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An investigation of the assessments used to determine the content knowledge of Post-Graduate Certificate in Education pre-service teachers for FET Life Sciences teaching and their performance in those assessments: a case study

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An investigation of the assessments used to determine the content knowledge of Post-Graduate Certificate in Education pre-service teachers for FET Life Sciences teaching and their performance in those assessments: A case study

A research report submitted to the Wits School of Education, Faculty of Humanities, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Education.

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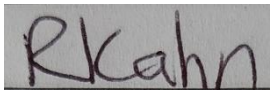
Abstract

This study investigated the content knowledge that is possessed by life sciences Post Graduate Certificate in Education (PGCE) students upon entrance into the PGCE course. All PGCE students are considered to have mastered the content of the subjects that they have chosen to train to teach during their previously completed academic degrees. At Wits School of Education (WSoE), the level of PGCE students' content knowledge is assessed at the beginning of the PGCE course. However, students' performance in these tests has never been documented and as a result the content knowledge of those who enrol into the PGCE Life Sciences course over the years is currently only known by those who teach them. This was the motivation for this case study in which I investigated the content knowledge possessed by the 2020 cohort of PGCE Life Sciences pre-service teachers (PSTs) at Wits School of Education with the aim of documenting it. The construct of content knowledge with a focus on substantive aspects (i.e., facts; concepts; theories; and history of science) and syntactic aspects (i.e., procedures pointing to the validity of different scientific facts and concepts; and different perspectives and controversies on specific topics) and Bloom's taxonomy were used as the conceptual framework for the study. Data included the Curriculum and Assessment Policy Statement (CAPS) document to determine the content knowledge that should be taught at FET level; four objective tests that were used to assess the PGCE students' content knowledge; students' responses to each test; and a questionnaire which was given to the PSTs to get their confidence levels on their content knowledge. The results of this study showed that the content knowledge that should be taught at FET level and hence the content knowledge that pre-service teachers are expected to teach consists mainly of substantive content knowledge and syntactic content knowledge. The study also revealed that the objective tests that were given to the PSTs assessed only certain aspects of substantive and syntactic content knowledge namely: facts; concepts; history; practical investigations; calculations; and practical equipment but not others: specifically not theories; different perspectives and controversies on specific topics; and controversial topics within the subject. In addition, the tests only assessed the lowest cognitive level of remembering and not the other cognitive levels of understanding, application, analysis, evaluation and creation. The results show that PGCE students' performance in these tests was very high and basing on this performance, one could conclude that PGCE students who participated in this study have high levels of life sciences content knowledge. However, considering that students' performance at higher cognitive levels was not assessed and that majority of questions tested mostly knowledge of facts and concepts and very little on theories

and syntactic aspects, this causes the findings above to be inconclusive and therefore their preparedness to teach once they have qualified cannot be ascertained. An interesting finding was that most of the questions that students answered correctly were on topics that they had covered in their first degree and those they got incorrect were on botany which most of the participants had not done. This may point to a possible gap in PGCE students' content knowledge as their first degree is not necessarily aligned to the topics to be taught at FET level. The study therefore recommends that in order to effectively assess PGCE students' content knowledge, the tests that are used to assess their content knowledge should include questions that assess all aspects of content knowledge and that cover all of the cognitive levels of Bloom's taxonomy.

Plagiarism Declaration

I, Robyn Raina Kahn (537449) declare that this research report is my own unaided work except where otherwise acknowledged. It is submitted for the degree of Master of Education at the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted before for any degree or examination at any other University.



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Date: 17/06/2021

Robyn Raina Kahn

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Chapter 1

Introduction

Teacher education is vital as it affects the quality of teachers whose job is to guide and help learners to develop competencies that will allow them to function and evolve in society after they have left school (Musset, 2010). The way in which pre-service teachers (PSTs) are trained is therefore significant as it provides the basis for how PSTs will implement their practice once they are qualified as teachers (Musset, 2010). The quality of future teachers is largely influenced by the structure of the initial teacher education programme in which pre-service teachers train (Zuzovski & Donitsa-Schmidt, 2017). This study therefore sought to evaluate the quality of a cohort of future teachers (PGCE pre-service teachers specifically) in terms of their content knowledge (CK) before they qualify as teachers. In this chapter, I discussed the consecutive model of teacher education through which PGCE PSTs are trained, the structure of the PGCE programme and the challenges that the consecutive model raises. This was followed by an introduction into the background and context of the study and a brief literature review that locates the study in the current debates. I then presented the problem statement and the research questions that guided the study.

1.1 Teacher education programmes

There are two main structural models of teacher education programmes that are used throughout higher education institutions (HEIs), namely the concurrent model and the consecutive model (Zuzovski & Donitsa-Schmidt, 2017). In both models, PSTs are taught the content of the subjects that they wish to teach (disciplinary studies) as well as the practical skills needed to teach those subjects (pedagogical studies) (Zuzovski & Donitsa-Schmidt, 2017). The manner in which PSTs are taught these disciplinary studies and pedagogical studies however differs between the two models and PGCE PSTs are taught through the consecutive model.

