Zoology) and specialize in a particular field. All the knowledge acquired by the students within this disciplines is what young termed as powerful knowledge. It is powerful because it empowers' learners cognitively, which is what they need to be able to participate in the society and be a part of it. Specialized knowledge can be differentiated by using two principal criteria and this according to Young and Muller (2014) are; the differences in the *internal* and *external* relations of the knowledge. The internal involves the body of theories and 'methods derived from them' while the external includes the capacity of the theory to describe reliably every other things and not only itself (Young & Muller, 2014). The theories are linked to each other and do not stand alone. Also, some of the theories which form part of the disciplinary structure of Life science have the tendency of being applied outside its field. Examples of such theories are, the theories in evolution and genetics, they are related to each other, and can as well be applied in other fields such as, Physics and Environmental sciences.

The disciplinary knowledge of science includes understanding the nature of science (NOS) which includes the scientific inquiry; evidence and reasoning in inquiry; scientific investigations; scientific theories and avoiding bias in science (American association for the advancement of science, 2001). Life science as a sub-discipline involves understanding the nature and history of science in addition to knowledge of its subject matter (SMK). Therefore, this study focused on the level of understanding of Life science as a scientific sub-discipline that the PGCE Life science pre-service teachers acquire at the end of their postgraduate program.

2.1.3 Subject Matter Knowledge (SMK)

Within the disciplinary knowledge of Life science is the subject matter knowledge (SMK) which Young (2007) termed as "content dependent", and according to Kind (2009) is an important factor which contributes to successful teaching. SMK provides basis for the development of pedagogical content knowledge (PCK) and shapes the teachers' practice (Jicama, 2014). Content knowledge entails "understanding the structures of the subject matter" (Shulman, 1986, p. 9). Content knowledge deals with the knowledge of the syntactic and substantive structures of academic discipline. The syntactic structures deal with the method adopted by a discipline or a researcher within a discipline to establish validity and invalidity, truth or falsehood in its field. While, the substantive structures deals with various ways in which a discipline organize their principles, ideas, understanding, proposition and basic concepts to integrate its facts (Shulman, 1986; Gudmundsdottir, 1990). For instance, Life science as a sub discipline is made up of various theories that are related to one another, as well as the methods in which they use in acquiring these theories.

Life science differs from other sub disciplines of science in terms of its syntactic and substantive structures. This view practically means that there is no essential difference in the kind of SMK for a teacher and that of a subject specialist. Shulman (1986) defined SMK as the knowledge of the concepts that makes up a subject. For example, life science comprises of the following concepts; the chemistry of life, cell division, support systems in animal, ecosystems, biodiversity, evolution, genetics, ecology, etc. (Department of basic education, DBE 2011). All of these concepts are presented at different level, to deliver the life science subject in a more extensive way (DBE, 2011).

According to Ball and McDiarmid (1989) subject matter knowledge is widely recognised as a 'central component' of what teachers are expected to know as part of their teaching profession. Although, research has not focused mainly on how teachers develop their subject matter knowledge and this seems to counter its importance in teaching and learning to teach. The idea that possession of good SMK is seen as a vital component of effective teaching has been revealed in several research studies e.g. Kind (2009). In her study, Kind explained how these studies (on SMK) indicate evidence that "specialised support help trainee science teachers to positively develop good SMK. Also, Darling-Hammond (2006) is of the opinion that subject matter knowledge is one of the leading factors in 'teacher effectiveness' because from the philosophical perspective, it influences the effort of the teacher in helping the students to learn subject matter (Jadama, 2014). He further explained that when a teacher is unable to acquire adequate subject matter knowledge, they can do more harm than good to the students because they possess 'inaccurate information and ideas' which they eventually pass to their students.

Teachers are likely to fail in correcting the misconceptions that the students bring with them to the classroom and use text uncritically (Jadama, 2014). Ball and Mcdiarmid (1989) posit that *"helping students to learn subject matter involves more than the delivery of facts and information"* (p. 2). It should involve helping them develop intellectual resources such as, reasoning, evaluation and assessment skills, which will enable them to participate in the key 'domains of human thought and inquiry'. Since teaching is seen as a learned profession, it is expected that a teacher should understand the structures of a subject matter as well as its principles for inquiry that will enable them to clarify; the important ideas and skills embedded in a domain and how new ideas are added to the theories of a domain while the old ones are dropped by the researchers in this domain (Shulman, 1987).

Subject matter knowledge (SMK) form part of the disciplinary knowledge which PGCE pre-service teachers acquire during their first and second year at undergraduate level, before engaging fully with their specialism where they gain in-depth knowledge of the subject. Therefore, they are expected to have knowledge of subject matter. In order to be seen as subject specialists in Life Science, PGCE PSTs should also have knowledge of nature of science (NOS). The SMK aspect of Life Science deals with its concepts, content and theories while the NOS deals with the enquiry, procedures, skills and nature of science itself and both SMK and NOS are components of the discipline of science of which Life Science is a sub-discipline. Although the PGCE Life science pre-service teachers are expected to have a solid background on SMK and NOS from their first degree, there are no studies that have been done to ascertain their level of understanding of Life Science as a sub-discipline of science. In Figure 1 below, I illustrate the nature of Life Sciences subject as a sub-discipline of science. The figure shows that Life science comprises of both SMK and the NOS. Subject matter knowledge involves concepts (cell, genetics), theories and methods of teaching Life sciences, while NOS involves evidence and reasoning in inquiries and scientific investigations. All of these components are what makes up the nature of Life science. Various specializations make up the Life sciences as a scientific discipline.

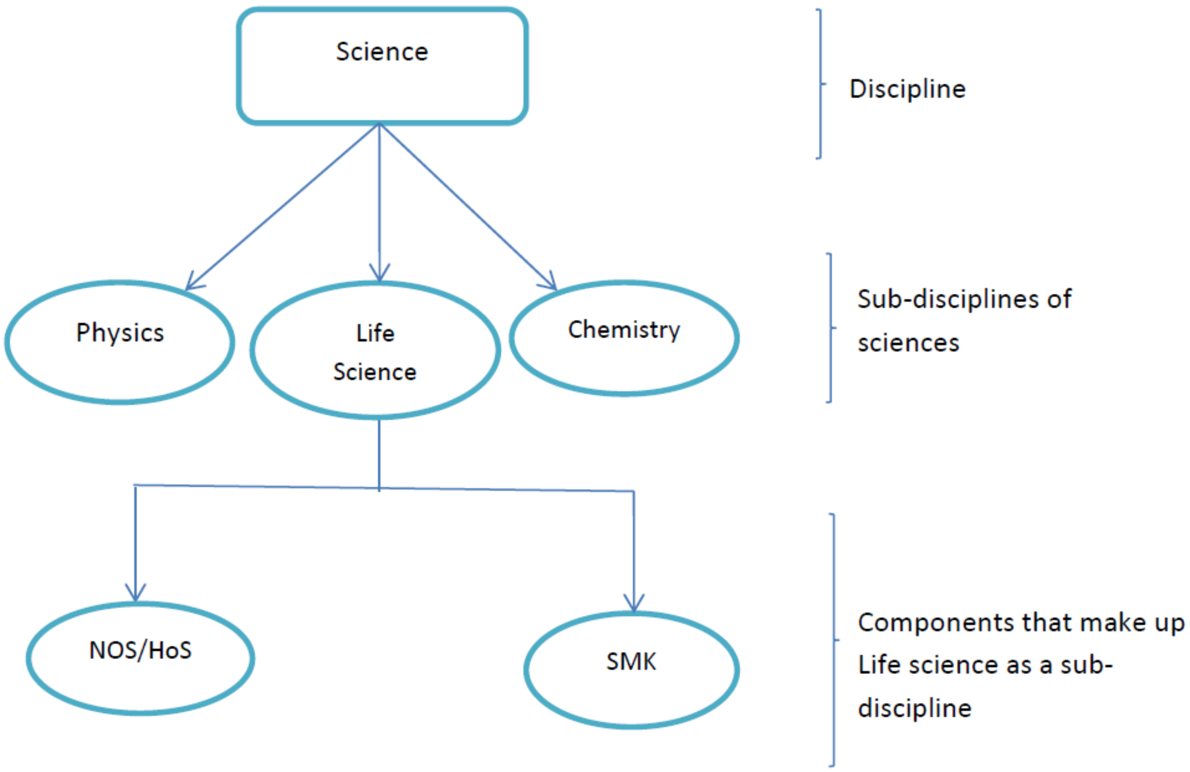

***Fig*. 2.1: An illustration of the nature of Life science and its specialization.**

2.1.4 Curricular knowledge (CK)

Curricular knowledge form part of the disciplinary knowledge of Life science. Curricular knowledge according to Shulman (1986) is the Knowledge of the curriculum, which is the teachers' understanding of the series of programs or activities that are designed in the curriculum for teaching specific concepts to specific level of students. It is *"represented by the full range of programs designed for the teaching of particular subjects and topics at a given level, the variety of instructional materials available in relation to those programs, and the set of characteristics that serve as both the indications and contraindications for the use of particular curriculum or program materials in particular circumstances"* (Shulman, 1986, p. 10). This kind of knowledge displays the teachers' ability to know which concept should be taught first and what instructional material can be used to achieve learning at different stages. Shulman further indicated two other categories of curriculum knowledge, which he explained as being important for teaching, and they include the *lateral curriculum knowledge* and the *vertical curriculum knowledge* respectively. The lateral knowledge is referred to as the knowledge that students learn in other subject areas, that is, it relates the knowledge of the curriculum that students are being taught to other knowledge they acquire in other subject disciplines (Balls *et al*., 2008).

The vertical knowledge deals with previously taught issues and topics in the same subject discipline and the topics that will be taught to the students later in the future. It also deals with the resources that represent them (Shulman, 1986). In the case of Life Science, Curricular knowledge deals with the teachers' ability to sequence and contextualize various concepts and also the ability to link the subject to other subject areas. CK also includes the use of appropriate instructional materials for teaching in the classroom. For instance, the use of botanical gardens to teach ecology or population (contextualization), using the right representations to teach topics such as genetics, etc. CK is in relation with Bernstein's' pedagogic device which consist of 'three fields of activities' such as "the field of production (Research), the field of re-contextualization (curriculum development) and the field of reproduction (teaching practice)" (Luckett, 2009, p. 443). Curricula knowledge differs according to context, that is, the CK in South Africa differ from that of Zimbabwe, and what is taught at grade 10 of one country differs from what is taught in grade 10 of another. But, the subject matter knowledge and NOS will be the same. Curricular knowledge forms part of the disciplinary knowledge of Life science, because it is a content knowledge as categorized by Shulman. Curricular knowledge is informed by disciplinary knowledge. Therefore as a teacher, the pre-service teachers need to understand Life science as a discipline, to enable them interpret curriculum documents when they go out to schools. Knowledge is re-contextualized to enable learners to gain access to its content with ease. Aside from learning and acquiring various forms of knowledge as discussed in the previous chapter, a teacher must also know how to make it accessible to learners during classroom practice. For instance, the ability of a Life science pre-service teacher to convert the knowledge acquired in higher education to a more understandable level while teaching in the classroom. The PGCE Life science pre-service teachers acquire various forms of knowledge and also how to make them accessible to the students they teach in the secondary schools during their methodology courses. Thus this study tends to investigate their understanding of the nature of Life Science in terms of the structure of the subject.

2.2 Science education in relation to the higher education curriculum

Disciplinary knowledge in Life science deals with the history and nature of science, as well as the SMK. Acquisition of disciplinary knowledge in Life science involves becoming enculturated into the ways of learning in science (Aikenhead, 2000). Therefore, science is a discipline that is taught in school, learning science in school is very important and it is known as science education or scientific literacy (Aikenhead, 2000). The history of science education has revealed the issues which have been debated concerning science in a way that probes what rationale is used for teaching science, 'what science education should be taught'; 'how science should be taught' and 'how it should be organized' and at 'whose interest should science education be taught' (Osborne, Collins, Ratcliffe, Millar & Duschl, 2003). In wheelahan's (2010) research study, he indicated that there are far-reaching reasons considered for knowledge to be displaced in the curriculum, and according to Muller and Young (2014) at the higher education (HE) milieu, the ones that are of utmost significance are related to the diverse affiliations found among institutions and society. Therefore, the roles of discipline and its disciplinary knowledge must be justified in relations to their significance in various situations. This justification can only be done by the discipline "by weakening their boundaries with the world, which further weakens traditional power and legitimacy" (Muller & Young, 2014, p. 133). It has also altered the focus on curricular from disciplinary education to a more common, person-oriented capabilities at the curriculum level. Therefore, what is considered legitimate in Life science should be made explicit in the curriculum. The curriculum for teaching the PGCE Life science pre-service teachers should have the structure that entails the pedagogic discourse (Bernstein, 2000) which comprises of two logically diverse elements such as the "instructional discourse (that carries specialized content and skills) and a regulative discourse (that creates the social and moral order of the curriculum)" (Lucket, 2009, p. 443).

2.3 Knowledge Structures of Life Science

Knowledge structure refers to what the students learn at a given period of time and the level of verticality (knowledge accumulation) in a discipline (Myers, 2016). Bernstein developed knowledge structures as 'fields of discourse' (Gamble, 2014). The ability of a teacher or educator to transmit knowledge lies in their skills in sequencing their knowledge structures according to the need of their learners, in this regards Bernstein (2000) establishes ways of conceptualizing 'structuring of knowledge' in different forms. Bernstein therefore differentiates them as; experiential knowledge *(horizontal discourse)* and *vertical discourse.*

2.3.1 Horizontal discourse

Horizontal discourse is also known as everyday knowledge (Gamble, 2014; Maton, 2009) that is context-dependent and specific, local, multi-layered, tacit and contradictory across contexts. Bernstein (2000) posits that the reason a part of a horizontal discourse is included in the curriculum is due to its usefulness as a strategy to facilitate access to curricular knowledge and also because of its limitation in the transmission of subject matter to that of the procedural level (pg. 169). But it cannot be the basis for constructing the curriculum (Rata, 2011). What this means in the life science context is that, learners bring with them prior concepts and misconceptions into the classroom, which they learn from their everyday life experience in their context and cultural background. Therefore it is the duty of the teacher to probe and use the students' prior knowledge to his/her advantage and relating it to the scientific concept during the teaching and learning process (Shulman, 1986). Also, the PGCE pre-service teachers, have prior knowledge as well, they have experience of the world outside the school context. Therefore, helping them learn Life science by contextualizing the concepts and linking them to their everyday life enable them to grasp the concepts easily. In this aspect, the semantic gravity is strong (i.e. meaning is context-dependent) because of its application to the Life science context. In addition, the nature of Life science is such that encourages contextualization of concepts, thereby allowing the students to learn through experience e.g. the use of the Botanical garden to teach ecology, population, etc. The idea of contextualizing a concept also helps in enhancing conceptual understanding. Therefore, my study investigated the level of understanding that the PGCE Life science pre-service teachers have regarding the nature of Life science.

2.3.2 Vertical discourse

The verticality (accumulation of knowledge from simple to complex) of the disciplinary knowledge in Life science is viewed as being systematically structured in nature. Vertical discourse is free from the local but takes the form of a comprehensible structure (Gamble, 2014; Maton, 2009), and systematically structured either 'hierarchically or horizontally'. In contrast to horizontal discourse, vertical discourse signifies 'specialized symbolic structures of 'explicit knowledge' and disciplinary knowledge thereby taking the shape of an overt and [2]'systematically principled structure' (Bernstein, 2000). For instance, the theories and methods in Life science as a scientific discipline are explicit and obvious in nature, especially in terms of its vertical structure (knowledge building).

Maton (2009) further acknowledged Bernstein's work by explaining that these knowledges are comprised of discourses which are characterized by 'functional relations of segments or contexts to the everyday life'. This implies that, for all knowledge acquired in a discipline, there is a language or grammar which makes it explicit. The function of this language that is used for knowledge building in a discipline, relates theories and concepts, thereby making knowledge to be systematically structured. For this reason, knowledge that is acquired in a particular context might have different meanings or grammar when used in another context, that is, the language used in knowledge building differ in different contexts. Therefore, knowledge from one context might be meaningless in other contexts (Bernstein, 2000) because meaning depends on its social context.

[2] Discourse in this context means power grammar used in teaching and accumulating disciplinary knowledge.

"The idea of verticality as a descriptor of knowledge for the curriculum has led to fruitful investigations which have been able to show that curricular subjects with different degrees of verticality require specific kinds of curricular sequencing and pacing to optimize their pedagogic transmission for all learners" (Young and Muller, 2014).

With this reason, disciplinary knowledge structures as referred to by Bernstein (2000) can be distinguished by either *hierarchical* or *horizontal* in the vertical discourse. The hierarchical knowledge structure is commonly found in science (Myers, 2016).

From the *internal relations* perspective of knowledge, the hierarchical knowledge according to Bernstein builds 'cumulatively and progressively' which causes the previous formulations to be incorporated by the later formulations. In hierarchical knowledge, different knowledge structures and their 'bodies of theory' are diverse in relation to their 'degrees of verticality' (Muller, 2007). For instance, in Life science as a scientific discipline, knowledge is accumulated and theories are built on existing theories, and what links the theories together is the discourse power. For example, the relationship between evolution and genetics can be traced to the idea of natural selection. In natural selection, the environment chooses certain characters or features of an organism which are determined by the gene. The environment causes mutation in the gene, thereby causing changes in the features of an organism. The change which occurred is then transferred from one generation to another, and this is the basis for evolution in Life science. But in contrast, the horizontal knowledge structure involves the increase of 'theories and relations' found between sets of concepts which do not occur as a result of one subsuming the other, but as a result of the accumulation of 'parallel theories'. In this regard, knowledge building in a discipline is not linked by the language of discourse, when new theories are formulated, they do not form a link with the existing theory e.g. Humanities. These forms of discourse according[i] to Young and Muller (2014) are irreducible to each other but can be ranked in terms of their 'degree of verticality'. From the *external relations* view, in the hierarchical knowledge structures, there is no separation between the grammars (syntax) and their theories; instead, there are sets of propositions which govern the description of various phenomena. There is a reality which cannot be separated from the phenomena that it explains (Young & Muller, 2014). From Bernstein's (2000) point of view, grammar refers only to the horizontal knowledge structure and it is the "series of specialised languages with specialised modes of interrogation (p. 157). According to Young and Muller (2014) it is the criteria for the "construction and circulation of texts" (p. 161) of a particular discipline in which its disciplinary knowledge is "theory proliferating" (Muller, 2007, p.72). For example, it refers to the language of science or scientific terms used in teaching concepts during the teaching and learning process (e.g. Photosynthesis).

In life science, concepts are sequenced hierarchically according to their relevance and they are connected and continuously built through theories, therefore, as they are taught to students they form links which enable students to understand them and the medium of transferring this knowledge is the use of science language. The concepts in Life science are well linked to each other in terms of its hierarchical structures (Bernstein, 2000) and it can also be related to other concepts outside its sub-discipline, which makes it context-independent. For instance, the Life science disciplinary knowledge structures are categorized according to their molecular level (e.g. the chemistry of life) and macro level, e.g. Biodiversity, as seen in the CAPs document.

Although the knowledge that the pre-service teachers have concerning their subject structures have not been investigated, but their understanding of the structures of their sub-discipline will enable them to understand its nature as well and what is considered legitimate in the discipline. The formation of subject matter structure (SMS) in Life science can be viewed to be as a result of the early content knowledge experience the pre-service teachers have, for example, their college content courses, and it is improved through the 'act of teaching or the learning of more content' (Gess-Newsome & Lederman, 1995). Furthermore, this subject matter structure enables the pre-service teachers to teach the concepts in the curriculum adequately, therefore, it is advisable to adequately prepare them during their teacher training program by considering the following three areas; "science content knowledge, SMS formation and implementation, and early experiences in science teaching" (p. 322). In this regard, Young (2009) posit that if the essence of school is to enable learners to acquire powerful knowledge, therefore the cooperation of groups of specialist teachers and university-based subject specialist both local and international will be needed for the selection, sequencing and inter-relating of knowledge in various domains (Young, 2009). But my study focused more on the vertical discourse of knowledge structure because, it emphasizes on how knowledge is accumulated in Life science and its disciplinary nature.