1.1.1 The consecutive model

In the consecutive model, PSTs first obtain an academic degree in a specific discipline whereafter they move to the school of education to learn the methodology and pedagogical skills that are specific to a school subject that aligns with their academic degree (Zuzovski & DonitsaSchmidt, 2017). At the end of the course, graduates will receive a professional certificate (usually a Post Graduate Certificate in Education (PGCE)) permitting them to teach

their chosen subjects based on their previously acquired academic degree. Since the academic degree focuses in depth on disciplinary studies, when students move to the school of education to obtain their professional certificate, the course is focused mainly on the practical, pedagogical skills that they will need in order to qualify as teachers (Li, 1999). This study therefore investigated the content knowledge that PGCE PSTs possessed by analysing the extent to which their content knowledge was assessed at the beginning of the PGCE course, how the PSTs performed in those assessments, and the PSTs' perspectives about their content knowledge and their preparedness to teach.

1.2 Background and context of the study: The Wits school of Education

This study took place at the school of education at the University of the Witwatersrand (also known as the Wits school of education or WSoE in short). The WSoE makes use of both the consecutive model and the concurrent model, however this study focused on Post Graduate Certificate in Education (PGCE) pre-service teachers who are taught through the consecutive model.

1.2.1 The structure of the PGCE programme

In the PGCE course, the structure of the course is such that in one stream, PSTs are taught the methodology for one academic subject related to their previously completed academic degree at the FET (further education and training) level (Wits School of Education, 2018). In another stream, PSTs are taught the methodology of either one or two subjects at the senior phase (SP) and in a third stream, the PGCE students are taught the theory of education. In the WSoE's Division of Science Education, if a PST has completed a Bachelor of Science (BSc) degree, they may study the methodology of how to teach Life Sciences at the FET level and natural sciences and/or mathematics at the SP level (Wits School of Education, 2018).

1.2.2 Challenges of learning to be a Life Sciences teacher via the consecutive model route

In the consecutive model, an individual will major in components of the teaching subjects such as biology, chemistry and physics which may be related to and not necessarily aligned to content that is taught at high school (FET) level (Ball & McDiarmid, 1989). That being the case, for those topics that are taught at FET level but are not covered in the university degrees, the only knowledge that individuals may have is what they can remember from when they were taught in high school (Ball & McDiarmid, 1989). Therefore, when graduating from a degree

such as a Bachelor of Science (BSc), an individual may not have adequate content knowledge for high school teaching. This is particularly relevant to individuals who wish to pursue a Post Graduate Certificate in Education (PGCE) once they have completed their academic degrees as they are considered to have mastered their content knowledge for teaching. This is in contrast to the Bachelor of Education (B Ed) degree where lecturers aim to align their teaching of content with the content that needs to be known in order to teach at high school (FET) level (Ball & McDiarmid, 1989).

1.3 What literature says about content knowledge and teaching

Content knowledge is crucial for effective teaching to take place as it not only familiarises PSTs with the conceptual knowledge that they need to teach their chosen subjects, it also creates the foundation upon which "pedagogical choices can be justified" (Taylor, 2014, p. 13). According to Rollnick *et al.* (2008), in order to teach effectively, a teacher must have pedagogical content knowledge (PCK). PCK is the knowledge gained by teachers when they are able to transform their content knowledge into teachable form (Shulman,1986). In order to develop this PCK a teacher must have four knowledge bases namely: knowledge of subject matter/content; general pedagogical knowledge; knowledge of the students and knowledge of context (Rollnick *et al.*, 2008). Although all four knowledge domains are important for effective teaching, this study focused on content knowledge and investigating the content knowledge of PGCE PSTs by analysing the extent to which their content knowledge was assessed, how the PSTs performed in those assessments, and the PSTs' perspectives about their content knowledge and their preparedness to teach.

1.4 Research problem and questions

In the PGCE course, PSTs are considered to have mastered the content of their chosen subjects (in their previously completed academic degree) and therefore they are only taught methodology when they come to the school of education. However, as discussed earlier, the content learned in their academic degree does not necessarily align with the content that they need to know in order to teach at school level and their preparedness to teach at school level is therefore questionable. The PGCE PSTs' preparedness to teach in terms of their content knowledge has not been documented and therefore their abilities to teach FET Life Sciences in terms of all of the knowledge sets has not been determined. The aim of this study was therefore to investigate the content knowledge possessed by PGCE Life Sciences pre-service teachers by analysing the extent to which their content knowledge was assessed, how the PSTs' performed

in those assessments, and the PSTs' perspectives about their content knowledge and their preparedness to teach.

The main question guiding this study is: To what extent are PGCE pre-service teachers prepared, in terms of their content knowledge, to teach at FET level?

The sub-questions guiding this study are:

1. What is the content knowledge that pre-service teachers are expected to teach at FET level after qualification?
2. How is the content knowledge that is assessed in the PGCE programme aligned to what the PSTs are expected to teach at FET level?
3. What strengths and weaknesses can be seen in the PGCE PSTs' content knowledge of FET Life Sciences?
4. To what extent are PGCE PSTs confident about their content knowledge?

1.5 Conclusion of the chapter

This research report has six chapters. Chapter one is an introduction into the study and its context. Chapter two contains the literature review and theoretical framework for the study. Chapter three describes the research design and methodology for this study. Chapters four and five contain the data analyses and present the results of the investigation. Finally, chapter 6 presents the conclusions and recommendations for the study.

In this chapter, I introduced the study and highlighted the motivation. I then described the context of the study. This was followed by a brief literature review to locate the study in the current debates. I then presented the problem statement and the research questions that guided the study. In the next chapter, I review the literature linked to my study.

Chapter 2

Literature review and theoretical framework

The focus of this study was to investigate the **content knowledge** that **PGCE** PSTs possessed when entering the school of education as well as how that content knowledge was **assessed** and the PSTs' perspectives about their content knowledge. The theory that guided this study therefore came from the literature on content knowledge; the consecutive model of teacher education; and assessment (specifically based on Bloom's taxonomy). The concept of content knowledge is used interchangeably in the literature with the term subject matter knowledge (SMK). In this study, I used the term content knowledge, however, when discussing literature in which the term SMK was used, I used it accordingly.

2.1 Importance of content knowledge (CK)

It is a teacher's responsibility to guide learners towards achieving an understanding of the content that they need to know. However, in order to accomplish this, teachers themselves must have a deep understanding of the content (Rollnick & Mavhunga, 2016). A teacher with profound content knowledge (CK) would therefore be more effective at helping learners develop a meaningful understanding of the content (Rollnick & Mavhunga, 2016). Content knowledge is also important because a teacher who has vast knowledge of the content will be more informed as to which explanations, assessments and learning activities will be most effective for learners to achieve an understanding of the content (Ball & McDiarmid, 1989). CK also allows teachers to form lesson plans that will most benefit the learners. If a teacher is ignorant, their lessons and chosen assessments may not be appropriate or beneficial for the learners as an ignorant teacher may be unaware of the nuances related to the teaching and learning of that specific subject (Ball & McDiarmid, 1989). Furthermore, a teacher with insufficient CK can have a negative impact on learners as insufficient CK can lead to misconceptions and teachers can pass those misconceptions on to their learners. A teacher may also be unable to challenge their learners' misconceptions if they do not understand the content well enough to counter those misconceptions (Ball & McDiarmid, 1989). The learning of content in teacher education programmes is clearly essential for pre-service teachers and this study investigated the content knowledge of pre-service teachers who participated in the Post Graduate Certificate in Education (PGCE) teacher education programme.

2.2 Conceptualising content knowledge

An understanding of content is an essential requirement for effective teaching, however content knowledge (including what it is made up of and what constitutes an understanding of subject matter) is not clearly defined (Ball, Thames & Phelps, 2008). Shulman (1986), believed that not enough attention was devoted to the study of content knowledge and felt that this was a "missing paradigm" in the research of teacher knowledge (Shulman, 1986, p. 6). He therefore researched the topic himself. Shulman (1986), defines content knowledge as the "amount and organisation…of knowledge in the mind of the teacher" (Shulman, 1986, p. 9). Shulman (1986), identified three domains which make up content knowledge: subject matter content knowledge; curricular knowledge and pedagogical content knowledge (PCK) (Shulman, 1986). The conceptualisation of content knowledge was a work in progress however and Shulman further tried to conceptualise content knowledge in 1987. When Shulman (1987) aimed to define the categories that make up the knowledge base that teachers should possess, he listed content knowledge, curricular knowledge and pedagogical content knowledge as separate categories rather than domains that make up content knowledge (Shulman, 1987). A further survey of the literature showed that even though the importance of CK in teaching was highlighted by Shulman in 1986, what actually constitutes content knowledge has not been clearly conceptualised, discussed and documented. In the sub-sections that follow below, I draw from the literature that discusses content knowledge with the aim to conceptualise content knowledge.

2.2.1 Subject matter content knowledge

When looking at subject matter content knowledge, Shulman (1986), believed that knowledge of content goes beyond just learning the facts or concepts of a *subject* to understanding the *substantive* and *syntactic* structures of the content. I describe these two components of CK in some detail below.

Substantive knowledge of content relates to the knowledge of the *facts*, *theories* and *concepts* of a subject (Ball & McDiarmid, 1989). Although the curriculum and therefore the content to teach subjects in school is continuously growing and changing, it is a teacher's job to know the core information and ideas (or facts) of the *topics* that need to be taught (Ball & McDiarmid, 1989). A scientific fact refers to a known truth that can be observed by individuals, for example, it is a fact that human beings can feel pain (Cohen, 2003). Concepts refer to the ideas or mental representations of events. These include observable entities (such as mountains in nature),

unobservable entities (such as genes or atoms) or processes (such as photosynthesis) (Kampourakis, 2018). Scientific theories are tested explanations that are informed by concepts and facts for example, the theory of Evolution (Branch & Mead, 2008). When looking at the theory of evolution as observed by researchers such as Charles Darwin, it is a widely accepted scientific theory due to the facts and concepts that are involved in this theory. Concepts and facts related to this theory include the concept of biodiversity which is observed by the fact that over two million existing species of living organisms have been observed today (Ayala, 2020).

Syntactic knowledge defines the ways in which the validity of a discipline is established. This can be further defined as a "set of rules for determining what is legitimate to say in a disciplinary domain and what "breaks" the rules" (Shulman, 1986, p. 9) e.g. the scientific method. A teacher needs to understand the validity of different ideas and perspectives on specific topics as well as the major disagreements and controversies within the field (Ball & McDiarmid, 1989).