This structure is what gives Life science its nature. Also, it describes how knowledge is sequenced and made accessible to learners by re-contextualizing it. With this in mind, my study investigates the level of understanding that the PGCE Life science pre-service teachers have regarding the structures of their subject area (Life science), and its relationship to the school curriculum.

2.4 Pedagogical Knowledge structure as regards the school curriculum

Since curricular knowledge is part of the DK of Life science, it comprises of both the knowledge of the NOS and SMK. Curricular knowledge is the knowledge of the curriculum and according to Carr (1993) the curriculum is a set of proposals which indicate how subject matter should be organized rather than a description of subject matter, its educational purpose, the learning outcome it is designed to achieve and the method of evaluating such outcomes. For example, in the south African context, the curriculum and assessment policy statement (CAPS) is structured in such a way that it reveals the step by step process in which teachers are expected to carry out their teaching. Also, the "*knowledge strands are used as a tool for organizing the content of the subject".* The knowledge strands signifies various ways the concepts are to be taught from simple to complex and known to unknown due to its content based nature.

The strategy of accumulating and sequencing of knowledge in Life science is what Bernstein (2000) termed as 'Knowledge structure'. Knowledge structure informs pre-service teachers' ability to understand their subject matter structures and be able to implement this knowledge through their classroom practice (Gess-Newsome & Lederman, 1995). Hierarchical knowledge structure enable pre-service teachers to understand the link between each concept and these links are considered in sequence under the supervision of a more knowledgeable expert in the field (Myers, 2016) during their teacher training program. This according to the author explains the reason "In a hierarchical knowledge structure, the teaching of introductory concepts is so critical for students and why there is little room to decide which concept is to be taught next" (p. 82). It informs the 'how to each' in disciplines, that is, it is the sequence adopted by various discipline on how to transfer knowledge from simple to complex in the teaching and learning situation (Hierarchical knowledge structures). For instance, the CAPs document clearly reflects SMK of what should be taught in grade 10 and then build on it in grades 11-12, and teachers can clearly see the structure. But in terms of NOS, they do not have a specific structure on how to teach it, the scientific reasoning and inquiry is scattered all over in the documents. It is expected that the knowledge of the NOS should be embedded when they are learning the SMK. The course outline also is structured systematically for teaching and learning purpose, revealing the step by step of constructing knowledge, but it does not also show the structures of the NOS. Also, in this regard, for disciplinary knowledge to be acquired in schools, the step by step structuring of knowledge (courses and subjects) is required in order to disseminate it for easy understanding and access. Hierarchical topics were displayed from a single topic to the next one in terms of the SMK in the curriculum, but it is not same in terms of the NOS. Therefore it is not clear to the pre-service teachers that NOS is the branch of Life science that they need to know explicitly and then to use it in their own teaching.

The knowledge structure of science discipline in the institution under study, from the first year to the final year is structured in such a way that students can acquire basic knowledge according to their ability, that is, from basic to complex. According to Myers (2016) the students 'construct new knowledge' as they build on their previous knowledge, which explains the "concept of cumulative learning" (p. 82). For instance, in Life science, the content to be learnt for first years is general science which relates to what students need to know in order to do science, and by the time they get to their final year, they are taught the complex part of science in their specialisms. At this stage, they can already conduct research or understand what it takes to engage in scientific enquiries. For this reason, it is important to ensure that the students understand thoroughly the 'foundational concepts' before they move to the next concept, as this will form the basis for future learning (Myers, 2016).

2.5 The emergent nature of specialized knowledge

Disciplinary knowledge is specialised knowledge. Young and Muller, (2014) posit that specialized knowledge is formed by 'social conditions and 'contexts' where it originates from, but it is not reducible to them. The context in which knowledge originates from can leave its mark on the acquired knowledge (Young & Muller, 2014) but the value of that knowledge is not dependent on the contexts, this is because of the need for knowledge to maintain its specialization, reliability and power, thereby preventing it from being limited. From this point of view, meaning is not dependent on the significance of the context where knowledge emanates from, but it is hierarchically related to other meanings. For example, the Life science is less contextual, but its emergence from context can still be quantified e.g. the term DNA can be used in other contexts while it retains its meaning, but it can still be traced to its context of emergence. For this reason Haslanger (2008) argues that no knowledge can emerge as entirely independent away from its context, therefore to an extent; knowledge is reducible to its context and the agents responsible for its production e.g. The Life science as a scientific discipline is responsible for the emergent of the scientific terms used. For example, the emergent nature of some scientific or biological term can be traced to scientists who are specialist in the field of Life science, such as, Aristotle (classification of living things, 384-322), Robert Hooke (cell, 1635-1703), Charles Darwin (origin of species, 1809-1882). Young and Muller (2014) further explained that for social knowledge to become knowledge, it must meet the criterial rules needed for it to be acceptable in various disciplines concerned.

Although the rules can be 'contextually sensitive', the knowledge is not contextual which makes it fit as a disciplinary norm. It is therefore these social rules or norms that control the 'judgement of knowledge', making it specialized and reliable and not the peculiarities of the contexts and its agent (Whimster, 2003). Life science is context-independent due to its ability to relate with other discourses or fields, that is, Life sciences is viewed to be less contextual in the sense that the knowledge acquired is applicable both in and outside the school context. Life science has a high material density, in terms of its densely packed syllabus and population. For instance, the discourse DNA can be used in any other context such as Medicine, Chemistry, and it will still maintain its meaning and power. Therefore, it is evident that the nature of Life science is highly diversified, considering the fact that the terms used in its context can be used or applied in any other context.

2.6 The disciplinary knowledge implications in pedagogy

Science is a community with distinct methods of practice and learning and its sub-disciplines (Biology, Physics, chemistry, and so on) also operate within its paradigm. Therefore, the induction of novice into its epistemic community of practice involves its method of learning, by practicing the scientific skills that are necessary for becoming a specialist in the field. Because science is a community, and preservice teachers of science are now members of that community through induction, which operates within this paradigm, they are expected to have the disciplinary knowledge of Life science as a scientific discipline. Harvey (2011) posit that learners do bring their own specific 'orientations' to school to learn, but the knowledge acquired from the disciplines influence them on the need and how to be a well-informed being. If pre-service teachers do not have this knowledge, they will not be able to teach the knowledge they have, therefore, it is crucial to have knowledge of the Life science as a discipline. When students acquire adequate subject matter knowledge, they become masters of that knowledge and are able to make the knowledge accessible to students in the classroom (Kind, 2009). Therefore, what students learn and how they acquire knowledge will determine how they make it accessible in the classroom teaching and learning process. Therefore if they do not learn about the disciplinary structure of Life science or the nature of Life science, they will not be able to teach accurately in the classroom. A biology pre-service teacher who learnt how to perform an experiment based on known outcome, by using the disciplines' established method, will also use this skill to impart knowledge on the students. Meaning if the disciplinary structure is not learnt, then their SMK might be poor.

The disciplinary knowledge acquired by PGCE pre-service teachers during their undergraduate program is expected to immerse them deeply into the knowledge of the content and scientific enquiry. They also acquire the knowledge of pedagogy in their methodology courses that they have been taught during their post graduate program, which will equip them and help them teach as professionals and ensure the students' adequate understanding of the subject in the classroom. In order to teach, one needs the content knowledge (Shulman, 1986), and for this reason, there is an eagerness to make content a requirement by policy makers. The requirements will be based on "commonsense notions of content knowledge" i.e. listing of topics without emphasizing the "nature of content knowledge needed" (Ball *et a*l., 2008, p. 394). The nature of content knowledge demand the use of accurate theories in the methods used in getting the content in Life science. Investigations have been carried out on pre-service teachers' content knowledge but not the nature of their disciplinary knowledge. The reason is that emphases are not made on the particular skills students should have during their training as teachers in the institution under study. This was the motivation for this study: to investigate the understanding the PGCE Life science pre-service teachers have of the nature of Life science as a sub-disciple of science.

2.7 Theoretical framework

2.7.1 Legitimation Code Theory (LCT)

The discussion that was presented in this research report is grounded on the legitimation code theory (LCT) contributing to knowledge building. Maton (2005a) is of the opinion that the practices and views of various participants in a field is made up of 'languages of legitimation' in which information concerning what need to be considered legitimate in a field is embedded. Legitimation code theory (LCT) is a social realist framework that is used in informing practice and research (Maton, 2010). It is a combination of several approaches that interpret knowledge as being real and socially formed (Wheelahan, 2010). The concept of LCT is used across disciplines for analysing research and also "revealing complex diversity of organizing principle at play" and giving room for knowledge-building (Maton, 2016, p. 6). LCT is made up of several dimensions, that is, it is a '*multi-dimensional conceptual toolkit*' and in each of this dimensions are concepts that can be used to analyse "a set of organising principles underlying practices as legitimation codes" (Gamble, 2014, p. 182). LCT is therefore made up of a system of codes within dimensions that one can use to bring out or view the structure of a body of knowledge (Maton, 2010).

LCT can be used to find out if a body of knowledge can be viewed as a discipline. The LCT dimensions are five in number and they are; the Autonomy, specialization, Semantics, Density and temporality dimensions respectively. They individually focus on 'conceptualizing' legitimation codes or organizing principles in different forms (Gamble, 2014). For this study, four dimensions such as, Specialization, Semantics, Density and

Temporality dimensions were focused on to investigate the level of understanding that the PGCE Life science pre-service teachers have in terms of the disciplinary structure of Life science.

2.7.1.1 Specialization Dimension

The specialization dimension of the LCT describes the proficiency found in the specialist knowledge and methods of a discipline. Proficiency has to do with membership, status, achievement and authority (Arbee, 2012) in a discipline. For example, for an individual to be considered as a legitimate knower in Life science as a scientific discipline, they must show an understanding of its unique 'knowledge base' and the procedures that are used in generating knowledge (Arbee, 2012). According to Maton (2005a) various fields are specialised in relation to knowledge and knowers, but the attributes of individuals are not considered to be important in as much as they are proficient in the knowledge and ways of knowing of a discipline.

The specialization dimension differentiates fields from each other basically in terms of what and how knowledge is legitimately pursued and who is considered as a 'legitimate knower'. Specialization focuses on what epistemological access consists of, and describes a disciplines' ways of 'knowing and being (nature) as its characteristics (Arbee, 2012). Therefore the specialization codes concepts can be analytically distinguished into their epistemic relations (ER), which relates with practices and their object; and social relations (SR), which relates with practices and their subjects (who enacts the practice) (Maton, 2016). The authors further explained that the specialization relations may be stronger (+) or weaker (-), but the two might be varied to create specialization codes (ER+/-, SR+/-) respectively. Below is a figure illustrating the specialization legitimation codes.

Specialization:

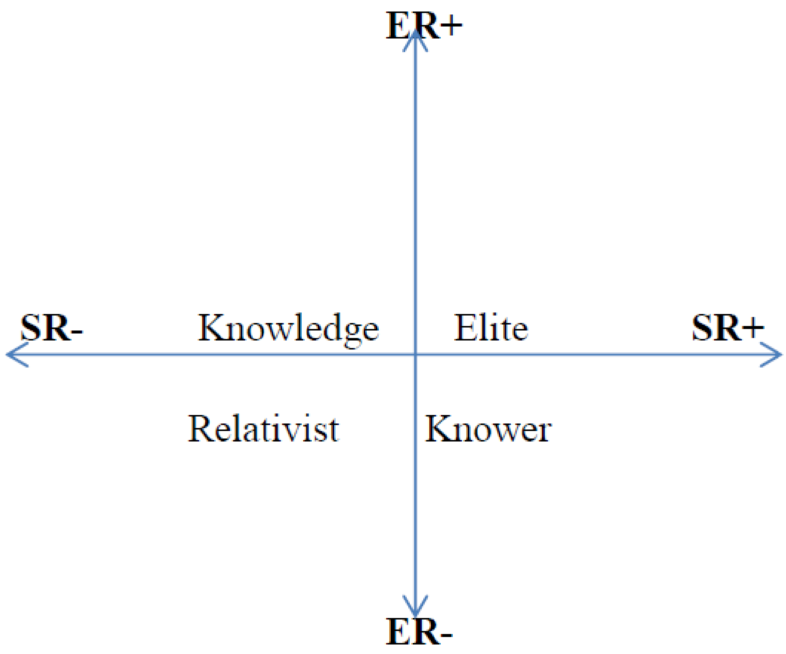

***Fig 2*: Illustrating the specialization codes, adapted from Arbee (2012)**

The ***knowledge code*** is known to be ER+ and SR- respectively along the plane. It talks about how the specialized knowledge possessed is emphasized upon, as well as how the principles relating to a specific object that is being studied are viewed as the main point of achievement, whereas, the knowers' attributes are ignored (Maton, 2016). Whereas, the ***knower code*** is represented by ER- and SR+ along the plane. In this category, the specialist knowledge and skills are not considered important, emphasis is more on the attributes of the individual as a measure for achievement (Arbee, 2012). These attributes could be natural talents, cultivated or social (Maton, 2016). In Life science sub-discipline, what matters is knowledge while the knower attribute is not considered in the sense that theories, methods of knowledge acquisition, knowledge structures are considered paramount compared to the personality and social skills, etc. Therefore the knowledge code is what is considered obtainable in the Life science field. The ***elite code*** is represented as ER+ and SR+ respectively. In the elite code, emphases are laid equally on both the knowledge and the knower. The basis of legitimacy is on the possession of both (Maton, 2016). There is no elite code in the Life science as only knowledge and not knower is what is important. The fourth code known as the ***relativist***

code is represented by ER- and SR- respectively, and it means that legitimacy is based on neither the knowledge nor the attributes of the knower. Both the elite and the relativist codes are not applicable in the Life science sub discipline. That is, what matters in Life science sub discipline is knowledge. After considering all four specialization codes and the hierarchical knowledge of Life Science, knowledge is what is important and not the knower. According to Myers (2016) in a discipline, knowledge is considered important and not the knower.

2.7.1.2 Semantic Dimension

The semantics dimension of the LCT talks about the extent at which meaning is bound to the context of a discipline, which may be stronger (+) or weaker (-) (Gamble, 2014). For instance, the scientific disciplines, such as Life science, physical science varies in relation to how knowledge is accumulated in their various fields. Some vertically progress through the integration of knowledge and building on existing knowledge to generate a much bigger theory while some laterally advance as they add new knowledge to the existing knowledge (Arbee, 2012). Semantics dimension enables the investigation of 'knowledge and meaning' as well as the fields' capacity to accumulate knowledge by the means of two basic concepts such as semantic gravity (SG) and semantic density (SD).

The semantic gravity focus on the level at which meaning is 'bound to a context' while semantic density focus on the level at which "meaning is condensed within socio-cultural practices" (Arbee, 2012, p. 46). The legitimation codes of the semantics dimension are categorized according to their strength, which differs individually to create semantic codes (SG+ and SG-, SD+ and SD-). For example; SG+ signifies that there is stronger context-dependence of meaning, while SG- represents a weaker context-dependence. Also, SD+ implies that the condensation of meaning to context is stronger, while SD- represents a weaker condensation of meaning to context (Maton, 2016). For instance, in Life science sub discipline, Knowledge is independent of context (weak semantic gravity-SG-) e.g. DNA means the same thing in SA, USA, UK, while knowledge is condensed (strong semantic density-SD+) e.g. one can write several pages from the word photosynthesis. Below is a figure displaying the semantics legitimation codes.

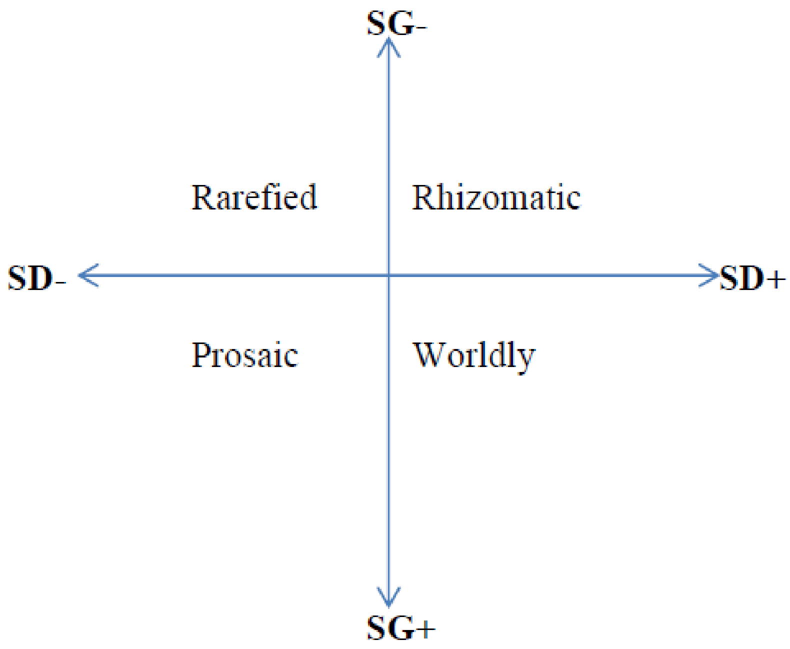

Fig. 3: **Illustrating the semantics legitimate codes, adapted from (Maton, 2016).**

Maton (2016) posit that the strength of the semantic codes can be pictured as "axes of the semantic plane", having four "principal modalities" (pg. 16). These modalities are; ***Rhizomatic codes*** which is represented by SG-, SD+ and it deals with the components of the basis of achievement as being "relatively context-independent and complex stances". The ***prosaic codes*** which is represented by SG+, SD-, deals with the accumulation of legitimacy to "relatively context-dependent and simpler stances" (Maton, 2016, pg. 16). The ***rarefied codes*** which is represent by SG-, SD-, talks about how legitimacy is grounded on "relatively context-dependent stances" and also having lesser meanings. The ***worldly codes*** which represented by SG+, SD+, talks about how legitimacy deals with "relatively context-dependent stances" and having diverse meanings (Maton, 2016).

2.7.1.3 Density Dimension

The density dimension deals with the differentiation of fields internally, the agreement made concerning what should be considered a disciplinary knowledge domain, its procedures, methods, focus and a common cultural practice of the discipline, enabling epistemic access (Arbee, 2012). The authors further explain that decisions are made on the coherence of the discipline and what makes up the “legitimate rules of the game” (p. 47). Density dimension deals with how diversified a field is and how they draw knowledge from other fields within as regards its content and beliefs for knowledge-building. For instance, the field of life science draws from several other fields within the discipline of science, that is, chemistry, physics, mathematics, geography, etc. when learning life science, the students also have a little bit of physic and chemistry knowledge due to the diverse nature of biology. It also deals with the size of the content being taught, its structuring principles found within the context and the size of the disciplinary community, this makes up the material density of the academic discipline, while the ‘school of thought, belief system of the discipline is referred to as ‘moral density’ (Maton, 2005a). Thus, the legitimation codes for the density dimension are; MaD+ and MoD+ which represents high material and high moral density of a discipline. High material density means that the amount of content to be taught in a discipline is very high and high moral density means that there are many beliefs and rules associated with the discipline. MaD- and MoD- represents diversity that is relatively low in material and moral density (Arbee, 2012).

Therefore, Life science sub discipline can be characterized by the code MaD+, MoD+ because of its highly dense material and moral nature. Below is a figure showing the legitimation codes of the density dimension along its planes.