By channelling both *substantive* and *syntactic* structures of content knowledge, teachers are not only able to understand the content and the concepts within a topic, but they are also able to understand why those concepts are relevant to a topic and how those concepts relate to the greater curriculum (Shulman, 1986). This can be further explained by using the subject of Life Sciences as an example. When looking at the substantive structure, Life Sciences can be organised into a variety of subsections including: ecological systems; living phenomena in terms of their integral parts and biological organisms (Shulman, 1986). When looking at the syntactic structure, a teacher should be able to explain controversies within certain topics and justify different points of view related to these controversies (Shulman, 1986). Examples of controversial topics in Life Sciences include evolution and biotechnology topics. A life sciences teacher who properly understands the content will be able to understand the different topics within the subject as well as why those topics are relevant and how they relate to the subject as a whole. This knowledge will influence the different ways in which a teacher will teach those topics (Ball & McDiarmid, 1989).

In 2008, Ball *et al.* (2008) suggested the division of content knowledge into two sub categories: *common content knowledge (CCK)* and *specialised content knowledge (SCK)*. Although this division of content knowledge was done in the context of mathematics, I see it as applying to science subjects as well. I describe these two categories next.

Common content knowledge refers to the overall knowledge that teachers must have in order to teach their chosen subjects. A teacher must "know the material they teach" (Ball *et al.,* 2008, p. 399) and in doing so they must know what they expect the learners to know. They also need to be able to recognise errors in textbook definitions as well as gaps in the knowledge of their learners (Ball *et al.,* 2008). If a learner gives an incorrect response or has a misconception, a teacher with common content knowledge will be able to identify the incorrect response or misconception and correct it. This type of content knowledge is considered to be nonspecific to the act of teaching itself as individuals who are not teachers but who may be knowledgeable on that specific subject would most probably have the same general knowledge (Ball *et al.,* 2008). This is therefore knowledge on a specific subject that is not unique to teachers.

Specialised content knowledge is knowledge on a specific subject that is unique to the profession of teaching. This type of knowledge includes having the ability to find patterns in errors made by learners and identify and understand different interpretations of the content (Ball *et al.,* 2008). An example of a pattern in errors when teaching Life Sciences can occur when learners see or hear the word adaptation. They may continuously refer to adaptation as a conscious action from individual organisms in order to better fit in with the environment. This is incorrect as adaptation is an unconscious, natural process that takes place in populations as a result of natural selection (Kampourakis, 2018). This is an erroneous pattern of thinking that a teacher should be able to identify if they have specialised content knowledge and understand the concept of adaptation and the different ways in which learners may interpret the phenomenon. This type of specialised knowledge therefore goes beyond the general knowledge of content that others might share, to a deeper knowledge and understanding of how learners may view the content and how the content can be more accessible to learners that is specific to teachers only (Ball *et al.,* 2008).

2.2.2 Curricular knowledge

As indicated earlier, in 1986, Shulman suggested that curricular knowledge was a domain that made up CK. However, in 1987 after further conceptualisation of the concept of CK, he listed curricular knowledge as being a separate category of teacher knowledge to content knowledge. I describe this category further to see how it aligns with CK.

A curriculum is an instructional representation for teaching a subject and its topics at the given level (Shulman, 1986). Various instructional materials are provided to guide teachers with regards to what exactly they should teach in a particular subject including why as well as how

to teach the subject. A teacher is said to possess curricular knowledge not only when they understand the content that they need to teach but also the materials needed to teach the content as well as visual materials that can be used to teach the content and alternative texts and demonstrations that can be used (Shulman, 1986). An in-depth look at Shulman's description of curricular knowledge shows that CK can be considered to be a component of curricular knowledge.

Curricular knowledge can be expanded to include lateral curricular knowledge and vertical curricular knowledge. A teacher is said to have lateral curricular knowledge when they are not only familiar with the curriculum of their own subject but they are also acquainted with the curricula of the other subjects that their learners are studying (Shulman, 1986). This knowledge is significant as it allows a teacher to relate the content of their subject with the content of the different subjects taken by the learners and this may make the content more relevant to the learners and therefore easier to learn. A teacher is said to have vertical curricular knowledge when they are aware of the topics that are taught in the same subject area but in the preceding or later years of the learners' school career (Shulman, 1986). This knowledge is significant as the teacher will be able to relate the current content to content that learners are already familiar with (making the content more accessible to learners) and it also allows teachers to 'lay the foundations' for future work that the learners will do (Shulman, 1986). This type of knowledge links to content knowledge because a curriculum describes content knowledge that is put together for the specific purpose of teaching that content. Once a teacher possesses the content knowledge that is present in a curriculum, they are said to have curricular knowledge. In the case of Life Sciences, teachers have curricular knowledge once they have knowledge of the content that they need to specifically teach for FET Life Sciences. Teachers can gain this knowledge from syllabus documents that are prepared for use in schools to guide educators on what to teach, how to teach it, when to teach it and why they teach it. In South Africa, this syllabus document is called the Curriculum and Assessment Policy Statement (CAPS) document.

2.3 What the CAPS document says about FET Life Sciences content knowledge

2.3.1 The Curriculum and Assessment Policy Statement (CAPS) document

The National Curriculum Statement (NCS) is the curriculum that is followed in all public schools in South Africa and makes use of the Curriculum and Assessment Policy Statement

(CAPS) document. I chose to use this document as it "gives expression to the knowledge, skills and values worth learning in South African schools" (Department of Basic Education – DBE, 2011, p. 4) and aims to provide learners with appropriate knowledge that is meaningful despite their socio-economic background, race or gender (DBE, 2011). The CAPS document is used widely throughout the country and it is likely that newly qualified teachers who are entering the workforce will teach from this document. This study focused specifically on the subject of Life Sciences at the FET (further education and training) level (specifically grades 10 and 11) (DBE, 2011).

2.3.2 The FET Life Sciences curriculum

The curriculum for Life Sciences at FET level provides content and context that increases in complexity as each grade progresses. The CAPS document states that at the FET level, Life Sciences learners will study: Biochemistry; Biotechnology; Microbiology; Genetics; Zoology; Botany; Entomology; Plant and animal Physiology; Plant and animal anatomy; Plant and animal morphology; Plant and animal taxonomy; Environmental studies and Socio-biology (animal behaviour) (DBE, 2011). These topics are taught at varying levels from grade 10 until grade 12 and they provide an expansive overview of Life Sciences. The Life Sciences FET curriculum is organised into four knowledge strands which are developed progressively over the three years of FET. These knowledge strands are:

Knowledge strand 1: Life at the molecular, cellular and tissue level;
Knowledge strand 2: Life processes in plants and animals;
Knowledge strand 3: Environmental studies; and
Knowledge strand 4: Diversity, change and continuity (DBE, 2011).

These different strands are connected to one another and no strand should be taught in isolation. These strands do not need to be taught in order, nor do they all need to be covered each year, this is just how the subject content is organised for the use of teachers. When teaching this content, teachers must be able to help learners to not only understand the content but to understand the links between the different knowledge strands and how they relate to real life (DBE, 2011).

2.4 The consecutive model of teacher preparation

As mentioned in chapter 1, in the consecutive model, individuals first complete an academic degree after which they pursue a PGCE. During the PGCE, the individuals study the

methodologies for teaching the school subject that is most related to what was learned in their academic degree (Sederevičiūtė-Pačiauskienė & Vainorytė, 2015). Studying the methodologies for teaching (the second component of the consecutive model, after completion of an academic degree) usually takes between one and two years to complete, after which graduates are awarded with a teaching certificate (Zuzovski & Donitsa-Schmidt, 2017). The second component of the consecutive model focuses on preparing PSTs for the teaching world and therefore concentrates on teaching methodology as individuals are considered to have already mastered the content during their academic degrees. This is considered to be less integrative than the concurrent model which teaches content and methodology alongside one another (Zuzovski & Donitsa-Schmidt, 2017).

Due to the nature of the consecutive model, PSTs who partake in a PGCE are generally older and more mature than those who entered into a B Ed degree. This is because students who decide to complete a PGCE most probably only made the decision to become teachers at a later stage, while already involved or after completion of their academic degrees (Li, 1999). Entering the field of education after completing an academic degree can be considered an advantage of the consecutive model as when PSTs enter the school of Education, they are more mature and more educated than PSTs who enter the school of Education at the beginning of their B Ed degrees and they can build on their previous knowledge acquired from their academic degrees (Zuzovski & Donitsa-Schmidt, 2017). A disadvantage of the consecutive model is that PSTs are only exposed to the field of Education for one year after completion of their previous degrees. This is not a lot of time to become familiar with and master the intricacies of teaching (Sederevičiūtė-Pačiauskienė & Vainorytė, 2015).

2.5 Assessment and Bloom's taxonomy

This study focused on the assessment of PGCE students' content knowledge. It is therefore important to briefly discuss what assessment is.

2.5.1 Assessment

Assessments are vital in education because they allow educators to determine whether learning has taken place or not (Fisher & Bandy, 2019). Educators need to know if their students have acquired desired skills and knowledge as it aids them in assessing whether their teaching instruction has been effective or whether they need to change their techniques (Wiliam, 2011). Since the PGCE course focuses primarily on methodology, it is important that the PSTs are

assessed on the content knowledge that they possess when they begin the course. These assessments allow teacher educators (TEs) to determine whether the PSTs' content knowledge is strong enough for them to competently teach content once they are qualified (Rusznyak & Bertram, 2015). Assessing the PSTs' content knowledge is important as it gives both the TEs and the PSTs insights into whether the PSTs are meeting the course learning objectives successfully as this will indicate whether these new PSTs are able to successfully meet the learning objectives (Fisher & Bandy, 2019). In the case of PGCE PSTs, TEs are able to assess whether the content knowledge that the PSTs possess from their previous degrees is sufficient to teach at school level (in this case at FET level for Life Sciences). Assessments at the beginning of the PGCE course therefore provide TEs with the information that they need in order to see if the PSTs have come to the school of Education with sufficient content knowledge of Life Sciences at FET level (Fisher & Bandy, 2019). There are two general forms of assessments: summative assessment and formative assessment (Sardareh & Saad, 2013). Formative assessment normally takes place before summative assessment and involves the use of various assessments throughout the learning of a specific course or section of study (Sardareh & Saad, 2013). This type of assessment allows for feedback and reflection so that students can prepare for their summative assessments (Sardareh & Saad, 2013). Summative assessment focuses on the overall levels of student achievement and should therefore be used at the end of a course or section of study (Sardareh & Saad, 2013). Often used in the form of tests or exams, summative assessments present educators with the sum of what their students have learned (Fisher & Bandy, 2019). This type of assessment is a summative assessment as it is given to PSTs to assess their overall knowledge or the sum of their content knowledge gained from their previous degrees (Fisher & Bandy, 2019). This type of assessment should therefore be comprehensive enough to determine whether or not students are able to meet the learning outcomes. The downfall with this type of assessment is that, since it is summative, students are often not given the opportunity to reflect on their performance and work on their weaknesses (Fisher & Bandy, 2019). In the case of the PGCE PSTs, if the PSTs fail their initial assessments, they are unable to continue with the PGCE course (personal communication).