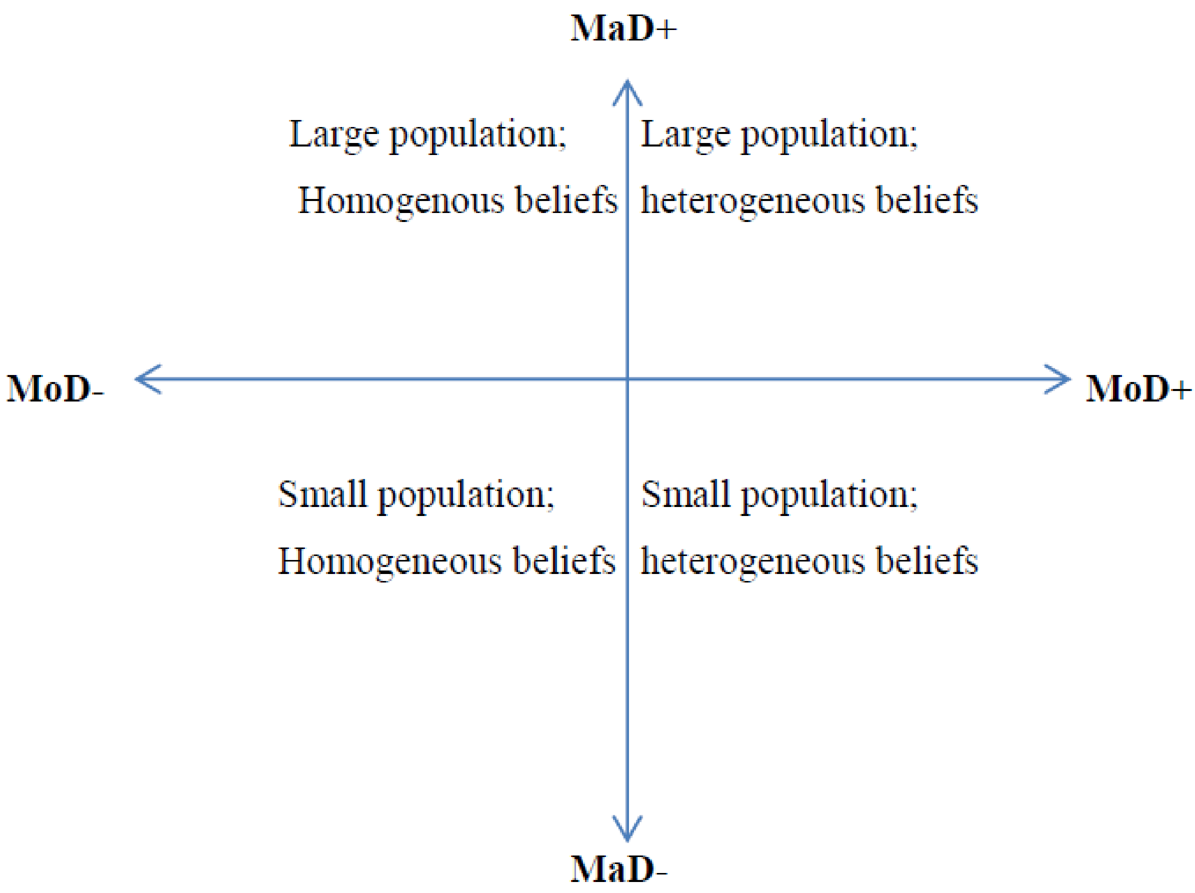

Fig. 4: Illustrating the Density codes, adapted from Arbee (2012)

Large or small population represents the size of the discipline in terms of its breadth, tightly packed syllabus, and the community associated with the discipline. Heterogeneous represents the different belief systems of the discipline which could lead to controversies on what should be considered legitimate in a discipline, while homogeneous belief represents similar belief system in a discipline. The nature of Life sciences can be found along the plane of MaD+, MoD+, which means that the discipline has a high material and moral density. Life sciences have high diversity, and its belief system such as the different beliefs among specialists and educators could cause issues of legitimation. For example, for theories of evolution, recreationist theories, stem cells, have caused controversial issues in the Life science discipline. What to teach and what not to teach is as a result of these various theories, because of its effect on the different beliefs of specialists and educators due to their cultural background, religion, and so on.

2.7.1.4 Temporality Dimension

The temporality dimension focuses on the establishment of a discipline, whether it is recently established or long established. It deals with how fields are differentiated according to their temporal profiles and also looks at the temporal positioning (TP) and temporal orientation (TO) of a discipline (Arbee, 2012). The features (temporal positioning and orientation) determine the level at which change occurs in a field (Maton, 2005a). For instance, the discipline of science has been long established before the 19th century. Therefore, since the Life science is a sub discipline of science, all its theories and methods are long established and future looking. For example, Evolution deals with how organisms have evolved from thousands of years ago. Also, Penicilium was used in the past to treat bacterial infections, but as organisms grew resistance to the anti-biotic, other forms of medications have evolved.

Also Khun (1962) confirmed the age of science through his study of the scientific revolution, where it talks about how science evolved and how scientific theories are being discarded as new theories and findings are formed. With this regard, Arbee (2012) is of the opinion that one of the criteria of considering a field is by looking at how long it was established or newly formed. Discipline such as science is a well-established discipline which has its own traditions, culture, theories and procedures that helps in understanding what should constitutes a legitimate way of knowing. The following are the four legitimation codes for temporality dimension; TP+ and TO+ represents Archeo-retrospective, which means that the discipline is old and backwards-looking; TP+ and TO- represents Archeo-prospective, and it means that the fields is old and forward-looking (e.g. Life science); TP- and TO+ represents Neo-retrospective, which means that the field is young and backward-looking; and TP- and TO- represents Neo-prospective, meaning that it is young and forward-looking. The figure below is an illustration of the legitimation code of the temporality dimension.

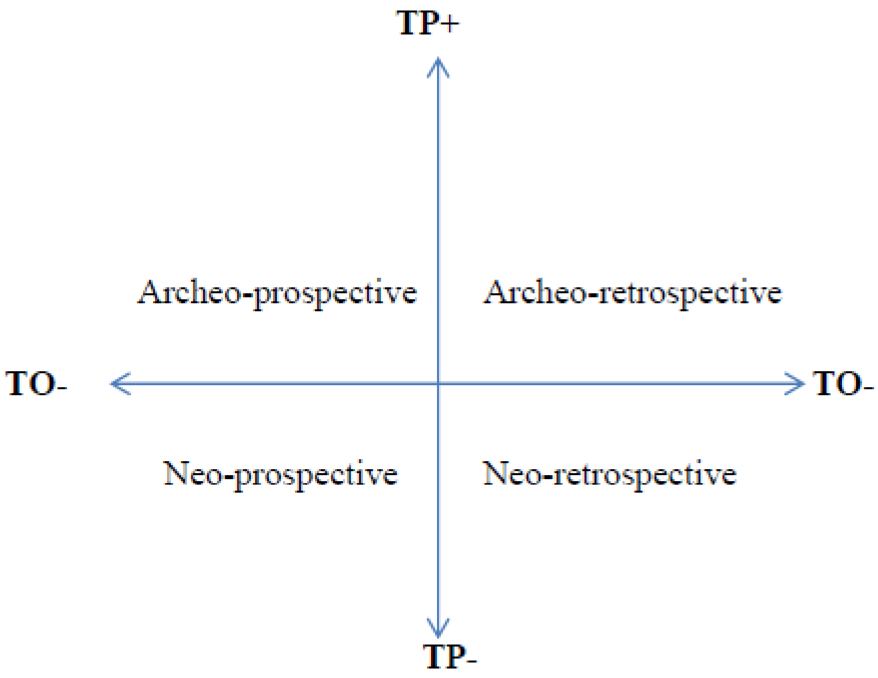

***Fig. 5*: Illustrating the Temporality legitimation codes, adapted from Arbee (2012)**

These four LCT dimensions were used in this study to analyse and bring out PGCE PSTs' levels of understanding of the disciplinary nature of Life Sciences. Although, there are few literatures and study conducted in this line of field, a similar study was conducted in the marketing department of the University of Kwazulu-Natal, by Aradhna Arbee in 2012. The finding of the research thesis showed that in marketing what matters most is the knower code, which means that the personality and attributes of the knower is more important than the knowledge of the discipline. Also, it was found that the discipline of Marketing is young and forward looking, and it revealed a high autonomy power from other disciplines. Marketing was found to have a relatively high level of density. Therefore, the author recommended that since Legitimation seems to arise from producing valuable knowledge that is applicable to specific contexts, rather than from the building up of an abstract and theoretical body of knowledge, therefore the ability to apply knowledge and familiarity with the context of application (the business world) are vital for the Marketing students.

2.8 Conclusion

As explained in this literature review, disciplinary knowledge of Life science deals with the SMK and the knowledge of the NOS. SMK is viewed as the main component of a discipline which a teacher requires to enable adequate conceptual understanding in the classroom. The NOS deals with the scientific investigations, inquiry, and so on. Knowledge structures are distinguished as horizontal and vertical knowledge structure. Literature was reviewed and the conceptual framework adopted for the literature was Young (2007) powerful knowledge. The various concepts linking to the study was explained in details. The theoretical framework adopted for this study was the legitimation code theory (LCT) which was explained in details.

Chapter three

Research design and methodology

3.0 Introduction

In this chapter, I discussed the various research approaches, research design and the samples that were needed for the research in order to answer the questions posed for my study. This study explored the PGCE pre-service teachers' level of understanding of the nature of life sciences as a sub-discipline at the end of their training. A case study approach was considered suitable to respond to the research questions for the purpose of my study.

3.1 Methodology

3.1.1 Research Design

In this study, a case study of PGCE students was used as the research strategy. The case study methodology is the most relevant when the method modelled for the research study stresses on an in-depth description of a social interaction. McMillan and Schumacher (2010) consider a case study as one of the various strategies for a detailed investigation of the interactions of a small group of people. Similar to that, Yin (2009) is of the view that case study investigations are carried out in their real-life context; understanding how the case impacts the phenomenon and is influenced by its context is usually of essential interest to case study researchers. Likewise, Creswell (2008) points out that a case study consists of a system bounded by factors, including time and place. This, according to the author, represents the significant features of every case study. With respect to that, this study considered detailed investigation of the disciplinary knowledge and SMK of a group of PGCE pre-service teachers who were studying together at the same institution for the same duration and at the same time.

Yin (2009) further explain**s** that case studies include the use of multiple sources of data such as interviews, observation, questionnaires, archival documents and even physical artefacts in order to allow triangulation of findings. Some case study research methods may use a mix of qualitative and quantitative data since it can accommodate different disciplinary perspective

(Merriam, 1998). In order to achieve the aim of gathering detailed information about PGCE preservice teachers' disciplinary knowledge, questionnaires and interviews were used to collect rich qualitative data in this study. Therefore, it was the researchers' intention to use the questionnaire and interview conducted to collect a well detailed data by probing the participants of the phenomenon. This is in line with the argument by Mcmillan and Schumacher (2010) that collecting multiple data in a case study helps in having adequate information on the phenomenon being studied.

The reason I chose the PGCE Life science pre-service teachers was because I needed to investigate the disciplinary knowledge of the students who acquired consecutively; the general (content knowledge) and professional (teaching skills) components during the course of their training program (please see section 1.1 for more details). Creswell (2013) posit that in a case study approach, the investigator explores a real-life contemporary bounded system (single case) or multiple bounded systems (multiple cases) through detailed data collection which involves multiple sources of information, a case description and reports. My study fits into the single case system because; it deals with the PGCE Life science pre-service teachers in a single context. In agreement with this, Opie (2004) is of the opinion that a single case study deals with a single unit of a phenomenon under study. When the boundaries between the 'phenomenon and context' of the research are not obvious, a case study approach is considered appropriate (Yin, 2009). In the case of this study, PGCE Life science pre-service teachers were part of the context, because they are students of the institution under study.

Therefore, in order to understand the disciplinary knowledge of PGCE students, there was need for in-depth analysis of the case. In this study, a qualitative method was adopted as the research approach. Embedded in this qualitative approach as used in this study, are the features of quantitative method. While in research studies, a qualitative method gives detailed description of events in narrative form using words, a quantitative method on the other hand uses numbers and statistical analysis in collecting and interpreting data (McMillan & Schumacher, 2010). The two methods make up the research design employed in collecting and analysing the data used in this study. The nature of the research question required that while qualitative method represented the main method, the quantitative method should be incorporated in providing quality answer. The quantitative part of analysis involved tables and numbers that were derived from the questionnaire responses while the qualitative part was on narrative discussion on both the open-ended and interview responses. As Basit (2010) posits that qualitative data is seen as a presentation of depth while the quantitative data present precision. Cohen, Manion and Morrison (2005) posit that there is no one perfect way of presenting and analysing data, there are many ways of presenting and organizing qualitative data such as, categorizing, merging themes through coding and discussing it as a narrative. For instance in my study, themes were formulated and then codes established from the responses given by the participants in the open ended section as well as during the interview. The codes were then interpreted as a narrative because of the social nature of the phenomena. In agreement with this, Marshall and Rossman (2011) were of the opinion that qualitative research is referred to as "a broad approach to the study of social phenomena. Its various genres are naturalistic, interpretative, and increasingly critical, and they draw on multiple methods of inquiry" (p. 2). In order to comprehensively understand the nature of the disciplinary knowledge that PGCE pre-service teachers acquired prior to and at the end of their post-graduate studies, the qualitative research was considered most appropriate in this study.

3.1.2 Research participants

The participants of this study were sixteen (16) PGCE pre-service life science students, out of 27 students who enrolled in Life science in 2016, and two (2) Life Science lecturers. The category of PGCE pre-service teachers used in this study was considered suitable and purposefully chosen for three reasons. First, their subject of specialization is life sciences and they are being trained to become teachers of the subject in the nearest future. Second, there is a kind of bounded system, which is considered by time and place (Yin, 2011). Third, the set of pre-service teachers involved were studying at the same time, for the same duration (one year for most of them); at the same institution of learning and for the same degree (Post-graduate certificate in Education). For these reasons, they are assumed to have been exposed to the same disciplinary knowledge in preparation for classroom teaching and learning of life sciences. This research is based on studying a unit within a single case study. According to Opie (2004) case study could involve a group of people within a setting and the life science PGCE pre-service teachers fit into this group of participant. A population is a group of persons or components who fit into certain specifications and is used to achieve information for the purpose of that particular research (McMillan &Schumacher, 2006), and is of interest to the researcher. This kind of group is also viewed as a target population due to the fact that it is a group of persons having similar characteristics identifiable to the researcher. All the PGCE class of Life sciences represents the sample. This study chose the sampling method based on the measure that questionnaires will be administered to the participants and a focus group interview with both the students and teacher educators. The teacher educators are the lecturers who are in charge of teaching the life science PGCE Life science pre-service teachers. The teacher educators were 1 male and 1 female who are both specialists in Life science. Below is a table showing the demographic information of the teacher educators.

Table 3.1 showing the information about the teacher educators

Participants	Gender	Years of experience	Specialization	Highest qualification in Life science
Teacher educator 1	Male	33	Life science	M.sc
Teacher educator 2	Female	35	Life science	Ph.D.

Please see appendix 5 for more details

3.2 Data collection method and Research Instruments

This study investigated the level of understanding that PGCE Life science pre-service teachers have regarding the nature of their subject area, that is, their disciplinary knowledge and subject matter knowledge. Therefore, the data collection tools were questionnaires and focus group interview questions which were adopted from a bigger project in the institution under study. The adopted questionnaires were already validated by the researchers in charge of the bigger project. The questionnaire suit my study because, it can be used to understand the disciplinary knowledge of the PGCE students and also to know to what extent the program equip the pre-service teachers with knowledge required for teaching. The interview was a semi-structured interview, and it was used to gather information from the participants since it is more flexible than the structured interview and will allow a depth of feeling to be discovered (Opie, 2004) which provides opportunities for the researcher to probe further, expanding the interviewee's responses. A copy of the interview can be found in appendix 7.

3.2.1 Questionnaire

Questionnaires are survey research instrument that are used to collect data from individuals about themselves, social related issues and other matter (Siniscalco & Auriat, 2005). The use of questionnaires allows participants to be fully involved in the research; this is because according to Cohen et al. (2005), they are observed as subject of the research process and not just an object. In this study, questionnaires allowed for participants' active involvement by asking questions relating to their acquired knowledge in the discipline and subject of specialization. Cohen et al. (2005) caution that when administering a questionnaire, participants of the research must not be forced in completing a questionnaire, it should be requested of them to make the decision of a voluntary participation. Efforts were made in this study to ensure the participants' voluntary participation in completing the administered questionnaires. Research instruments are generally known to have both strengths and weaknesses. Questionnaires are known to have their strengths and weaknesses. Mcmillan and Schumacher (2006) mentioned that the weaknesses of a questionnaire are; first, the answers of a questionnaire may be false and social desirability; second, the inability of the researcher to probe and clarify; third, low rate of response from mailed questionnaires; fourth, to score the open-ended section is usually difficult; fifth, questionnaires are restricted to participants who can read and write.

The authors also mention the strengths to be that; questionnaires are usually easy to score, anonymity is encouraged, it is economical, gives the subject adequate time to think of their responses and it encourages a uniform procedure and standard questions to be administered (Mcmillan & Schumacher, 2006). This study considered the strengths mentioned above, as it allowed adequate time for the participants to respond to the questionnaires and also, its uniform procedures provided during the responses. In this study, the researcher took the onus of administering the questionnaires to the participants and then after a while collected the responses to avoid delays from emails. Also, at the time of this study, all the PGCE Life science pre-service teachers had already completed their course work for 2016 session and were preparing for their examinations; therefore the issue of not being able to read and write were not encountered. The purpose for choosing this period is to enable the researcher to be able to gather information on their knowledge of Life science at the end of their PGCE program. Also, all the questions were accessible to the PPGCE pre-service teachers due to its simplicity. The use of questionnaire was to explore the nature of the disciplinary knowledge of the pre-service teachers, which was supported by an interview. The type of questionnaire administered for this study was a Likert scale questionnaire. The Likert scale questionnaire was explained in more detail in the next section.

3.2.1.1 The structure of the questionnaire

The questionnaire had three sections; the first section contained the program of study of the participants, their specialization and their experience in the field of study; the second section was a Likert scale. According to McMillan and Schumacher (2014) a Likert scale is "*one in which the stem includes a value or direction and the respondent indicates agreement or disagreement with the statement*" (p. 214). A Likert scale is of benefit in that it provides great flexibility due to the descriptors it contains which can vary to fit the nature of the question or statement in a particular study (McMillan & Schumacher, 2014). While, agree-disagree format is commonly used in Likert-scale, McMillan and Schumacher (2014) argue that such format could be very misleading. The use of 'neutral' category was included in addition to 'agree' and 'disagree' in this study. This was done to avoid the participants being forced either to make a choice that is incorrect or not to respond at all. The Likert scale items were twenty two (22) in number while the open ended statements were two. The Likert scale section focused on eliciting the pre-service teachers understanding of Life science in terms of the three dimensions of the LCT theory (Specialization, Density and Temporality). The third section contained two open ended questions which aimed at eliciting their understanding of Life science as a sub discipline. The open-ended section was designed to support the responses given in the questionnaire (please refer to appendix 4).

3.2.2.2 Explanation of the Likert scale items

The Likert scale items focused on three different dimensions of the LCT. Items 1, 2, 3, 4, 5, 10 and 20 focused on the Specialization dimension, items 6, 7, 8, 9 focused on Temporality dimension, while items11, 12, 13, 14, 15, 16, 17, 18, 19, 21, and 22 focused on Density dimension respectively. The reason these questions are different is because they connote different meanings as they represent the dimensions. Also, they are different in order to explore the understanding that the PGCE pre-service teachers have regarding their disciplinary knowledge. Below is a table showing the item statements of the questionnaire based on the specialization dimension of the legitimation code theory. The items in table 3.2 depict the specialization dimension of the legitimation code theory. The purpose of these questions was to understand the views of the PGCE pre-service teachers concerning the relationship between personality (social relations) and knowledge (epistemic relations) within Life science as a sub discipline of Science. To know whether they think personality is the ground for knowing life sciences or knowledge. The questions deal with whether it is important to have some special attributes to understand the subject (knower matters) or whether knowledge is what matters (Arbee, 2012). The total number of the items in the specialization dimension was six (6).

For items 1 and 20, if a respondent chooses agreed, it means that they believe that what matters most in Life science are the knower attribute and not the disciplinary knowledge itself. But if the respondent chooses disagreed, it means that a person's attributes do not matter when learning about Life science as a sub discipline.

For items 2, 3, 4, 5 and 10, if a respondent chooses agreed, this means that the respondent believes that what matters most in Life science are knowledge and not the knower attribute. But if they choose disagreed, it shows that the respondents do not agree that what matters most in Life science is knowledge, but the knower attributes. Below is a table showing the items for specialization dimension and their explanations.