2.5.2 Bloom's taxonomy

When looking at assessing the content knowledge of the PGCE PSTs, it is important to consider the different levels of difficulty and skills that should be demonstrated by the PSTs when answering each question of the assessment. Bloom's taxonomy is a classification system that defines the different cognitive levels that students should display (Adams, 2015). Over the years, this classification system has been revised in order to properly define cognitive levels that range from the ability to perform lower-order skills (that require low levels of cognitive processing) to higher-order skills (that require higher levels of cognitive processing) (Forehand, 2010). The different cognitive levels in the revised Bloom's taxonomy (ranging from the lowest level to the highest level) are: remember; understand; apply; analyse; evaluate; and create (Adams, 2015). I further explain each cognitive level below.

Remember or remembering is the lowest cognitive level and requires students to retrieve or recall specific information from memory (Forehand, 2010). According to Overbaugh and Schultz (2013), when designing a question on the cognitive level of remembering, one should aim to answer the question: can the individual recall or remember this information? (Overbaugh & Schultz, 2013). An example of a question that tests remembering or recall is: *Identify the functions of the kidney.* In this way, an educator will be able to determine whether an individual is able to remember or recall the different functions of the kidney.

Understand or understanding requires students to construct meaning from or explain specific information (Adams, 2015). Overbaugh and Schultz (2013), state that when designing a question on the cognitive level of understanding, one should aim to answer the question: can the individual explain or describe ideas or concepts? (Overbaugh & Schultz, 2013). An example of a question that tests understanding is: *Explain in your own words how the kidney performs its functions*. This goes beyond just remembering the functions of the kidney and those who do not understand how the kidney functions would most probably struggle to explain exactly how those functions are performed.

Apply or applying requires students to implement or carry out specific procedures in order to come to a correct answer (Efe & Efe, 2011). When designing a question on the cognitive level of applying, one should aim to answer the question: can the individual solve a problem or demonstrate information in a new way? (Overbaugh & Schultz, 2013). An example of a question that tests application is: *If a single cell undergoes three rounds of division by mitosis, how many cells will be present at the end of the third division?* In this way, educators will be

able to determine whether individuals are able to take their knowledge of the nature of cell division by mitosis and apply it to this specific question.

Analyse or analysing requires students to differentiate or organise information in order to determine how specific information relates to an overall information structure (Forehand, 2010). When designing a question on the cognitive level of analysing, one should aim to answer the question: can the individual compare or differentiate between different aspects of content? (Overbaugh & Schultz, 2013). An example of a question that tests for analysis is: *compare and contrast the processes of mitosis and meiosis*. In this way, individuals are expected to analyse what they know about both processes, organise that information, and see how they relate to one another in terms of their similarities and differences.

Evaluate or evaluating requires students to critique specific information or make judgements based on specific criteria (Efe & Efe, 2011). According to Overbaugh and Schultz (2013), when designing a question on the cognitive level of evaluating, one should aim to answer the question: can the individual justify or argue for or against a specific topic or position? (Overbaugh & Schultz, 2013). An example of a question that tests evaluation is: *Justify this statement – "Organisms that reproduce sexually have a higher chance of adapting to changing environmental conditions in comparison with those that reproduce asexually*. In this case, the individual is expected to critique or evaluate the above statement in order to provide the relevant information that would justify the statement.

Create or creating requires students to put information together in order to generate, plan or produce functional knowledge (Forehand, 2010). When designing a question on the cognitive level of creating, Overbaugh and Schultz (2013), suggest that one should aim to answer the question: can the individual create a new point of view or product? (Overbaugh & Schultz, 2013). An example of a question that tests creating is: Develop a project and come up with solutions for protecting endangered species. In this way, individuals need to synthesise an appropriate plan that provides suitable solutions for protecting endangered species.

This is a widely used classification scheme and it is therefore important that the assessments made to test the content knowledge of the PGCE PSTs cover and assess the PSTs' abilities to perform at each cognitive level.

2.6 Concepts that frame this study

From this literature review, figure 1 below summarises the key concepts that will form the conceptual framework which will aid in analysing my data.

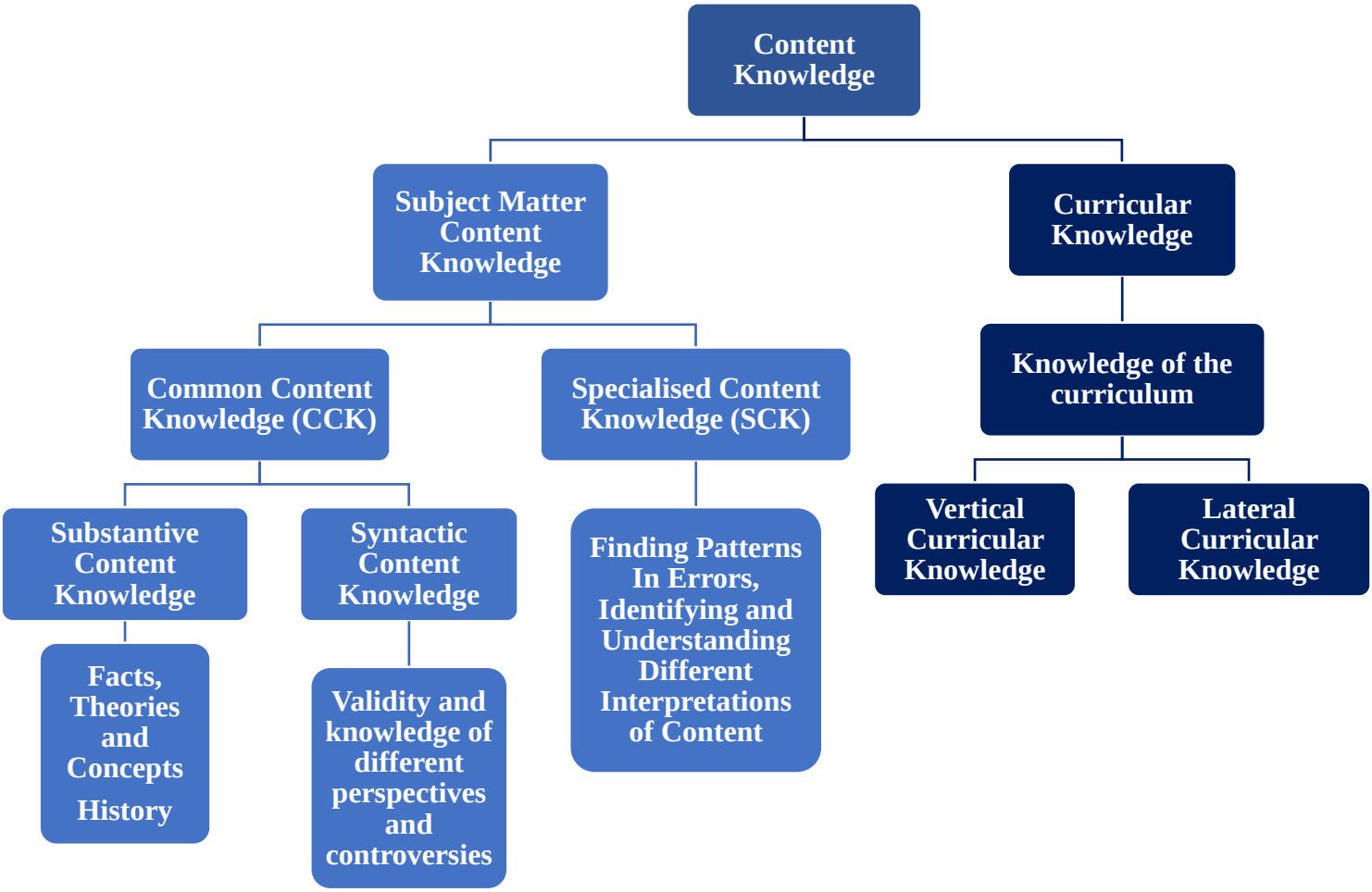


Figure 1: They key components of content knowledge[1]

[1] The different shades of blue in Figure 1 above represent the different aspects of content knowledge that this investigation has focused on. In this investigation I have focused on subject matter content knowledge and its components and curricular knowledge and its components. It is important to note that technically, common content knowledge can also be a component of curricular knowledge. This is because, as mentioned above, curricular knowledge describes content knowledge that should be taught in a particular context. Knowledge of that content would also be considered as CCK. However, for the purposes of this study, I have separated curricular knowledge from subject matter content knowledge in order to focus on how the PSTs display knowledge of each aspect separately.

As displayed in the conceptual framework, Figure 1 aims to define content knowledge and the components that make up content knowledge. Although Shulman (1986) states that content knowledge can be divided into three sub components: subject matter content knowledge; curricular knowledge and pedagogical content knowledge, this study focuses on the subject matter knowledge and curricular knowledge. Subject matter content knowledge can be further divided into common content knowledge (CCK) and specialised content knowledge (SCK). CCK can be further divided into substantive content knowledge and syntactic content knowledge. The reason for this is that CCK involves the overall knowledge that individuals have on a specific topic or subject and that overall knowledge includes both the knowledge of facts, theories and concepts (as well as knowledge of the history of the topic – as informed by the CAPS document (DBE, 2011)) (substantive content knowledge) and the knowledge of different perspectives and controversies within the subject, as well as their validity (syntactic content knowledge) (Ball *et al*., 2008). SCK requires a deeper knowledge and understanding of the subject matter to the point where teachers are able to find patterns in errors and identify and understand different interpretations of the content (Ball & McDiarmid, 1989). I have already elaborated on these concepts in the literature review above. If we are able to understand content knowledge and what it means to master all the different facets of content knowledge, we can better analyse and shape teacher preparation programmes to improve the quality of subject matter knowledge of pre-service teachers.