3.2.2.3 Specialization Dimension

Table 3.2: Showing the items representing the Specialization dimension

Item No.	Item statement	Explanation of the statements
1	It takes someone with a special kind of personality to be an expert in this subject	An individual must have some special attributes to be viewed as an expert. Therefore, 'agree' means knower matters
2	Anyone can learn this subject given sufficient time or training	There are no special attributes required to learn and become an expert in Life Science. Therefore, 'agree' means who the knower is does not matter
3	There is a special kind of knowledge that a subject specialist needs	Life Sciences have a defined body of knowledge that an individual needs to learn in order to become a Life Sciences specialist. Therefore, 'agree' means that knowledge is what matters in the discipline.
4	There are special skills that one develops when learning this subject	Life science is made up of scientific skills which are required to be a Life science specialist. 'Agree' means that what matters in Life science is knowledge
5	To learn this subject, one needs to 'get a feel' for it through experience	An individual needs to be encultured into the Life science community of practice in order to be acquainted with it. 'Agree' means that knower does not matter, everyone must acquaint with the knowledge.
10	It is vital for teachers to understand what this subject is, and what it is not	Life science specialist must understand the knowledge barriers of the field. 'Agree' implies that what matters most is knowledge.
20	Certain kinds of people understand this subject better than others	Personal attributes are not important in Life science. Therefore, 'agree' means that students think that who the knower is matters.

Total number of questions: 7

Note: In all cases, disagree does not necessarily mean the opposite, but rather it means the student has a different view to what agree means.

3.2.2.4 Density Dimension

The items on table 3.3 depict the density dimension of the legitimation code theory. The purpose of these questions was to understand whether the respondents understand the nature of the content and its structuring principles, that the subject has network of theories supporting it and also their views of the subject as a body of knowledge. For all the items, when a respondent chooses agreed, this means that they agree that the disciplinary knowledge of Life science is well diversified and it composes of various theories relating to one another. Agreed means that there is a high material and moral density in Life science. When a respondent chooses disagree, this means that the respondent does not believe in the diversified nature of Life science, therefore it has a low material and moral density. Below is a table showing the Density dimension items and their explanations

Table 3.3: Showing the items representing the Density dimension

Item No.	Item statements	Explanation of the statement
11	People can use knowledge from this subject for purposes that exist outside the discipline	The knowledge acquired in Life science is diverse, as it can be applied in other disciplines. 'Agree' implies an understanding that Life science has high material and moral density.
12	When teaching this subject, teachers draw on knowledge that is located outside the subject	The diversified nature of Life science allows teachers to make reference to other knowledge domain. Therefore 'agree' means that the student have an understanding that Life science has high material density
13	This subject makes links between theoretical concepts and real world examples/problems	The nature of Life science discipline is such that it includes real world issues in its body of knowledge, and this result in a large volume of content, hence high material density. Therefore, 'agree' implies an understanding that Life science has a high material density.
14	A course in this subject would be made up of a collection of different (often dependent) modules	Life science is made up of several linking concepts; hence 'agree' means high material density.
15	The sequencing of modules in	The sequencing of modules reflects certain

	this subject is essential for students' understanding of the subject.	beliefs and ideas about the content. A survey of modules and textbooks shows different structuring principles and beliefs. Therefore, 'agree' means high moral density.
16	There is wide agreement amongst subject experts about the nature of the subject	The Life science disciplinary community is very diverse with a wide range of beliefs as explained in chapter two. Therefore 'agree' means high moral density.
17	There are strong theories that hold this Subject together as a networked body of knowledge	Life science is made up of several linking theories and people think differently about the theories; hence 'agree' means high material and moral density.
18	It is very clear where these subject boundaries are	Life science as a body of knowledge has boundaries within its concepts and topics. Therefore 'agree' means a low material density
19	This subject is connected to many other subjects	Life science is highly diversified. Therefore, agree means high material density
21	To be an expert in this subject requires that one holds certain beliefs	Life science has a large amount of content, and the specialists in it have different belief systems regarding the content. Therefore, 'agree' means that the student understand that the discipline has a high material and moral density.
22	This subject gives one a special way of understanding real life problems, and addressing them	The diverse nature of Life science as a body of knowledge is such that helps in understanding the outside world as well as solving real issues. Therefore 'agree' means a high mora density.

Total number of item (s): 11

3.2.2.5 Temporality Dimension

The items in table 3.4 depict the Temporality dimension of the legitimation code theory. The questions means that all the knowledge accumulated in Life science as a scientific discipline can be used to understand past knowledge and events that happened in the past, as well as new discoveries in the future. The questions are posed to understand how the respondents view science in terms of its origin and nature. And also their views on how the disciplinary knowledge of Life science can be used to understand the past, whether there is a connection between the present knowledge about the subject and the past. The total number of the items in the temporality dimension table is four. For items 6, 8 and 9, if a respondent chooses agree, this means that they believe that the disciplinary knowledge of Life science is old and forward looking. But when a respondent chooses disagree, it means that the disciplinary knowledge of Life science is new and forward looking. Meanwhile for item 7, if a respondent chooses agree, this means that they believe that the disciplinary knowledge of Life science is old and backward looking. But when the response is disagree, then it means that the disciplinary knowledge is new and backward looking. Below is a table showing the items of the Temporality dimension and their explanation.

Table 3.4: Showing the items representing the Temporality dimension

Item No.	Item statement	Explanation of statements
6	This subject makes connection across time	Life science is an old body of knowledge which is future oriented. Hence 'agree' means that the students understand that it is archeo-prospective (old and forward looking)
7	This subject tries to understand how things were in the past.	Life science as a body of knowledge deals with past knowledge. Therefore, 'agree' means that it is Archeo-retrospective (old and backward looking).
8	This subject tries to understand how things are in the present	Life science deals with knowledge of the present discoveries. Therefore, 'agree' means that the students have the understanding that it is archeo-prospective (old and forward looking).
9	This subject makes predictions for the future, or informs planning for the future	Life science as a body of knowledge helps to understand or focus on what happens in the future. Therefore, 'agree' means that it is Archeo-prospective (old and forward looking).

Total number of items: 4

3.2.3 Analysis of the open ended section of the questionnaire

The open ended section of the questionnaire had two statements. The first statement states; *when someone studies this subject, they learn about…?* While the second statement states; *When someone studies this subject, they learn how to…?*

The purpose of the first statement was to establish the SMK of the pre-service teachers while the purpose of the second statement was to establish their knowledge of the NOS. Analysis of the open-ended responses was deductive. SMK and NOS are the codes that I used to code what students were saying. Below are examples of a response from a participant to show how the data was going to be analysed.

When someone studies this subject, they learn about…

> ***PGCE3:*** *the components of life such as cell and its components (SMK). The human body and how it works (SMK). Interactions between organisms and their environment (Density, SMK). History of life (NOS)…..*

The response cites examples of content knowledge that the student learnt-cells and its components which is part of SMK and also the history of life sciences which is part of the NOS. For example, I expected them to list concepts for SMK and for NOS I expected them to mention the history of science, skills, and so on. See table 3.6 for example of responses showing SMK and NOS.

When someone studies this subject, they learn how to…?

> ***PGCE3:*** *respect the environment (Density) and the components of the environment (SMK). Conservation of nature and resources (SMK, Density). Understand how their bodies work. Relate the history of life to current life (NOS). How the aspect of life has evolved (Temporality) and how science has contributed to medicine (Density)….*

3.2.3 Interview

In this study, interviewing was used as another method of collecting data. An interview, as described by Opie (2004) is a suitable research instrument used to elicit information regarding participants' opinions about issues under investigation. Using an interview in this study helped examining the PGCE pre-service teachers' disciplinary knowledge of Life science. There are structured, semi-structured and unstructured types of interview. Structured type of interview is used when a study deals with large samples with the aim of generalizing the findings obtained (Opie, 2004). As such, Breakwell and Rose (1995) is of the opinion that structured interviews do not normally allow participants to give other important information since they are restricted to stay within the responses suggested by the researcher. Since essential pieces of information were needed from the participating PGCE students, structured interview was considered unsuitable in this study. Similarly, the unstructured type of interviews is known to generate large amount of information (data) that eventually requires a lot of time to analyse and thus more expertise (Opie, 2004). As a result, the unstructured interview was inappropriate in this study considering the time constraints and demand for expert researchers. The third type of interview, that is, semi-structured interview was considered appropriate and thus used in this study.

According to Descombe (2008) semi-structured interview provide enough data due to the fact that it is flexible in nature as participants are allowed to give responses without constraints. Opie (2004) also argue in semi-structured interviews that the interviewees are free to say as much as they can in the course while the interviewer has less control over the responses. Thus, using semi-structured interview in this study encouraged retrieval of deeper information from the participants by asking them probing and follow-up questions in order to have a comprehensive understanding of the issues being investigated. Some of the weaknesses of interview are such that, irrespective of the semi-structured nature of the interview questions, a researcher could be biased due to the fact that he/she would like to interpret the responses from the interviewees to suit their values and beliefs, which could digress from the intended research (Opie, 2004). Interviewees may give responses to please the interviewer, due to a close interaction between them (Descombe, 2008). Therefore to address this setback the responses of the interviewed participants were transcribed, and a copy of the transcribed text was sent to the participants to confirm that they indeed made the transcribed comments. Also, the interview section was audio recorded to enable the researcher to revisit the comments made and have accurate information of the interview conducted while transcribing.

Therefore in my study, semi-structured interview questions were adopted to gather data and to support the questionnaires administered to the PGCE pre-service teachers, in order to explore the nature of their disciplinary knowledge and subject matter knowledge. The questions were nine (9) in numbers and were almost similar to that of the questionnaire. The questions were different in the sense that it was not as structured as the questionnaire itself. But the questions were similar in terms of its purpose to further elicit their understanding of the disciplinary knowledge in Life science. The interview questions were adopted from the bigger project in the institution under study. A forty (40) minutes focus group interview was conducted with the students and two lecturers who are in charge of the PGCE pre-service teachers program at different intervals. The questions were used to initiate the interview process, and also more probing was done with the responses the respondents gave. Five out of the respondents from the questionnaire were chosen for the interview because; they showed interest in the interview, while the rest of the respondents did not show interest to participate in the interview. The purpose of interviewing the teacher educators was to see if they have similar understanding concerning Life science. Also, I wanted to know if their disciplinary views are same with that of the students. A copy of the interview transcript can be found in appendix 2.

3.3 Research setting

The setting of this research was at a higher institution of learning. The study focused on the PGCE Life science pre-service teachers whose program of study is within the duration of one year. In this study, data was collected from the PGCE students in the University. The purpose of choosing this University is because it is a well-known research institution and also for the researcher to work within a familiar context as a student. According to Opie (2004) case study research focuses on a “real situation, with real people” found often in a context that the researcher is familiar with (p. 74). The University is an institution that trains both the undergraduate and postgraduate students, preparing them to be professional teachers in the classroom teaching practice and also to participate in the socio-cultural issues of the society.

3.4 Method of sampling: purposeful sampling

For this study, a purposeful sampling method was chosen due to the principle that the participants of the study should be familiar with the 'phenomenon' under study. Creswell (2013) emphasized on the importance of the participants' experience of the phenomenon under study. The sampling method is adopted purposefully to investigate a particular group of people, and it will enlighten the researcher easily on the research problem that is being examined (Creswell, 2013). There are various types of sampling, but for this study the researcher used a purposive sampling which involves the researcher in making a cognizant decision on the particular context and individuals that would best provide the anticipated facts (Burns & Grove, 2007). Sampling method is about selecting a smaller group to be studied, which Wilson (2009) advised that effort should be taken to consider and justify the selection of the sample before embarking on a research study. The target population selected is shown below in a table 3.5.

Table 3.5: Target population

School	PGCE Pre-service student teachers	Teacher educators
Institution A	16	2

See appendix 1 for participants' information

3.5 Triangulation

In qualitative research, triangulation is one of the common ways of ensuring credibility of the findings. Triangulation involves the use of diverse sources of data for information in such a way that evidence gathered is used in building coherent justifications for the themes (Jonsen & Jehn, 2009). As examined by Patton (2002) triangulation is considered to be of the forms which include: methodological triangulation; theory triangulation; investigator triangulation; and data triangulation. Patton (2015) explains that “triangulation, in whatever form, increases credibility and quality by countering the concern (or accusation) that a study’s findings are simply an artefact of a single method, a single source, or a single investigator’s blinders” (p. 674). Thus, because of the nature of this study, the use of data triangulation was considered in this study. Data triangulation as used in this study involved building coherent evidence by comparing and cross-checking the data collected through the administered questionnaire and interviews as the two major sources of data.

3.6 Data analysis method

It was the intention of the researcher to respond to the research questions through data analysis methods that were chosen in this study. The researcher intended to investigate the level of understanding of Life science as a scientific discipline that the PGCE Life science pre-service teachers acquired at the end of their postgraduate program. To achieve this, the data collected was analysed using the LCT toolkit. All aspects of methodology and data collection both follow from the research questions (Mcmillan & Schumacher, 2010). The nature of the research questions matches the research methods and approaches of this study, which steered the implementation of the research instruments (questionnaire and interview). Each of the questionnaires was coded before they were administered to the participants. For example, each of the questionnaires had PGCE1, PGCE2, PGCE3 up to PGCE16, as a way of collecting data orderly and not to miss any questionnaire. After collecting the questionnaires, the items on the Likert scale section were categorised according to their relationship to the LCT dimensions. That is, each statement depicting specialization were identified and placed under it.

After the statements had been categorized, each of the responses was plotted along the planes of the different dimensions as discussed in the literature of previous chapter. The dimensions identified in the instrument were Specialization, Density and Temporality. The questions revealing the specialization dimension were seven (7). The specialisation codes are; (ER+, SR-) which represents the knowledge code; (ER-, SR+) represents the knower code; (ER+, SR+) represents the elite code; (ER-, SR-) represent the relativist code. The questions revealing the density dimension of the LCT were eleven (11). Density reveals the level of content and belief of a subject in a context and also the size of the discipline. The density codes are; (MaD+ and MoD+) which represents a higher diversity of content and heterogeneous beliefs within the discipline, (MaD- and MoD-) which represents a low diversity of content and homogenous beliefs. The questions revealing Temporality in the LCT dimension were four (4). Temporality reveals the age of existence of a discipline, and also its past and present impact on knowledge. The responses gathered from the respondents were analysed along the temporality plane to understand their view of the subject; whether it's old or new and its impact on present knowledge. The four temporality codes along the plane are; (TP+, TO+) represents the Archeo-retrospective code i.e. old and backward looking; (TP+, TO-) represents the Archeo-prospective i.e. old and forward-looking; (TP-, TO+) Neo-retrospective i.e. young and backward-looking; and (TP-, TO-) represents Neo-prospective i.e. young and forward-looking.

Also, the responses from the open ended section were analysed using the LCT concepts to organise data into codes, in order to understand the disciplinary knowledge of the respondents. SMK and NOS were also used as codes. That is, every word reflecting the NOS and SMK were identified and coded. Below is an example of a transcribed data from the open ended section of the questionnaire;

PGCE1: *The workings of their bodies (digestion, excretion, skeleton, (SMK)) which is very important. They also learn about the environment (SMK). Will help them appreciate it more and join (Moral density) in the efforts to conserve (Moral density) the biodiversity (SMK). They are also exposed to the history of science and discoveries (Temporality, NOS).*

The underlined words reveal the students' understanding of the structure of Life science in terms of Temporality, Moral density and SMK and the knowledge of the NOS of the participants. Also, the words in the table below show how the words were categorised and coded to understand the nature of the disciplinary knowledge of Life science.

Table 3.6: Showing an example of how data coding was categorised

SMK	NOS	LCT dimensions
Digestion, excretion, skeleton	History of science	Attitudes and beliefs (moral density)
Environment	Discoveries	Appreciating the environment (Moral density)
Biodiversity		Efforts to conserve (moral density)
Conserve		History of science, Discoveries (temporality)

For the interview, I transcribed the responses that were gathered from the interviewee and excerpts were formed. The responses were used to support the results from the questionnaires. The analysis was deductive; it was informed by the aspects of nature of science that I discussed in chapter two. Just like Boyce and Neale (2006) explain that while analysing data, the researcher must first transcribe the data and then second, analyse all interview data by reading carefully through the interview responses and looking for patterns or themes among the participants, then making groups of themes in a meaningful way.

3.7 Trustworthiness in qualitative studies

3.7.1 Validity

Data quality in research studies is of great importance and in most cases determined by the quality of each strand (either qualitative or quantitative or both) involved. Building on that, Letts, Wilkins, Law, Bosch and Westmorland (2007) referred to trustworthiness as an amalgamation of both reliability and validity. The authors further classified the quality of findings as well as that of the data to consist of the credibility, dependability, transferability and conformability. Thus, validity is an important key for effective research (Cohen et al., 2005). In qualitative research validity could be achieved through the depth, richness and scope of the data collection, the number of participants approached as well as the objectivity of the researcher. Although contents of the questionnaire as well as the interview schedules were extracted from validated instruments, I enhanced validity in my study by triangulating the two different sources of data. Results from the two data sources were compared for consistency to enhance the result obtained from the study. Just as Patton (2001) mentioned that qualitative researchers should be concerned about validity and reliability as factors to be considered while designing a study, analysing results and judging the quality of the study. The instruments used in collecting data for this study were adopted from a bigger project which is being conducted in the institution. The researcher observed that all the statements in the instruments were adequate enough to elicit the disciplinary knowledge of the participants under study. Therefore, the interview section was audio recorded to enable the researcher to revisit the comments made and have accurate information of the interview conducted while transcribing.

3.7.2 Reliability

Fraenkel and Wallen (1993) posit that reliability is the constancy of the results obtained from the study. It depends on the consistence of a final result from the measurement of an instrument (Leedy & Omrod, 2001). Reliability in a qualitative research is seen as suitable between what really happened in the natural settings of the research and what the researcher has recorded as data (Bodgan & Biklen, 1992). In this study, the two data collection instruments were designed in such a way that administration of any of the instruments should be able to produce similar results on the phenomenon under study. This was achieved by using both questionnaire and interviews. Also, the results achieved from both the lecturers and that of the participants were compared to ensure a reliable result from the study. The results are seen to be reliable because of its consistence in answering the research question posed for the study. The interview questions were designed to complement the questionnaires for both the lecturers and students. Data from the two instruments revealed common correlations. Also, responses from the interview and questionnaires conducted and administered to the two lecturers revealed common similar trends of views of the phenomenon being studied. Wilson (2009) is of the opinion that the idea of reliability relates with consistency, rigour and trustworthiness of the study. In this study, the use of triangulation is believed to eradicate any inconsistence in the responses, considering the nature of the instrument used.

3.8 Ethical issues

In conducting a research, one of the most important aspects is to safeguard the participants of that research from harm. For this reason, a variety of ethical issues must be addressed before commencing research and this includes; the human subjects (Iacono, 2006). Ethics clearance was obtained for this research because it involved humans. It was obtained from the University of Witwatersrand. At the beginning of this study, the researcher informed the respondents that all data will be considered confidential and will not be shared with others, as this is one of the principles and rules attached to research. Bodgan and Biklen (1992) confirmed that there must be trust and honesty during the research process as well as respect for the participants as subject and not as object of research. For this reason, permission was taken from teacher educators to be interviewed and students by giving out consent forms to be filled. Participants were made to understand that participation is voluntary and therefore were enlightened on what the research entailed, because for participants to make a choice of whether to participate in any research study, there must be accurate information availed to them (DeVause, 2002). The questionnaires were administered soon after their lecture. With this, information sheets were distributed to the participants before the questionnaires were filled in order to address all issues regarding the research.

3.9 Conclusion

This chapter dealt with the methodologies applied in conducting this research. This study adopted a case study approach and also a qualitative method of approach which deals with the in-depth study of the phenomenon. The instrument used in gathering data for this research was both questionnaire and a focus group interview questions. Validity and reliability of this study were explained as well as the ethical issues. The subjects of this research were the PGCE Life science pre-service teachers who are studying within the duration of one year in life science.

Chapter Four

Data Analysis and Discussion

4.0 Introduction

The aim of this study was to investigate PGCE pre-service teachers' level of understanding of life sciences as a scientific discipline. In this study, data was analysed using both qualitative and quantitative methods of analysis. The qualitative aspect consisted of interviews which were transcribed, coded and interpreted, while the quantitative aspect consisted of the questionnaire (Likert scale section) responses analysed along the plane of LCT dimensions and then organised into tables, and interpreted. The legitimation code theory (LCT) informed the analysis of the data obtained from the questionnaire and interview responses.

4.1 Data analysis and results

4.1.1 Analysis of responses to the questionnaire

This section dealt with the analysis of the Likert scale and the open-ended sections of the questionnaire. Table 4.1 is a summary of the Likert scale results while table 4.2 shows the open-ended results. The questionnaire that was completed by the students aimed at exploring the understanding that the PGCE Life science pre-service teachers have about the nature of life science subject. The first twenty two questions were the Likert scale items, after which were two open-ended items. The statement of the first open-ended item says; *when someone studies this subject, they learn about*…. While the second statement says; *When someone studies this subject, they learn how to*… Below, I will start off by summarizing the students' responses to the twenty two Likert scale items, followed by a summary of students' responses to the two open-ended items.

Table 4.1 is a frequency table showing the summary of the data that I collected from the questionnaires.

Table 4.1: summary of results from the Likert scale items (n=16)

Questions	LCT Dimensions	Student responses		
		Agreed	Neutral	Disagreed
1	Specialization	1	2	13
2	Specialization	14	1	1
3	Specialization	13	3	0
4	Specialization	16	0	0
5	Specialization	9	5	2
6	Temporality	15	1	0
7	Temporality	12	3	1
8	Temporality	15	0	1
9	Temporality	15	0	1
10	Specialization	15	1	0
11	Density	14	2	0
12	Density	13	1	2
13	Density	15	1	0
14	Density	6	5	5
15	Density	13	2	1
16	Density	10	5	1
17	Density	14	1	1
18	Density	6	6	4
19	Density	12	4	0
20	Specialization	8	5	3
21	Density	1	4	11
22	Density	12	3	1

Table 4.1 show the number of students who responded to the survey and their responses. The response from the students are represented with agreed, neutral and disagreed and categorised

according to the LCT dimensions reflected in the instrument. In the table above, seven (7) questions depict specialization, four (4) depicts Temporality dimensions, while eleven (11) questions depict density.

The open ended statements were analysed deductively by identifying aspects of SMK and NOS. I also used the four dimensions of the LCT as codes. Therefore, their responses were categorised according to their SMK and NOS and the four dimensions of the LCT (e.g. specialization, semantics, density and temporality) which makes up the nature of Life science. Below is an example of the coding of the response by PGCE5

When someone studies this subject, they learn about…

> **PGCEB5:** *Several key aspects pertaining to the science of life (on earth) (SMK). A student will learn about life science from a microscopic level (SMK) (components which makeup life i.e., DNA (SMK) and cell (SMK) to the macroscopic level (SMK) (interactions between biotic and abiotic factors) (SMK), they will learn about the origin of life on earth and life over time (Temporality) (change over 4 billion years), learn critical thinking (NOS) and reasoning skills (NOS) pertaining to research & science in society (Density).*

Below is a table showing how many students made reference in their responses that indicated Temporality, NOS, SMK, Density, Semantics.

Table4.2: Showing the number of respondents for the open-ended items

Dimensions	Number of respondents
SMK	16
NOS	13
Density	9
Temporality	3
Semantics	8

See appendix 4 for the coded responses from the open-ended section.

Almost all the respondents said something about SMK, NOS, Density, Temporality, but their descriptions do not show that they have a temporal view of specialization, SMK and NOS, etc. For example, where the student mentioned ‘cell’, this does not say anything about temporality, but if a student goes on to say ‘we look at the history of how a cell was identified and how the knowledge came about’.

It is not just the content but also the temporal features of the content. But most of them just end their statement by saying ‘we learnt about cell’. They don’t have the language of saying the history and how the knowledge of cell was accumulated. Therefore their nature of understanding ends at just listing the concepts and the topics. They do not have a grasp of why they are being taught as history, they only look at the history and then forward. It could be said that all these deformities in knowledge could be as a result of the way the educators teach them in Life science.

16 students showed that they had knowledge of SMK, by listing the various concepts that make up the Life science discipline. For example; when someone studies this subject, they learn about……

PGCE13: *One will develop their knowledge of key biological concepts, processes, systems and theories (SMK).*

Thirteen listed aspects that fall under the NOS, for example; when someone studies this subject, they learn how…

PGCE4: *Critically evaluate scientific evidence and (hopefully) make clear decisions about results and validity of scientific data (NOS).*

The description of nine out of sixteen respondents also reflected the NOS in terms of its material and moral density. For example; when someone studies this subject, they learn about……

PGCE14: *Mostly plant and animal biology (SMK); some chemistry (Material density) and some history of science (NOS, Temporality).*

Although, direct questions were not asked on temporality dimension, their answers shows that there is history in Life science, therefore it is forward looking and backward looking. Temporality is only three as shown in the table above. The respondents understand the moral and belief system of the discipline**.** Although in the Likert scale items, it shows that, they know that the concepts have temporality, but they know that they are also learning that. It is not in their language, views and understanding, it is not coming out, and all of this depends on the educators. Table 4.1 above show the results from students' responses to open-ended questions and their relationship to the LCT dimensions. The results from the open ended were used to support the responses of the Likert scale. The results shown above are discussed below. In the next section, I present the results and findings, dimension by dimension.

4.2 The Specialization dimension

Table 4.3 shows results of the epistemic nature of Life science. Seven Out of twenty two questions relate to students' understanding of their specialization. Section A of the questionnaire, that is, the Likert scale section is categorized into various LCT dimensions. The specialization section of the table is illustrated below in table 4.3.

Table 4.3: Results showing the responses of the PGCE life science pre-service teachers on specialization dimension.

Item No.	Student responses		
	Agreed	Neutral	Disagreed
1	1	2	13
2	14	1	1
3	13	3	0
4	16	0	0
5	9	5	2
10	15	1	0
20	8	5	3

4.3.1 Explanation of table 4.3

The specialisation codes are; (ER+, SR-) which represents the knowledge code; (ER-, SR+) represents the knower code; (ER+, SR-) represents the elite code; (ER-, SR-) represent the relativist code respectively. For item 1, one respondent chose 'Agree', which means that the respondent believes that what matters is the personality of an individual and not knowledge. Thirteen respondents chose 'Disagree', which means that the personality of an individual does not matter in the Life science discipline. While two respondents chose neutral, which means that they do not have a position as to what should be considered legitimate in Life science. Hence, the result reveals that what matters most is knowledge. In agreement with this, Arbee (2012) are of the opinion that to learn Life science, personal attributes are not put into consideration, in as much as the individual is habituated in the knowledge and ways of knowing in the discipline. For items two, three, four, five, ten and twenty, the respondents chose 'agree', this means that in Life science what matters most is knowledge and not the knower. Although for item five, five respondents chose neutral, which means that they do not have any idea of whether knowledge or knower matters. Two respondents chose disagree for item five which means that they do not believe that what matters most in Life science is knowledge. The result on the table is also represented in a bar chart and scored in percentage to reveal the code which appeared most during the analysis.

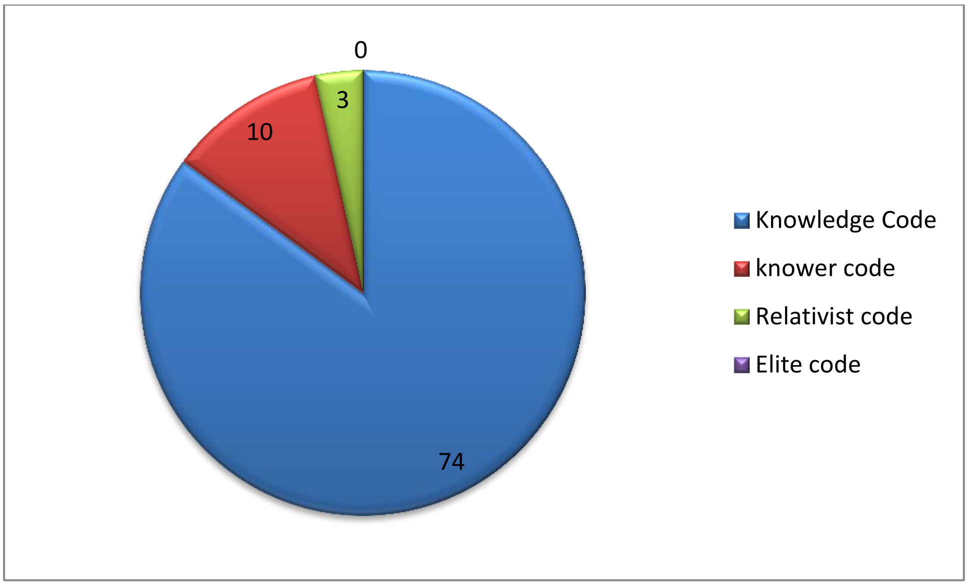

Fig. 4.1: *Illustrating the result of the specialization dimension in percentage.*

The bar chart shows that for the specialisation aspect the number of response for the knowledge code is 74%, the number of responses for the knower code is 10%, elite code is 3% while no response was found in the relativist code. Most of the responses fell into the category of the knowledge code ER+, SR-. Showing that the majority of the PGCE pre-service teachers who participated are of the view that in Life sciences knowledge is what is important. The results from the analysis of responses from the open ended section were used to support the Likert scale section in order to ascertain consistency in result. The results from the open ended section showed that the participants understand that in Life science students learn SMK as shown by listing of various concepts.

They have an idea that SMK is part of their required knowledge in Life science. They reflect that various biology topics are what they learn in Life science. In addition, the response also shows that the students have also learnt about the NOS.

An example can be shown from a response;

> **PGCE8:** *Life and <u>life system</u> (SMK), <u>human biology</u> (SMK) /<u>anatomy</u>, <u>plants/ecosystem</u> (SMK), <u>food groups</u> (SMK), <u>biotechnology</u> (SMK), <u>human /plant/animal diseases</u> (SMK), preventative measures/cures, ethics, legal aspects/copyright (moral density), the <u>scientific method</u> (NOS), effective communication.*

The students have also acquired diverse understanding of the diverse nature of the content of Life science, which is reflected by listing of the following aspects; human/plant/animal diseases/preventive measures/cures/ethics, legal aspects, copyright.

PGCE8's response shows a list of concepts which reveal the nature of Life sciences in terms of SMK, Density and NOS and more (see appendix 4 for more similar features in students' responses) Therefore the findings from both sections of the questionnaire indicate that, PGCE students at the end of their training have acquired an understanding of the nature of the discipline of Life science. Knowledge of the subject is what matters most in order to be a subject specialist, and knower/attributes do not matter, that is, the personality of an individual. This understanding is in agreement with Maton (2016) who explains that the basis of achievement is emphasized by considering the individual's possession of a ‘specialized knowledge’ and the procedures as regards the object that is being studied. PGCE students’ understanding is also in agreement with Arbee (2012) who are of the opinion that the attributes of the knower is less important. To be a specialist in the Life sciences, there is need to have a special kind of knowledge and in agreement with this, Arbee (2012) mention that legitimacy in natural science as an academic discipline, relates to expertise in the “disciplines’ specialist knowledge and techniques” (p. 44). And that specialist knowledge and techniques are reflected in students’ responses to the open ended items.

4.3 The Density Dimension

The Density dimension consist of two codes namely; material density (MaD) and moral density (MoD). The material density code defines the size of a discipline as well as the breadth of its knowledge base (whether it is big or small). On the other hand, moral density code takes into consideration the belief system governing a discipline, such as what should be taught and what not to teach, the controversies concerning the theory of evolution, and so on. According to Arbee (2012) these beliefs could be either homogenous (same, MoD-) or heterogeneous in nature (different, MoD+).

The density codes appear as; (MaD+ and MoD+) which represents a higher diversity of content and heterogeneous beliefs (MaD- and MoD-) which represents a low diversity of content and homogeneous beliefs. Therefore, legitimation in Life sciences as a sub-discipline is characterized by MaD+ and MoD+ density code. The analysis done on the responses along the dimension plane revealed that the number of responses for MaD+ and MoD+ were relatively high, thus appearing in all the results.

Table 4.4: Results of the PGCE life science pre-service teachers' responses to Density dimension items.

Item No.	Students responses			Result
	Agree	Neutral	Disagree	
11	14	2	0	MaD+, MoD+
12	13	1	2	MaD+, MoD+
13	15	1	0	MaD+, MoD+
14	6	5	5	MaD+, MoD+
15	13	2	1	MaD+, MoD+
16	10	5	1	MaD+, MoD+
17	14	1	1	MaD+, MoD+
18	6	6	4	MaD+, MoD+
19	12	4	0	MaD+, MoD+
21	1	4	11	MaD+, MoD+
22	12	3	1	MaD+, MoD+

4.3.1 Explanation of table 4.4

The table above shows the students' responses on the diversified nature of Life science. For all the items, the respondents chose agree, which means that the nature of Life science as a body of knowledge has high material and moral density. For item 11, 12, 13, 15, 16, 17, 19 and 22, the respondents chose agree, which means that the nature of Life science is highly diversified. That is, Life science has a high material and moral density. Although for items 14 and 18, the responses were almost evenly distributed along agree, neutral and disagreed. It may be as a result of the fact that the pre-service teachers do not understand the use of modules in the discipline, just like the item depicts. The university do not use modules, but topics in the discipline. For item 21, eleven respondents chose disagree, which means that the PGCE Life science pre-service teachers believe that the nature of Life science has low material and moral density. Four respondents chose neutral, which means that they do not have a particular view concerning the belief system of the discipline, while one respondent chose agree, this means that the respondent do not believe that Life science has a high moral density. This is evidence that the participants have the understanding that the Life science content comprises of very high material and moral density. That is, the participants are of the opinion that Life science is densely populated and the knowledge diverse within and outside the field.

Results in Table 4.4 shows that the number of responses for MaD+ and MoD+ represent a high diversity of knowledge in Life science. This is evidence that the participants have the understanding that the Life science content learnt during their PGCE program comprises of very high material and moral density. That is, the participants are of the opinion that Life science is densely populated and the knowledge acquired has a high diversity within and outside the field. The result reveals the level of content and belief of a subject in a context and also the size of the discipline.

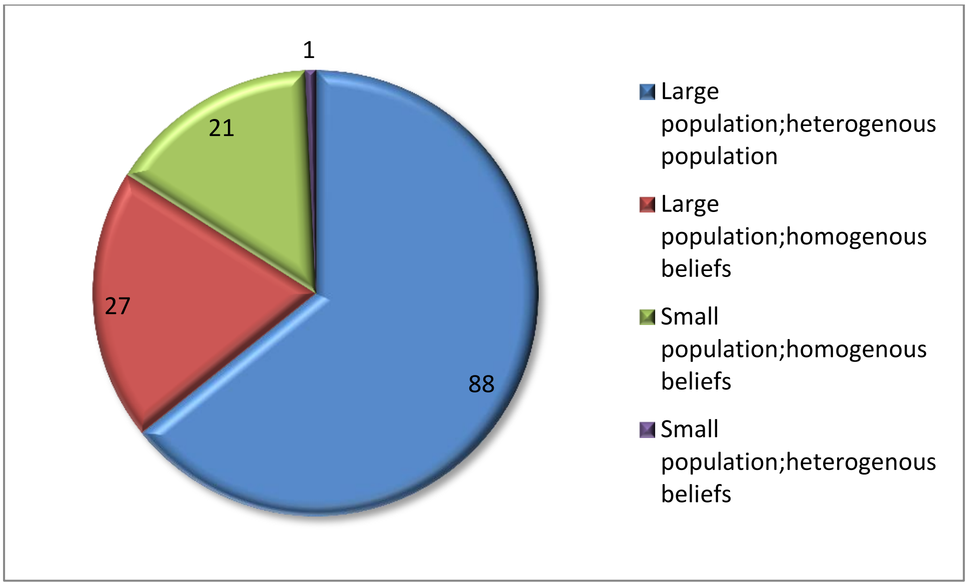

Fig. 4.2: *Illustrating the result of the Density dimension in percentage.*

The students have also acquired diverse understanding of the diverse nature of the content of Life science reflected by listing

The number of responses found on the MaD+, MoD+ plane was 88%, MaD+, MoD- plane was 27%, MaD-, MoD- plane was 21% and MaD-, MoD+ plane was 3% respectively. The analysis on the bar chart reveals that responses for Mad+ and MoD+ were relatively high with 88%. The result also means that the PGCE students had the understanding that the content of Life Sciences is highly diversified and can be applied in every other field. Although the number of disagree in some items were evenly distributed, due to different views of the respondent, the number of respondents whose view was that the knowledge of Life science is diversified was very high (88%).

For instance, according to literature, the concept of ecology as part of life science content involves the integration of several other concepts from various knowledge domain such as chemistry, physics, medicine, mathematics and concepts in biology itself such as genetics, morphology, cytology, etc. (Potyrala, 2004). This is an indication that PGCE Life science students understand that Life science characterized by a large community which is highly diversified in terms of the content that forms the discipline. Also, the result is an indication that Life science students understand that Life science content, e.g. theories are formed by different belief systems, and in agreement with this, Mansour (2009) in his study explains how beliefs form the main element in the formulation of theories, because they are static and are able to exist past the control of individuals. According to him, beliefs are non-flexible due to the fact that they "represent internal truths that remain unchanged in the teacher's mind, regardless of the situation" (pg. 27). Most of the responses from the section two of the questionnaire, that is, the open ended section, all reflected the density dimension of MaD+ and MoD+, except in few cases (please refer to table two). The following responses were given by the participants in the open ended section. *When someone studies this subject, they learn about…*

> **PGCE16:** *Organisms (SMK), systems (SMK), nature (SMK), ecosystems (SMK), chemistry of life (SMK). How to conserve and appreciate nature (Moral density), the systems in human and animal bodies and systems in plants (SMK), how animals and plants are related to each other (SMK), skills related to the subject (drawing graphs, tables) (NOS), diseases in certain organs (SMK), structure and functions of (structure related to functions) (SMK), diseases affecting the organs (SMK) and how to prevent and treat these diseases (Moral density).*

When someone studies this subject, they learn how to…

> **PGCE16:** *Conserve nature (Moral density), appreciate nature (Moral density), relate to real life things (Material density), access data and representing data (applying and analysing data) (NOS), use knowledge to solve real life problems (Material density), how the ecosystem works and how it is disturbed (SMK).*

The statements above is also an indication that the participants understand how diversified the nature of Life science is. The result reveals that Life science is made up of content that is condensed with varieties of concepts and theories from the microscopic to macroscopic levels. In agreement with this, Medawar (1977) is of the opinion that the size of a discipline is determined when its subject holds so much diversified content. Because a sub-discipline such as Life science consists of various specialisms, it requires more subject specialist who can enhance the accumulated knowledge and ensure its application/practicality outside its field. The findings from focus group interview supported that students had acquired an understanding that Life science is diversified in nature. When students were asked to provide response on who is an ideal biologist? Betty said.…

"um, *I do agree that you need certain amount of experience……I don't know, experience is subjective. So I mean I consider myself as a biologist when I left honours. Because when I did my honours project, I did it so intensely, and I went into the field that was barely touched, I was doing interesting work that nobody else was doing within the biological field. I felt like, I had to teach myself a lot, and I had to use many integrated processes and other things….. I feel like any type of scientist especially biologist is someone who can integrate different content from different fields of science. Especially in mathematics, physics and chemistry. So my ideal scientist, what I will think of someone who is a scientist, specifically a biologist is based on someone I know, is when they are explaining ….."*

The statement above supports the idea that the PGCE Life science pre-service teachers view Life science as a well-diversified discipline which is indicated by MaD+. Also, result shows that Life science has different belief systems guiding it, and it reflected as MoD+ from the responses gathered (refer to table 4.2). The result means that there are heterogeneous beliefs among the subject specialist in life science, which causes controversies sometimes concerning what should be considered legitimate in the discipline. In agreement with this, Arbee (2012) recognize the place of an internal agreement that is being made by the experts in a discipline concerning what constitutes the methods, disciplinary knowledge domain, culture and the 'legitimate rules of the game' of a discipline to make knowledge accessible to students. For example, the concepts 'evolution, sexuality, stem cells, Genetic mutation, to mention a few, are some of the topics in Life science that are linked to such controversies due to different beliefs of the subject specialists. Supporting this argument regarding beliefs and controversies is the study of Ngxola and Sanders (2008) which mentions that human evolution, genetics and biotechnology are concepts that are most difficult to teach in Life science, due to the difference in beliefs of individuals in the discipline. When there is a relatively high moral density, it means that there is a lack of agreement on how and what should be taught in a discipline, which may cause disagreement among lecturers as to what should be considered legitimate in the disciplinary discourse of Life science (Arbee, 2012). Amidst all the controversies and disagreements among science educators, students and policy makers, its educational implication is such that could cause negative effects on the disciplinary gaze of the PGCE students. Nevertheless, from the findings of this study, it shows that the Life sciences have high material and moral density represented by the code (MaD+, MoD+) due to its diversified content, its structuring principles (Maton, 2005a), that is, tightly packed structure (syllabus) and heterogeneous beliefs. Therefore, the disciplinary gaze the PGCE Life science pre-service teachers have concerning their discipline can be said to be adequate enough for them to be considered specialists in the field.

4.4 The Temporality Dimension

Temporality dimension speaks about how old a discipline is and its contribution to the world at large. Temporality dimension is concerned with the temporal positioning and orientation of a field, as well as how young or old the field is. Literature shows that Life science is old and forward looking, through its accumulation of knowledge. Four out of twenty two questions in the questionnaire sought to find out students' understanding of the temporal orientation of Life science in terms of its existence. The four temporality codes are; (TP+, TO+) which represents the Archeo-retrospective code; (TP+, TO-) represents the Archeo-prospective; (TP-, TO+) Neo-retrospective; and (TP-, TO-) represents Neo-prospective respectively. Table 4.5 shows the results of the analysis of students' responses to the 4 temporality dimension items.

Table 4.5: Results of the PGCE life science pre-service teachers' understanding of the temporality dimension of Life Sciences.

Questions	Student responses		
	Agree	Neutral	Disagree
6	15	1	0
7	12	3	1
8	15	0	1
9	15	0	1

The table above reveals the Results in Table 4.5, which shows that the PGCE Life sciences pre-service teachers view the Life sciences as being Archeo-prospective as it reflects in its code (TP+, TO-) on the table above. For all the items, the students chose agree, this means that Life science as a body of knowledge is old and forward looking. The response to the items 6, 8, and 9 reveals the understanding that the PGCE pre-service teachers have concerning Life science. Also, the responses on item 7 revealed that the students understand that their disciplinary knowledge is old and backward looking. Therefore, Life science is old and forward looking as well as old and backwards looking.

Also, the bar chart below shows the percentage of the responses that reflects that the participants have the understanding that Life science is old and forward looking.

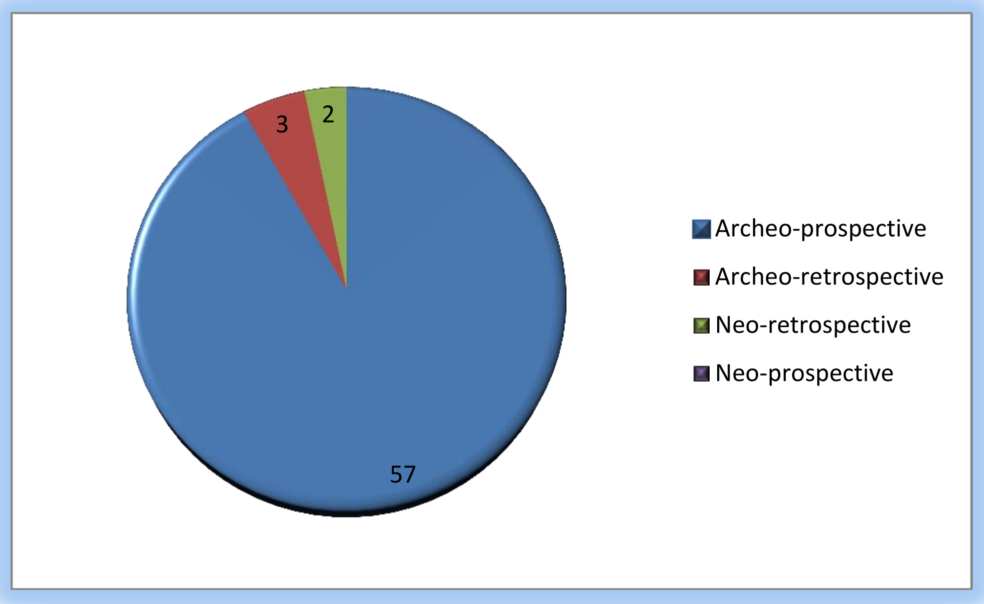

Fig. 4.3: *Illustrating the result of the Temporality Dimension in percentage*

From the analysis, the percentage of the responses which fell along the TP+, TO- plane was 92%, which is the highest number of occurrence while the responses which appeared on the TP+, TO+ plane was 5%, and TO-, TP- was 3%. The subject is viewed to make connections across time. In line with the result, Magner (2002) is of the opinion that the modern biology comprises of various 'scientific disciplines' that are very old and very new and its temporal positioning and orientation determines the rate at which changes occur in the field. For this reason, the author encouraged the need to view the knowledge of Life sciences as a concept that is evolving, a methodology for the emergent of new knowledge as well as foretelling future knowledge. Evidence can also be drawn from the responses given by the participants in the open ended section of the questionnaire

> **PGCEB3:** *Relate the history of life to current life (Archeo-prospective), how the aspects of life have evolved (Archeo-prospective & Archeo-retrospective) and how science has contributed to medicine and improving human life as a whole.*

> **PGCEB5:** *They will learn about the origin of life on earth and life over time (change over 4 billion years (Archeo-prospective).*

From the responses above, it is evident that the PGCE pre-service teachers' understanding of the nature of Life science is Archeo-prospective (TP+, TO-) as reflected in the table in 4.5 above. In agreement with this, Arbee (2012) posits that one of the criteria of considering a field is by looking at how long it was established or newly formed. Also, as reviewed in the literature, the disciplinary knowledge that is learnt at the end of the PGCE program involved the acquisition of scientific skills, history and nature of science, SMK for the specializations, scientific investigations, the theories they learnt at their undergraduate level and methodology. Doing science involve learning various concepts and specializations, as well as the scientific methods and skills that has being in use from the past till present for teaching science. Also, the findings made through inquiry can be used to curb intended natural disasters and prevent certain crisis from happening in the future (Gitari, 2012).

In the literature, the course outline of the PGCE students was explained, thereby, revealing the various courses to be taken. At postgraduate level, they do more of methodology and less content because of their exposure to adequate content at their undergraduate level. Judging from the knowledge acquired by the PGCE pre-service teachers as well as the results presented above, it is evident that opportunities are presented for the PGCE pre-service teachers to acquire a gaze of what the nature of Life science is all about. The disciplinary knowledge of Life science involves its content (SMK), structuring principles and NOS (enquiries, reasoning and the history of science), and it has been in existence for centuries. Therefore, the PGCE pre-service teachers' gaze concerning their disciplinary knowledge can be said to be in accuracy with literature, as the findings reflect on the Archeo-prospective (TP+, TO-) plane of the Temporality dimension.

4.5 Results of the analysis of the focus group interviews.

4.5.1 PGCE pre-service teachers' understanding of disciplinary knowledge in response to the interview

The disciplinary knowledge of Life science comprises of the knowledge of the NOS and SMK. During the interview with the students, they were asked what they understood by disciplinary knowledge and SMK, and their response was that;

> ***Researcher:*** *I will like to know what your view is on DK, like when you hear the word DK, what is the first thing that comes into your mind?*
>
> ***Part 1:*** *what do you mean DK?*
>
> ***Part 2:*** *you mean discipline?*
>
> ***Part 3:*** *teaching life science. You know the content, you have a background in the knowledge from somewhere, and then you know it enough to be able to teach it.*
>
> ***Researcher:*** *ok, what about SMK?*
>
> ***Part 4:*** *I disagree with her response*
>
> ***Researcher:*** *ok, let's hear your own response*
>
> ***Part 4:*** *I think what you described was more like a content knowledge. Of course you need the disciplinary knowledge in order to engage with the subject properly. The subject matter is what is basically what is in the textbook and DK is a bigger deeper understanding of what science is and the nature of science and experimental, like practical and scientific skills.*

The response above is an indication that the PGCE students do not really understand what disciplinary knowledge was. Their responses show their level of understanding. Although, one of the participants got a clear a clear understanding of what disciplinary knowledge was. The participant who understood disciplinary knowledge, was able to make it clear that the SMK can be found in the disciplinary knowledge of Life science. (See appendix 2)

To support the interview response above, an example of the open-ended responses will be provided to see how the participants further views Life science. When ask, *when someone studies this subject, they learn about…*

> **PGCE10:** *Interpret and draw graphs and tables (NOS), follow instructions to do practical work (NOS) and then be able to do the hypothesis and aims (NOS) and write up the scientific repot (NOS). Draw biological diagrams (SMK) and label it correctly with an appropriate heading (Density). Recognize imbalance in the human body (Moral density) and environment (Material Density). To know what can be done about it. (see appendix 4)*

The statements in the open ended section of the questionnaire depict both SMK and the knowledge of NOS of the PGCE pre-service teachers. Therefore, the PGCE students show understanding of what their disciplinary knowledge is comprised of, but they do not have an explicit understanding of it.

4.5.2 PGCE pre-service teachers' understanding of SMK from the analysis of open-ended items.

The response from the interview is also an indication that SMK is knowledge of the concepts of a subject. The purpose of the open ended statement is to elicit the understanding the PGCE pre-service teachers have in relation to what is expected of them concerning their SMK. The responses given for this statement indicates that the PGCE pre-service students understand that there is need to have SMK in order to be a specialist in the field of Life science. Below is a response to the question; from the responses of the open ended section, a student mentioned that; *when someone learns this subject, they learn how…*

> **PGCEB13:** *<u>Living things</u> from <u>molecular level</u> to their <u>interactions</u> with one another and their <u>environment.</u> One will develop their knowledge of <u>key biological concepts</u>, <u>processes</u>, <u>systems</u> and <u>theories.</u> Will also develop understanding of ways in which human have impacted negatively on the environment and <u>organism</u> live in it.*

> **PGCEB5:** *Several key aspects pertaining to the <u>science of life</u> (on earth). A student will learn about life science from a <u>microscopic level</u> (components which makeup life*

i.e., DNA and cell) to the macroscopic level (interactions between biotic and abiotic factors), they will learn about the origin of life on earth and life over time (change over 4 billion years).

From the analysis, the PGCE pre-service teachers have the understanding that SMK is made up of several concepts and theories which reveal its material density (refer to appendix 4). Also, it confirms that what is important in the discipline of Life science is Knowledge (specialized dimension). The result of the open ended section supports the analysis in the Likert scale questionnaire (please refer to table 4.2). The responses depict specialization and density dimensions. The result shows that knowledge is what matters most in Life science, and also it reflects the structures of Life science just like the students mentioned in their responses. To show that SMK is important in Life science, Ball and McDiarmid (1989) is of the opinion that subject matter knowledge is widely recognized as a 'central component' of what teachers are expected to know as part of their teaching profession. Looking at the responses from both the lecturer and PGCE students, it means that the lecturers and students share same views concerning what is considered legitimate in the discipline, that is, the content to be learnt and skills necessary to be a subject specialist. Therefore, the students have an understanding of the nature of Life science as their disciplinary knowledge.

4.5.3 Students' understanding of the Nature of Life Science

The NOS form part of the disciplinary knowledge of Life science. The knowledge of the NOS deals with the understanding of various scientific skills, philosophy, history and nature of a subject. The knowledge of the NOS gives a teacher the insight as to how to teach various scientific concepts, as well as understanding the root of the accumulated knowledge of a discipline. In the literature, it shows that disciplinary knowledge involves knowing and doing science by understanding the nature of science (NOS) and it includes the scientific inquiry; evidence and reasoning in inquiry; scientific investigations; scientific theories and avoiding bias in science (American association for the advancement of science, 2001). From the open ended section, the second item states that; *when someone learns this subject they learn how to…* and it depicts the NOS. The purpose of the statement was to understand the

PGCE students' understanding of NOS. The responses presented by the PGCE pre-service teachers concerning this statement are presented below in table 4.6;

Table 4.6 showing the emerging themes and codes from the second open-ended item for NOS.

NOS			
Responses/codes	Themes		Total number of respondents
Scientific experiments, Variables, opinions, arguments, justify, Scientific jargons, Research, Scientific method, hypothesis, develop skills, evaluate, scientific evidence, results, validity of scientific data, laboratory	Life science practical skills	Density dimension	15
analyse situations, solutions, evaluate scientific information, decisions, field investigations	Application of skills	Density dimension	9

The table above shows two themes that emerged from the responses given by the PGCE students. The table shows that fifteen out of sixteen respondents indicated the necessary scientific skills that are needed to be a part of Life science, while nine out of sixteen respondents indicated the need to apply the acquired skills in the everyday world. To support this evidence is the response from the interview conducted with the students. The statements states that; who is an ideal biological scientist?

R2: *I think obviously they have to be on top of the knowledge, they have to be in research, laboratory…….. doing it for the outcome, doing it for the scientific enquiry, I think they have to be very good, exception to the science field, to the science field, you have to be in it for it to have that pure passion, otherwise that is what I think …….*

From the result above, there is an indication that the pre-service teachers have an understanding of what should be considered legitimate in the disciplinary discourse of Life science. The required knowledge of the PGCE students is SMK and the knowledge of the NOS, therefore, it is expected that the PGCE pre-service teachers have developed adequate skills judging from their general opinions and understanding of the nature of Life science as a sub-discipline.

4.6 Teacher educators' understanding of the disciplinary knowledge of the PGCE students

4.6.1 Analysis of the Likert scale questionnaire

The questionnaire administered to the students was also administered to the lecturers in charge of teaching the PGCE pre-service teachers their various courses. The table below shows the summary and number of responses and their position along the LCT plane.

Table 4.7: Showing the summary of the Likert scale result from the teacher educators

Dimensions	Codes			
Specialization	ER+, SR-	ER+, SR+	ER-, SR+	ER-, SR-
	11	0	0	1
Density	MaD+, MoD+	MaD+, MoD-	MaD-, MoD-	MoD+, MaD-
	15	2	1	0
Temporality	TP+, TO+	TP+, TO-	TP-, TO+	TP-, TO-
	1	6	0	0

The responses were analysed along the planes of the LCT dimensions and it was found that on the specialization plane, the responses fell on the ER+, SR- knowledge code. This is an indication that knowledge matters most and it is similar to the result found with the PGCE pre-service teachers. Also, the results found in the density (MaD+, MoD+), temporality and (TP+, TO-) were similar to that of the students except in some exceptional cases. This means that the lecturers and students share same views concerning the nature of Life science. The results from the questionnaire were compared to their interview response and it was found that they follow similar trend.

The two teacher educators were interviewed regarding what they understood by disciplinary knowledge and here is what they have to say. Although one of them did not give me basic information, but the other educator did. The two teacher educators were aske same question and one of them gave this response;

> ***TE1:*** *em…I suppose I would see the DK as more than just a subject matter, so I would look at it in terms of the* skills, *(NOS)* values (moral density), beliefs *(moral density),* attitudes *(moral density) that people develop. So it's more like an over chain thing on the life sciences. What does LS involve in total? So it might be philosophical attitude (moral density) towards teaching the life sciences, what they feel is important, etc. so when you looking at the discipline, you looking at many aspects and not just the subjects. (See appendix 3 for more responses)*

As can be observe, both the teacher educator and students have similar understanding of what the disciplinary knowledge of Life science should entail, except that the teacher educator did not list concepts for SMK.

The results are used to support the findings of the questionnaire because they revealed what knowledge is considered legitimate for the PGCE life science pre-service teachers and what knowledge they are expected to have at the end of their program. The following excerpt is evidence revealing what is expected of the PGCE students at the end of their program;

TE1: "*So we don't do specifically subject content knowledge, but when they prepare their mini lessons, when they prepare the…. Activities, they have to go and research that subject content in a specific field. So we don't go and say, I am going to look at cell respiration and explore that topic. But if they do mini lesson on cell respiration, they would have to explore that. In other ways, it comes in, in the nature of the task we gave them, they design an exam for grade 10, and they have to make sure they understand the subject content of grade 10 in order to design the exam".* Recounted from the interview, the response indicates what is expected of the students at the end of their program as they are trained as professional teachers. But emphasis is not laid on their SMK because they had already acquired the general component at B.Sc. level before enrolling for the professional component at the postgraduate level.

Evidence can be drawn from the excerpt for the interview below;

TE 2: *I think in the life science…….we do not spend time talking about the subject content, we assume that they come with the content knowledge. So the purpose of the subject competent test is to make sure that they have developed the content knowledge… if they are behind the subject content, they catch it up…*

From the excerpt, there is evidence that the PGCE Life science pre-service teachers are expected to have SMK, which enable them to develop a 'gaze' of the disciplinary knowledge of Life science. SMK and NOS form the nature of the disciplinary knowledge as explained in the literature. Therefore, Kind (2009) view it as an important factor contributing to successful teaching, because it provides basis for the development of pedagogical content knowledge (PCK) and shapes the teachers' practice (Jadama, 2014).

4.7 Summary of the findings

Findings from this study reveals the level of understanding that the PGCE pre-service students demonstrate about the nature of Life science and to what extent they have developed their gaze of Life science at the end of their program. Therefore, from the result shown it can be said that they have shown understanding of the disciplinary nature of Life science. Judging from the results from the Likert scale, it revealed that the PGCE pre-service teachers understand that knowledge is what matters most in Life science. Also, findings showed that the PGCE pre-service students understand that the Life sciences have a high material and moral density, which is as a result of the size of the discipline in terms of its knowledge accumulation and diversity. The belief of the individuals in Life science is heterogeneous in nature, thereby accommodating the beliefs and different views of different individual.

The result from the open ended section reveals also, the understanding that the PGCE pre-service teachers have concerning what knowledge is necessary or legitimate in Life science. Therefore, the results from this section shows that the SMK and NOS which make up the disciplinary nature of Life science is what the PGCE pre-service teachers need to be a specialist in the field. The SMK is content knowledge which helps them to transform their knowledge into accessible forms; therefore it is of utmost important as suggested by Kind (2009). It was also revealed that the PGCE pre-service students had more understanding in terms of their SMK; this could be as a result of the lack of structuring of the NOS in the curriculum.

The analysis of the Likert scale questionnaire using the LCT dimensions revealed PGCE students understanding that in Life sciences knowledge is important instead of the knower, that Life science has high material and moral density. Result of the Density dimension shows that Life science is characterized by a large population of specialist and researchers with heterogeneous beliefs as to what is considered legitimate in the field. These results put together, answer the two research question which states that; what levels of understanding of the nature of Life sciences as a discipline is demonstrated by PGCE Life science PSTs? And To what extent do PSTs develop the required gaze about Life sciences from their PGCE program?

4.8 Conclusion

This analysis chapter discussed the data that was collected from the PGCE Life science pre-service teachers to measure their understanding and views of the nature of the Life sciences.

The analysis confirmed that the data from the questionnaires relate with the data gathered from the interviews. Although the evidence shown concerning the extent of the disciplinary knowledge and subject matter knowledge of the PGCE pre-service teachers shows their understanding of Life science, therefore it reveals what is obtainable at the end of their program. The questionnaires were able to measure the gaze of the PGCE pre-service teachers in terms of its structures, content knowledge and nature of Life science as a scientific discipline. The interviews and the open ended questions helped to support data and measure the level of conceptual understanding and contents of Life science. The ability to plot the responses along the planes of the different LCT dimension also enabled a good assembling of findings.

Chapter Five

General Conclusion and Recommendation

5.0 Introduction

In this chapter, an insightful summary of this study was provided based on the ideas discussed in the previous chapters. The study investigated the PGCE pre-service teachers' level of understanding of Life sciences as a scientific discipline. In this chapter, I give an overview of the study, summarise findings and answer research questions.

5.1 Overview of the study

The problem statement that was identified for this study was that; research has been conducted on the SMK of pre-service teachers, but little is known about their understanding of the nature of the disciplinary knowledge of Life science. There have been reports on learners' inability to understand some of the concepts being taught during teaching and learning, and this could be as a result of other conceptual problems that have been reported to be as a result of the teachers' poor preparation and hence poor understanding of the required content concepts (Rollnick & Mavhunga, 2014). Spaull (2013) is of the opinion that in South African schools, some of these difficulties are linked to inadequate content knowledge, and the teachers' inability to transform knowledge, that is, making concepts accessible to students.

Therefore, the purpose of this study was to understand the level of understanding of Life science that the PGCE pre-service teachers have acquired during their postgraduate program and their viewpoint concerning the nature of Life science discipline. In Life science, the disciplinary structure includes epistemological (theories, methods, beliefs) and its ontological (nature) perspectives entails and how they are sequenced. Therefore, Life science deals with teacher knowledge of the purposes and methods of inquiry as well as understanding the existing kinds of connections, models and data that validate knowledge (Windschitl, 2004). The understanding of Life science structure is known to influence the methods adopted in teaching its concepts, and it depends on a number of factors such as, teachers' understanding of the nature of science (NOS), subject matter knowledge (SMK), pedagogical knowledge (PK) and teacher beliefs (Ekborg, 2005). This is why the need to review the PGCE Life Science pre-service teachers understanding of the disciplinary structure of Life Science at the end of their postgraduate program in the university was required. Therefore, this study will help to understand the knowledge of the disciplinary structure of Life science that the pre-service teachers have at the end of their program. In order to achieve the purpose of this study, two research questions were formulated to guide this study. The questions and answers to them are discussed in the following section.

5.1.1 Answering the Research questions for this study

Research question 1: What levels of understanding of the nature of Life sciences as a scientific discipline is demonstrated by PGCE Life science PSTs? The question was posed to elicit the participants' views regarding SMK, NOS and structuring principles which makes up the nature of Life science. The data collected from the PGCE pre-service teachers' responses was analysed using three LCT dimension. The dimensions were specialization, density and temporality. The results from the analysis of each dimension individually contributed to answering research question one. For specialization, result showed that PGCE students have an understanding that in Life science what matters most is knowledge and not the personality of the individual. From the density dimension, the result indicates two important things. First, it is an indication that the PGCE Life science pre-service teachers view Life science as a well-diversified discipline. Second, the students view Life science as having different belief systems guiding it. For the Temporality dimension, the analysis revealed that PGCE pre-service teachers view Life science as being Archeo-prospective, which means that Life science as a sub-discipline is an old subject which is forward looking. From all the aforementioned points on specialization, density and temporality dimensions, and from their responses to open-ended items, the answer to the research question is that, the PGCE Life science pre-service teachers have a satisfactory understanding of the nature of Life science by acknowledging that: in Life science what matters most is knowledge and not the knower; the knowledge accumulated in Life science is diversified and have a wide range of belief systems; and the disciplinary knowledge of Life science is old and forward looking.

Research question 2: To what extent do PSTs develop the required gaze about Life sciences from their PGCE program? The purpose of this question is to understand the magnitude of the knowledge gaze that the PGCE pre-service teachers have regarding their disciplinary knowledge in Life science. By gaze I mean the perception or understanding of PGCE pre-service teachers regarding the nature of Life science. The data collected from the open ended section was coded and themes formed in order to analyse the responses from the participants. Also, the data was supported with the interview transcript to elicit the views of the students and their teacher educator concerning the disciplinary knowledge of Life science.

From the result, it was evident that the PGCE pre-service teachers have the understanding of the SMK that makes up the Life sciences and that the SMK is made up of several concepts and theories which reveals Life sciences' high material density, as well as confirming that what is important in the discipline of Life science is Knowledge. Also in their responses, it was evident that they recognize the place of NOS as part of their disciplinary knowledge, that is, they show an understanding of the need for scientific inquiry based skills, history of science, and so on. From all the mentioned points above, the answer to the research question is that the pre-service teachers show a good understanding of the knowledge that is considered legitimate in the disciplinary discourse of Life science. They also understand that to be a subject specialist in Life sciences, there is a need to have SMK and the knowledge of the NOS, which is a prerequisite to be seen as a subject specialist in Life science. In agreement with this statements, Arbee (2012) mention that legitimacy in a discipline (Life science), relates to expertise in the "disciplines' specialist knowledge and techniques" (p. 44).

Only three of the LCT dimensions were identified in the questionnaire. The reason for this is because, the questionnaire was developed by a bigger project under which this research is being carried out, and it was developed for various disciplines. Therefore, after the questionnaire has being thoroughly checked, it was found that three out of the five dimensions reflected in the questionnaire. This could be as a result of the discipline being studied as well as the nature of the research questions posed for the study.

5.2 Critical reflection on the research process

5.2.1 The adopted research methodology

This study adopted both qualitative and quantitative methodology. The quantitative approach was only visible in the analysis of data into tables while the qualitative approach was used in interpreting the data collected from the open ended questionnaire and interviews. The philosophical theory connected with the use of the qualitative approach is found within the interpretivist paradigm. The descriptive explanations were used to answer the research questions posed for the study. The use of quantitative and qualitative methods in this study helped me in much important way. I was able to gain a better insight on complex phenomenon and research problems compared to using just one method. Because of this experience, I was able to access various perspectives of analysing the LCT dimensions (Arbee, 2012). During the course of my research, I found that a quantitative method was much more suitable in correlating data, especially when the need to count number of occurrence and percentage is concerned. Also, I realized that using qualitative method of approach was more suitable in interpreting data with the LCT concepts and codes. The evidence can be seen in the study when the concepts and codes were used in discussing the findings. Also, it is suitable because one of the strength of the legitimation code is in its tendency of being applied at different levels of analysis, in order to explore various types of phenomena (Maton, 2016). The LCT framework gave the opportunity of interpreting data using the different dimensions and codes. Therefore, the qualitative aspect enabled explanations and interpretation of the data found within the LCT dimensions, by making explicit the extent at which the PGCE preservice teachers develop their gaze of the nature of Life science. The quantitative method with the LCT dimensions assisted in understanding the viewpoints of the PGCE pre-service teachers concerning their disciplinary knowledge.

5.2.2 Critical analysis of the questionnaire

As mentioned earlier in the methodology chapter, the research instruments used for collecting data for this research were questionnaires and an open-ended question. Some items of the questionnaire were not speaking directly to the study. And this could be due to the intention of using the instrument in other disciplines. For example, the item (18) that states; it is very clear where these subject boundaries are… can cause a misconception regarding the nature of Life science not being diversified. Contrary, the Life science discipline has no boundaries because of its verticality and power of discourse (Bernstein, 2000), it is context-independent with a strong semantic gravity and has no boundaries within its concepts. Therefore, the responses from the participants were; agree (6), Neutral (6) and disagree (4). The responses were almost evenly distributed, meaning that either the respondents do not understand the question clearly, or they got the misconception of their disciplinary knowledge as having boundaries (see table 3.3). Also item (14) states; a course in this subject would be made up of a collection of different (often dependent) modules….the construction of this item did not consider the context of the project. The statement also gave rise to almost evenly distributed responses for, agree (6), Neutral (5) and disagree (5). This could also be the issue of how the statement was constructed or worded. If I were to do this research again, I would reword these statements to achieve a better result for my study. The instrument was constructed for the whole school of education, so some of them were not speaking specifically to science. Therefore, when constructing an instrument for a bigger project, the context, unit of analysis, and the problem of the study must be put into consideration, as this will add value to the project as a whole.

5.2.3 Validity and trustworthiness of the study

In a study with qualitative and quantitative approach, investigating the quality of the data collected and findings of the research is of utmost important. For this reason, Ihantola and Kihn (2011) suggest that in a research with such combination of qualitative and quantitative methods, data quality will dwell on the standards of individual strand that is involved. In agreement with this, researchers such as Teddie and Tashakkori (2009) are of the opinion that if the data of each strand is credible and valid, then the research has greater tendency of generating good findings. As indicated in the methodology chapter, this study is part of the existing bigger project in the institution under study. The trustworthiness of the findings in this study was ensured in that *the instruments used for collecting data in this study were adopted from a bigger project in the institution under study.* The research instruments were already designed, developed and piloted in the bigger project. *The bigger study has same focus as my study, because they both target the nature of disciplinary knowledge. Efforts were made in this study to ensure that the statements (i.e. questionnaire items) are in line with the study and this was done by me and two colleagues under same research project.* Also, we reached an agreement on the raw data before I proceeded in analysing and reporting the data. Moreover, as much as trustworthiness strengthens the research findings, such should also be found reliable. Reliability describes in detail, the consistency of a research instrument in achieving similar results when it is used to measure same phenomena under same context repeatedly. Tavakol and Dennick (2011) are of the opinion that a research tool cannot be proven valid except it is reliable. Based on this, the LCT toolkit was used to analyse the responses gathered from the questionnaire, which had both a Likert scale (closed ended) section and an open ended section. The result from the open ended section was used to support the results from the Likert scale, because of the similarity in results. Also, the results from the interviews conducted were used to support the data from the questionnaire. Further efforts made to ensure that reliability was achieved in this study were by involving the same research colleagues in the analysis process. The findings from Likert scale and interviews were triangulated. Triangulation of data collected for this study was followed as suggested by (Ihantola & Kihn, 2011). Triangulation allowed the privilege of collecting data and information from varied sources.

5.3 Implication of the study to the institution and to Science education

The history of science education has discovered the issues that have been deliberated upon with regards to science in a way that reviews what rationale is used for teaching science, as well as 'what science education should be taught' and 'how it should be taught' and 'how it should be organized' and at 'whose interest should science education be taught' (Osborne, Collins, Ratcliffe, Millar & Duschl, 2003). Based on the result that was achieved from this study, there is an indication that the disciplinary knowledge acquired by PGCE pre-service teachers during their postgraduate program will immerse them deeply into the knowledge of the content and scientific enquiry.

The disciplinary knowledge of Life science involves SMK and the knowledge of NOS; therefore the result from this study shows that indeed the PGCE Life science pre-service teachers show an understanding of the disciplinary nature of Life science. Based on this, Darling-Hammond (2006) posit that subject matter knowledge is one of the leading factors in 'teacher effectiveness' because from the philosophical perspective, it will influence the effort of the teacher in helping the students to learn subject matter (Jadama, 2014). Also, the implication of exposing the PGCE pre-service teachers to content knowledge as well as the knowledge of pedagogy is to equip them and help them teach as professionals and ensure the students' adequate understanding of the subject in the classroom. Because the pre-service teachers need the content knowledge (CK) in order to teach effectively in the classroom (Shulman, 1986), there is an eagerness to make content a requirement by policy makers. The requirements will be based on listing of topics without emphasizing the "nature of content knowledge needed" (Ball *et al*., 2008, p. 394). The disciplinary knowledge also involve curricular knowledge (CK) as part of its content knowledge, therefore if well taught to the PGCE pre-service teachers, there is a possibility of helping them teach concepts adequately in the classroom.

Exposing the PGCE pre-service teachers to the disciplinary knowledge of Life science will also enhance teaching and learning process in their classroom because, the pre-service teachers need to understand Life science as a discipline, to enable them interpret curriculum documents in schools. Also, the disciplinary knowledge acquired by the pre-service teachers also include knowledge of the curriculum, which is the teachers' understanding of the series of programs or activities that are designed in the curriculum for teaching specific concepts to specific level of students Shulman (1986). Therefore, this will enable the pre-service teachers to adequately teach Life science according to its structuring principles, thereby enabling understanding of the concept in the classroom. The result from the study reveals that the PGCE pre-service teachers have a good understanding of SMK and NOS of their discipline, which means that they have developed a gaze of Life science. In respect to this, Jadama (2014) is of the opinion that when a teacher is unable to acquire adequate subject matter knowledge, they can do more harm than good to the students because they possess 'inaccurate information and ideas' which they eventually pass to their students. Learning Life science also means understanding its structures; therefore, knowledge of the subject matter structure (SMK & NOS) will enable the pre-service teachers to teach the concepts in the curriculum adequately. From the findings of this study, the PGCE pre-service teachers have shown adequate knowledge of the SMK and NOS as regards the nature of Life science.

5.4 Limitations of the study

The first identified limitation of this study is connected to the fact that the sample size was small. The small sample size was predetermined by the number of Life science pre-service teachers who were enrolled for the 2016 PGCE program at that time, although, not all the students who enrolled participated in the research. For example, the sample size of 16 PGCE pre-service teachers out of the total number of 27 who enrolled for the program voluntarily consented to take part in this study. As a result, it was ensured that the conclusions on answers to the research questions were drawn by considering the analysis of the entire participants' responses. Hence, understanding the PGCE pre-service teachers' knowledge gaze was restricted to the context where it was planned. While the findings in this study may not be a generalized type, they could be considered based on the efforts made in analysing the entire participants' responses and drawing conclusions. Similarly, the limitation of this study was related to the strategy employed in unravelling the level of PGCE pre-service teachers' understanding of the nature of Life science.

The PGCE pre-service teachers had taken a competent test, which is used to measure their previous content knowledge done for Bachelor of Science degree, before enrolling for the program. Therefore, investigating the PGCE pre-service teachers' level of understanding of the nature of Life science could have been further established by analysing their test score for the competent test. However, due to time constraint and the nature of the research question such could not be achieved. Since the major target in this study was to understand the participants' interpretations of the nature of Life Science, efforts solely focused on the questions that asked for their descriptions. Also, classroom observation would have been another method to collect data for this study, but it was not realized because the PGCE students were on their teaching practice as at the time when data was collected for this study.

5.5 Recommendation

As issues concerning science education and teacher training programs keep arising, little is known concerning what the pre-service teachers take with them while undertaking the courses which have been designed to equip them with the understanding of the subject matter (Abell, 2007). Generally, the SMK of pre-service teachers is what is being tested, but their knowledge of the discipline is not being tested. The study however shared that while the nature of Life Science is not explicitly taught, the students do acquire the understanding and gaze. What I would therefore recommend is that importantly, the nature of Life science as a discipline of knowing, and teaching the nature of Life science should be made explicit. The nature of Life science is such that includes the SMK, knowledge of the NOS and its structures as a whole. Therefore, from the findings of this study, it was revealed that the PGCE Life science pre-service teachers have a satisfactory understanding of the nature of their disciplinary knowledge, especially the content, but the structures of the NOS is not evident in the results. They understand the various concepts for the SMK, but lack the structuring principles guiding the concepts of the NOS (e.g. inquiry skills). Just like the CAPS document, it has structures of the SMK, but the structures for teaching the NOS are not made explicit in the curriculum. Therefore, it is advised that during teacher training programs emphases should be made concerning "the teaching of introductory concepts, which is so critical for students because, there is little room to decide which concept is to be taught next. It informs the 'how to each' in disciplines, that is, it is the sequence adopted by various discipline in a hierarchical knowledge structure, on how to transfer knowledge from simple to complex in the teaching and learning situation (Hierarchical knowledge structures).

5.6 Conclusion

Efforts towards improving the quality of science classroom teaching and learning involve researching teachers' acquisition of subject matter knowledge in their disciplines. Particularly, in the case of the subject matter experts undergoing training to become teachers (i.e. PGCE pre-service teachers, little is known whether the PGCE Life science pre-service teachers understand the Life science structure, therefore in addressing some of these difficulties, it is important to establish the understanding of Life Science disciplinary structures acquired by the PGCE Life science pre-service teachers (PGCE) at the institution under study. The study investigated the PGCE pre-service teachers' level of understanding of Life Science as a scientific discipline. The findings from this study showed that the PGCE Life science pre-service teachers portrayed a satisfactory understanding of the nature of Life science. Also, it was revealed that the level of their gaze regarding Life science as a scientific discipline satisfactory understanding of the nature of Life science by acknowledging that: in Life science what matters most is knowledge and not the knower; the knowledge accumulated in Life science is diversified and have high belief moral systems; and the disciplinary knowledge of Life science is old and forward looking.

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Appendices

Appendix 1

Code of respondent	Discipline specialization	Did you take this subject (Grade 12) level as a National Senior Certificate subject?
PGCE1	Life science	yes
PGCE2	Life Science	Yes
PGCE3	Life Science and Physical science	Yes
PGCE4	Life science	Yes
PGCE5	Life science	Yes
PGCE6	Life science	Yes
PGCE7	Life science	Yes
PGCE8	Life science	Yes
PGCE9	Life science	Yes
PGCE10	Life science	Yes
PGCE11	Life science	Yes
PGCE12	Life science	Yes
PGCE13	Life science	Yes
PGCE14	Life Science and Physical science	Yes
PGCE15	Life Science	Yes
PGCE16	Life science	Yes

Participants' information and experience in Life science

Appendix 2

Transcript for the focus group interview

Interviewer: introduction. Welcome and thank you for responding to my re

Like I said before, my research is on the SMK and DK of PGCE students, and you fall into that group. Before we move on, I will like to know what your view is on DK, like when you hear the word DK, what is the first thing that comes into your mind?

> ***Researcher:*** *I will like to know what your view is on DK, like when you hear the word DK, what is the first thing that comes into your mind?*
>
> ***Part 1:*** *what do you mean DK*
>
> ***Part 2:*** *you mean discipline?*
>
> ***Part 3:*** *teaching life science. You know the content, you have a background in the knowledge from somewhere, then you know it enough to be able to teach it.*
>
> ***Researcher:*** *ok, what about SMK?*
>
> ***Part 4:*** *I disagree with her response*
>
> ***Researcher:*** *ok, lets hear your own response*
>
> ***Part 4:*** *I think what you described was more like a content knowledge. Of course you need the disciplinary knowledge in order to engage with the subject properly. The subject matter is what is basically what is in the textbook and DK is a bigger deeper understanding of what science is and the nature of science and experimental, like practical and scientific skills.*
>
> **Part 2:** *of course you need the disciplinary knowledge in order to engage with the subject properly. The subject matter is what is basically what is in the textbook and DK is a bigger deeper understanding of what science is and the nature of science and experimental, like practical and scientific skills.*
>
> **Question 1**
>
> *Who is the ideal biological scientist?*

Part1: *I think obviously they have to be on top of the knowledge, they have to be in research, laboratory, …….. doing it for the outcome, doing it for the scientific enquiry, I think they have to be very good, exception to the science field, to the science field, you have to be in it for it to have that pure passion, otherwise that is what I think …….*

Interviewer: lets say for example I am teaching someone something related to biology, what is it that you will see that will make you say I am a biologist?

Part 2: *I think it is also that broad and integrated outlook, you need to specialize by the time you get into need to*

We believe that when people have their degree, even if they are specialized in cell biology, they develop the skill during the degree to go and read up and learn about environmental Science….. so its very different to a B.ed where you do things…. Em… we try to cover all the things we do at school. But when you do a B.sc, as you said, they are specialized, but you develop a skill that I see when I go into the classroom, where people can actually go and read up and find out, then know how to hand out that information. And they do all have to pass, em.. the first course in their first year, it's a very broad course, so it covers all the topics, so they have got that first year foundation, but they haven't specialized and gone into great details. And I would argue that much of that first year course is what people do at 3rd and 4th year level here, so they would have desame amount of content. Can I emphasize, our purpose is not to teach content knowledge.

Appendix 3

Transcript from the interview for teacher educators

Researcher: what can you disciplinary knowledge is…..?

TE1: *em…I suppose I would see the DK as more than just a SM, so I would look at it in terms of the skills, values, beliefs, attitudes that people develop. So its more like an over chain thing on the life Science. What does LS involve in total. So it might be philosophical attitude towards teaching the life Science, what they feel is important, etc. so when you looking at the discipline, you looking at many aspects and not just the subjects.*

Researcher: what about SMK?

TE1: *It depends on how you are defining SMK, but em.. if am looking at……I will just define it as a concept, biological concept, it might also involve perhaps the skills, the understanding of process skills, em.. so that is the aspect of it, the application to the society, SMK is anything that is ……..associated with the subject matter.*

Q1: what concepts and skills are important?

TE 2*:* *I think in the life science…….we do not spend time talking about the subject content, we assume that they come with the content knowledge. So the purpose of the subject competent test is to make sure that they develop… if they are behind the subject content, they catch it up. So, ……. Dis year we set for them grade 10 n 11 test and about one third of the class failed the test, now that is to be expected, because when they specialize in their degrees, they are not covering school stuff, so they come in for the test, they think they know the stuff, but they forget that is very broad, very shallow, and very broad, and then they specialize in a very narrow area. So Some of them get 90 percent, some of them take it seriously, the subject competent test and they study for it and they get a 100 percent of 90 percent, and others get 30percent. So they haven't taken it seriously and they don't realize how much they don't know. And then I have to repeat the test, so this year when I repeated the test, all of them passed. So its just a matter of catching up.*

Q2: do your course materials and assessment tasks develop the necessary knowledge and skills that the students will use in their disciplinary practice?

TE2: *We don't do specifically subject content knowledge, but when they prepare their mini lessons, when they prepare the…. Activities, they have to go and research that subject content in a specific field. So we don't go and say, I am going to look at cell respiration and explore that topic. But if they do mini lesson on cell respiration, they would have to explore that. In other ways, it comes in, in the nature of the task we gave them, they design an exam for grade 10, they have to make sure they understand the subject content of grade 10 in order to design the exam. They are not allowed to go on teaching experience until they pass the test.*

Appendix 4

When someone studies this subject, they learn about…	When someone studies this subject, they learn how to
The workings of their bodies (digestion, excretion, skeleton, etc) (SMK),which is very important. They also learn about the environment (SMK). Will help them appreciate it more and join in the efforts to conserve the biodiversity (moral density). They are also exposed to the history of science and discoveries (NOS< temporality).	-conduct proper scientific experiments. Replicates variables, etc. (NOS) -express and respect others opinions without getting into arguments(moral density) -justify their opinions (Moral density) -understand scientific jargons (NOS) -do proper research for assignments (NOS) -understand scientific method (hypothesis, methods, etc) (NOS)
The basic unit of life (the cell) right through to ecosystem and biomes (SMK). In essence, anything that is related to the life of an organism (SMK). You also learn about how this subject applies to and is relevant about life outside the classroom (material density). You also learn a number of skills, e.g practical work that is unique to the discipline. (NOS)	Refine and develop skills that are important to the discipline (material density, NOS). That organisms, relate to one another and how to make connections (SMK). They learn how to apply their knowledge outside the classroom (material density).
-the components of life such as cell and its components (SMK) -the human body and how it works (SMK) -interactions between organisms and their environments (SMK) -history of life (NOS) -human ecology and population dynamics (SMK) -relate how the human body works to disease and malfunctions (SMK) -remedies. (density)	-respect the environment and the components of the environment (moral density) -conservation of nature and resources (SMK, moral density) -understand how their bodies work (SMK) -relate the history of life to current life, how the aspects of life have evolved and how science has contributed to medicine and improving human life as a whole (NOS, temporality).
Real world processes (material density) and understanding how the natural world and organisms interact and function (SMK). Microscopic and macroscopic workings of organisms (SMK)	Critically evaluate scientific evidence and (hopefully) make clear decisions about results and validity of scientific data (NOS). Carry out basic scientific life science practical experiments/manipulations ad record data in a correct scientific format (NOS). -apply their scientific knowledge to interpret

	scientific experiments and data. (NOS) -Have an appreciation for workings of living organisms on earth and have a desire to share this science with others in everyday life. (moral and material density)
Several key aspects pertaining to the science of life (on earth) (SMK). A student will learn about life science from a microscopic level (components with makeup life i.e., DNA and cell) (SMK) to the macroscopic level (interactions between biotic and abiotic factors) (SMK), they will learn about the origin of life on earth and life over time (change over 4 billion years) (temporality), learn critical thinking and reasoning skills pertaining to research & science in society. Students will also learn and become skilled in several skills & research components of science, how to conduct research in science that is valid & reliable, conducting experiments with appropriate equipment setting, using & improving recording skills (report writing/scientific method, graph skills, etc.) (NOS)	-Introduce a component of life science by introducing the big picture/big idea & then breaking down the concepts & content over a set period of time (material density). -structure component consecutively in such a way as not to overload any student (starting with life science basics & building complexity over time through all integrated components) (material density). -improve scientific skills, (NOS) -address misconceptions about all life Science components, research, science & science in society. (moral density) -continuously learn about life science, improve own skills, own understanding of life science, purpose & meaning of life science (NOS)
-how living organisms function the way they do (SMK) -important life processes (SMK) From a molecular level to an ecosystem level -interactions at all levels(SMK)	-formulate their own understanding about how their bodies work (NOS) -critically access situations from a scientific perspective (NOS) -be responsible towards the environment and other living organisms (moral density) -use practical skills (NOS)
The workings of the body, plants and animals as well as the interactions between different organisms (SMK). It's really about all living things, their processes and how they act with the non-living things around them (this includes humans) (SMK). You also learn about how the world as we know it came about & how it might change, both naturally & as a result of human action. (SMK, temporality)	-apply their scientific knowledge to everyday occurrences (NOS) -construct scientific data in the forms of tables, graphs, etc (NOS) -calculate certain relevant figures (NOS) -learn how to see/identify the interactions between different systems & organisms (NOS)
-life and life system (SMK) -human biology /anatomy (SMK) -plants/ecosystem (SMK)	-have/use time management (NOS) -make use of study/method skills (NOS) -have research resources (NOS)

-food groups (SMK) -biotechnology (SMK) -human /plant/animal diseases (SMK) -preventative measures/cures (SMK) -ethics, legal aspects/copyright (moral density) -the scientific method (NOS) -Effective communication	-keep up to date with scientific research (media) -communicate their findings to others/group members (NOS) -be patient -use trial/error (NOS) -practice certain procedures (NOS) -strike a balance between work/personal life -treat every colleague/resources with respect
How the complex interplay of chemical reactions make up the processes of life (SMK). These processes can act in individual cells but form the basis of complex operations at a scale well beyond even individual organisms. (SMK)	Understand biological concepts and processes by applying a specific cognitive discourse associated with biology (SMK)
-The living world (SMK). All interactions of life on earth. (SMK) -How living systems and organisms work. (SMK) -they learn about their own body systems and their environment (SMK) -they learn about human beings attraction to the environment. (SMK)	Interpret and draw graphs and tables (NOS) -follow instructions to do practical work and then be able to do the hypothesis and aims and write up the scientific repot. (NOS) -draw biological diagrams and label it correctly with an appropriate heading (NOS). -recognize imbalance in the human body and environment (SMK). -to know what can be done about it (material density).
Life and spheres (SMK), it looks into what is life, classifying it and make connections to other things (material density). How, why and when are things the way they are.(temporality) -it is aware of the dangers that might rise, if certain factors continues and how or what can be done to prevent, control or maintain the conditions. (moral density) -it is about a thing supporting a thing, one depending on the other. -basically, it is about understanding life and the environment supporting it (moral density, material density).	Make sense of their own world , and enables one to acquire skills to teach others (moral density, NOS). How to communicate the truth with reference. (NOS)
Living and non-living things in the environment and how they interact with each other, and how they interact with their environment (SMK). -they also learn about their body systems and how they work (SMK). They also learn about things that may go wrong in those systems and how to keep them healthy (SMK)	Live life much healthier. They learn how to take care of themselves and the importance of chemical balance in the body (SMK, material density). -analyze situations and find what is wrong and have solutions (NOS). They also learn how to use what they learn in class and apply

	it to their everyday life.(material density)
Living things from molecular level to their interactions with one another and their environment (SMK). One will develop their knowledge of key biological concepts, processes, systems and theories (SMK). Will also develop understanding of ways in which human have impacted negatively on the environment and organism live in it (material density).	-analyze information/data and be able to interpret it (NOS) -recognize relationships between existing knowledge and ideas (material density) -categorize information -evaluate scientific information (NOS)
Mostly plant and animal biology; some chemistry (material density)and some history of science(SMK)	Memorize and analyze known facts about biology; -perform laboratory and field investigations; (NOS) -situate their knowledge in the broader context of science. (material density)
Theoretical basis of life Science (SMK) -practical skills and investigation methods that apply in science (NOS) -critical and analytical thinking (NOS)	Apply scientific practice in all spheres of science -write and understand scientific language (NOS) -think out of the box (NOS)
Organisms, systems, nature, ecosystems, chemistry of life (SMK). How to conserve and appreciate nature. (moral density, SMK) -the systems in human and animal bodies and systems in plants (SMK). -how animals and plants are related to each other (SMK) -skills related to the subject (drawing graphs, tables) (NOS). -diseases in certain organs, structure and functions of (structure related to functions), (SMK) -diseases affecting the organs and how to prevent and treat these diseases (SMK< moral density).	-conserve nature (moral density) -appreciate nature (moral density) -relate to real life things (material density) -access data and representing data (applying and analyzing data) (NOS) -use knowledge to solve real life problems (Material density) -how the ecosystem works and how it is disturbed (SMK).

Appendix 5

Teacher educators'' experience

Teaching the teachers: Knowledge structures in Education and Teaching Subjects

University Staff Questionnaire

Name			
Email address			
Tel ext number			
University school	**Education**		
Department	**Science Educ**		
Please indicate your subject/ discipline specialisation?			
	Physical science		
	Life Science	**X**	
Highest level at which you have studied this subject/discipline	**M.Sc.**		
Research publications and involvement in the development of the subject **My answers are in relation to Education, not pure Science**	I belong to academic or professional associations in this subject/discipline	YES	
	I have contributed to the writing of school textbooks in this subject/discipline	YES	
	I have published research in this subject/discipline	YES	
	I regularly read academic papers related to this subject/discipline	YES	
	I have presented conference papers related to this subject/discipline	YES	
	I have attended conferences related to this subject/discipline	YES	
Years of teaching this subject/discipline	School level: 4 Tertiary level: 29 years Other:		

Teaching the teachers: Knowledge structures in Education and Teaching Subjects

University Staff Questionnaire

Name			
Email address			
Tel ext number			
University school	**Education**		
Department	**Science**		
Please indicate your subject/ discipline specialisation?			
	Physical science		
	Life Science	**X**	
Highest level at which you have studied this subject/discipline	**Hons – Zoology** **M Ed, PhD – Science Education**		
Research publications and involvement in the development of the subject	I belong to academic or professional associations in this subject/discipline	YES X	NO
	I have contributed to the writing of school textbooks in this subject/discipline	YES X	NO
	I have published research in this subject/discipline	YES X	NO
	I regularly read academic papers related to this subject/discipline	YES X	NO
	I have presented conference papers related to this subject/discipline	YES X	NO
	I have attended conferences related to this subject/discipline	YES X	NO
Years of teaching this subject/discipline	School level: Tertiary level: Other: INSET 5 yrs	7 28	

Appendix 6:

Life science lecturers schedule for focus group questions.

Questions	Sub questions	Why are we asking these questions? Link with LCT?
1. Who is the ideal biological scientist?	What do they know? What can they do with that knowledge? What personal attributes do they have? Can anyone study this subject?	Specialisation code
2. How does our curriculum seek to develop the ideal knower?	What concepts and skills are important? How does our curriculum seek to involve students into the knowledge practice of our subject?	Autonomy Specialisation code Density
3. What is the relationship in this subject between theoretical ideas and real world problems?	When? Where? And how do you connect them?	Autonomy Semantics
4. Where do you get the knowledge from, for the course work?	What constitutes legitimate subject matter knowledge? How do you recognize it as valid knowledge?	Autonomy Density Semantics Temporality
5. What are the relationships between your subject and the others?	Do you make links explicit?	Autonomy Density Semantics
6. How do you use coursework and assessment to make disciplinary knowledge and skills accessible to the students?	Do your course materials and assessment tasks develop the necessary knowledge and skills that the students will use in their disciplinary practice?	Density Semantics Specialisation code
7. How does your curriculum take into consideration what the students will do with subject once they graduate?	How does the curriculum seek to involve the students in the knowledge practice of the subject?	Autonomy Semantics Specialisation code Temporality
8. To what extent do you think that your	Have your students acquire a disciplinary gaze?	Specialisation code

students understand what your subject is all about?		
9. What impact does the way that you teach your discipline have on the preparing the students to be subject specialists?	Is there something about the way you present the coursework that helps them to become subject specialist?	Pedagogical approach?

Appendix 7

PGCE. Life science PSTs schedule for focus group questions.

Questions	Sub questions	Why are we asking these questions? Link with LCT?
1. Who is the ideal biological scientist?	What do they know? What can they do with that knowledge? What personal attributes do they have? Can anyone study this subject?	Specialisation code
2. How does the curriculum seek to develop the ideal knower?	What concepts and skills are important? How does the curriculum seek to involve you as PST into the knowledge practice of your subject?	Autonomy Specialisation code Density
3. What is the relationship in this subject between theoretical ideas and real world problems?	When? Where? And how do you connect them?	Autonomy Semantics
4. Where do you get the knowledge from, is it from the course work?	What constitutes legitimate subject matter knowledge? How do you recognize it as valid knowledge?	Autonomy Density Semantics Temporality
5. What are the relationships between your subject (life science) and the others?	Do you make links explicit?	Autonomy Density Semantics
6. Does the use of coursework and assessment make disciplinary knowledge and skills accessible to you?	Do the course materials and assessment tasks develop the necessary knowledge and skills that you as a PST will use in your disciplinary practice?	Density Semantics Specialisation code
7. How does the curriculum take into consideration what you as the PST will do with subject once you graduate?	How does the curriculum seek to involve you in the knowledge practice of the subject?	Autonomy Semantics Specialisation code Temporality
8. To what extent do you think that you understand what your	Do you think that you have acquired a disciplinary gaze?	Specialisation code

subject is all about?		
9. What impact does the way that you are taught your discipline have on preparing you to be a subject specialist?	Is there something about the way your lecturers present the coursework that helps you the PST to become subject specialist?	Pedagogical approach?

Appendix: 8

Questionnaire sample for pre-service teachers

<table>
<tr><td>Name</td><td colspan="2"></td></tr>
<tr><td>Email address</td><td colspan="2"></td></tr>
<tr><td>Tel number</td><td colspan="2"></td></tr>
<tr><td>Programme</td><td colspan="2">PGCE</td></tr>
<tr><td rowspan="10">Which is your subject/ discipline specialisation?</td><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Life Science</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Did you take this subject (Grade 12) level as a National Senior Certificate subject?</td><td colspan="2">YES

NO</td></tr>
<tr><td>For how many years have you studied this subject at University?</td><td colspan="2">0: I’m in my first year of study
1 year
2 years
3 years
4 years</td></tr>
</table>

Please read through all the following statements and then indicate the extent to which you agree or disagree with each one by placing an X in the chosen block.

		Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	It takes someone with a natural talent to learn this subject.					
2	Anyone can learn this subject given sufficient time or training.					
3	There is a special kind of knowledge that a subject specialist needs.					
4	There are special skills that one develops when learning this subject.					
5	To learn this subject, one needs to 'get a feel' for it through experience.					
6	This subject makes connections across time.					
7	This subject tries to understand how things were in the past.					
8	This subject tries to understand how things are in the present.					
9	This subject makes predictions for the future, or informs planning for the future.					
10	It is vital for teachers to understand what this subject is, and what it's *not.*					
11	People can use knowledge from this subject for purposes that exist outside the discipline.					
12	When teaching this subject, teachers draw on knowledge that is located outside the subject.					
13	This subject makes links between theoretical concepts and real world examples/ problems.					
14	A course in this subject would be made up of a collection of different (often independent) modules.					

15	The sequencing of modules in this subject is essential for students' understanding of the subject.					
16	There is wide agreement amongst subject experts about the nature of the subject.					
17	There are strong theories that hold this subject together as a networked body of knowledge.					
18	It is very clear where this subject boundary are					
19	This subject is connected to many other subjects.					
20	Certain *kinds of people* understand this subject better than others.					
21	To be an expert in this subject requires that one holds certain beliefs.					
22	This subject gives one a special way of understanding real life problems, and addressing them.					

The following two questions are open-ended and require more detail in answering them:

22. When someone studies this subject, they learn about…

23. When someone studies this subject, they learn how to…

Thank you for your participation!

Appendix 10

INFORMATION SHEETS FOR PGCE LIFE SCIENCE STUDENTS AND LECTURERS

University of the Witwatersrand Private Bag 3 Wits 2050 Johannesburg +27 11 7173414 f+27 11 7173259

Masters Student: Ahanonye Uchechi

Student No.: 1180216

1180216@students.wits.ac.za

Cell phone number: 0847586461

Dear Student

Re: Invitation to participate in a research study on disciplinary and subject matter knowledge for student teachers

My name is Uchechi Ahanonye and I am a fulltime Masters in Science Education student in the School of Education at the University of the Witwatersrand. I am currently conducting a study aimed at understanding the extent of Subject matter knowledge that 4th year B.Ed and PGCE Life Science students demonstrate at the end of their initial teacher training course. My study is under a bigger study that is being conducted at the Wits School of Education (WSoE).

Recent research points to the importance of understanding of disciplinary and subject matter knowledge structures regarding their ability to teach effectively and make sound judgments. For this reason, the Teaching and Learning Committee based at the Wits School of Education is conducting a research entitled "Teaching the teachers: Disciplinary Knowledge in Education and Teaching Subjects". The research team seeks to do a comparative analysis of the disciplinary knowledge that prospective teachers learn when they take the Bachelor of Education (BEd) route and the Post Graduate Certificate of Education (PGCE) route to qualifying. The study seeks to find out, how student teachers' understand the nature of the subjects they have learnt during the course of their studies.

So, I would like to invite you to participate in this study. Your participation would involve providing me consent to analyse the questionnaire and to also to participate in a 45 minute focus group interview, convened at a date, time and venue convenient to you.

Participation in this research is entirely voluntary. There will be no negative consequences should you not participate. If you do choose to participate, all information about you will be kept confidential, and no-one would be able to recognize you in any publication or presentation arising from the research. You may at any time withdraw from the study with no negative consequences. All data (electronic and material) will be kept securely in locked offices and would be destroyed within five years of the completion of the project. It is envisaged that the results of the research will be used for academic purposes (including books, journals and conference proceedings). Please let me know if you require any further information.

Thank you very much for your help.

Yours sincerely,

Uchechi Ahanonye (1180216)

Appendix: 11

PGCE Life Science Student Teacher's Consent Form

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called: **Investigating the extent of subject matter knowledge and disciplinary knowledge that final year life science pre-service teachers demonstrate at the end of their B.Ed undergraduate program**.

I, _________________________ give my consent for the following:

Circle one

Permission to be interviewed

I agree to be interviewed for this study. YES/NO

I know that I can stop the interview at any time and don't have to answer all the questions asked. YES/NO

Permission for questionnaire

I agree to fill in a questionnaire for this study. YES/NO

Permission to be audiotaped

I agree to be audiotaped. YES/NO

I know that the audiotape will be used for this project only. YES/NO

Informed Consent

I understand that:

- My name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audiotaped
- All the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign______________________________ Date____________________________

PGCE Life Science Lecturers Consent Form

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called: **Investigating the extent of subject matter knowledge and disciplinary knowledge that final year life science pre-service teachers demonstrate at the end of their B.Ed undergraduate program**.

I, ________________________ give my consent for the following:

	Circle one
Permission to be interviewed	
I agree to be interviewed for this study.	YES/NO
I know that I can stop the interview at any time and don't have to answer all the questions asked.	YES/NO
Permission for questionnaire	
I agree to fill in a questionnaire for this study.	YES/NO
Permission to be audiotaped	
I agree to be audiotaped.	YES/NO
I know that the audiotape will be used for this project only.	YES/NO

Informed Consent

I understand that:

- My name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audiotaped

- All the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign______________________________ Date____________________________