2.7 Conclusion of the chapter

In this chapter, I examined the importance of content knowledge and how the CAPS document describes content knowledge for FET Life Sciences. I also examined the importance of assessing content knowledge when training future teachers through the consecutive model and how Bloom's taxonomy describes the different cognitive levels that should be assessed. Lastly, I used literature on educational research in order to conceptualise what constitutes content knowledge and I used this conceptualisation to identify content knowledge concepts that formed part of the framework for the study.

Chapter 3

Research Design and methodology

This chapter highlights the method of data collection that was used, including the research instruments and research participants.

3.1 Qualitative and Quantitative research

In this section I discussed two research approaches: the quantitative research approach and the qualitative research approach because I used both of these approaches in this study.

3.1.1 Quantitative research

Quantitative research involves the objective collection and study of measurable variables (numerical data) within a phenomenon (Park & Park, 2016). After quantifying the numerical data, a researcher can interpret the data and make decisions and conclusions on the study (Arghode, 2012). This is an objective, unbiased approach as the results of quantitative research are not, in any way, influenced by the researcher (Arghode, 2012). An advantage of the quantitative research approach is that a large sample size is used which allows the researcher to use the sample to generalise and relate the findings to a whole population or subpopulation (Rahman, 2017). Another advantage of the quantitative research approach is that data analysis is not too time consuming as statistical software can often be used for the analysis. A disadvantage of quantitative research is that the data analysis does not go further to attempt to understand, interpret and find meaning in phenomena, rather it focuses only on the numerical data (Rahman, 2017). Since the focus in only on measuring variables objectively, the researcher does not consider how events that occurred before data collection could have potentially influenced the outcome of the study (Rahman, 2017).

3.1.2 Qualitative research

Qualitative research does not rely on variables such as numerical data, rather it goes further to explore and gain a deep understanding of specific phenomena (Pathak, Jena & Kalra, 2013). In order to collect data in a way that allows for exploration and the use of rich descriptions, the researcher needs to focus on the participants of the study (Harrison, Birks, Franklin & Mills, 2017). The researcher must understand the social and cultural backgrounds of the participant and how they influence their points of view (McLeod, 2017). An advantage of qualitative research is that it goes beyond numerical data and allows for an in-depth study that delves into the human and personal aspects of research (McLeod, 2017). A further advantage is that the

researcher is able to gain insight into the study and analyse and present the data in a narrative and descriptive style. A disadvantage of this type of study is that the in-depth analysis is often time consuming and therefore difficult to perform on a large scale (McLeod, 2017). In this study, I was able to expand on and validate the quantitative data collected from the written tests, the PSTs' responses to the tests, and certain aspects of the PST questionnaires by comparing and contrasting them with the qualitative data collected from the PST questionnaires. In this way, I was able to investigate the content knowledge of the PGCE PSTs, how that content knowledge was assessed as well as the PSTs' feelings on their levels of preparedness to teach Life Sciences at FET level.

I collected and analysed data by combining elements of both quantitative and qualitative research approaches. This approach allowed me to answer my research questions with heightened knowledge as the data collected through a qualitative approach (PST questionnaires) aided in exploring, illustrating and validating the data collected through a quantitative approach (objective tests, test responses, and PST questionnaires) (Schoonenboom & Jonson, 2017).

3.2 Research Methodology

Case study

I chose to use a case study for my research as case studies allow for the investigation of a wide range of complex matters in a real-world setting (Harrison *et al.*, 2017). Creswell *et al.* (2007) explains that a case study is an in-depth process that, over time and using multiple sources of data, explains one or multiple phenomena, (Creswell, Hanson, Plano, Vicki & Morales, 2007). One can use the case study method to define a problem within one's research; formulate hypotheses based on the problem, collect data and analyse that data (Teegavarapu, Summers & Mocko, 2008). A case study can be implemented when collecting data using both qualitative and quantitative approaches and is therefore a versatile methodology in research (Teegavarapu *et al*., 2008). Once quantitative data has been collected, a researcher can move beyond the statistical data and delve into the qualitative aspects through researching and understanding behaviours and thoughts of the research participants (Zainal, 2007). In this study, I investigated the outcomes of the assessment process of PGCE PSTs' content knowledge by assessing the content knowledge of the pre-service teachers as a product of the assessments used to test their content knowledge. This research was therefore an exploratory case study (Zainal, 2007) as I explored the effectiveness of the content knowledge assessments as part of determining PGCE

PSTs' readiness for the work place in terms of their content knowledge. In addition to the above, an advantage of using a case study for research is that the data can be collected within the context of its use (the situation in which the activity takes place) (Harrison *et al.,* 2017, Zainal, 2007). In this study, data was collected from PSTs involved in the PGCE qualification who performed the authentic task of completing standard tests for the assessment of their levels of content knowledge. I was therefore able to collect data from the PSTs in an authentic learning environment. A disadvantage of using case studies is that the small number of research participants makes it difficult to extend the results of the research to other, related aspects of research. The small sample size can also lead to biased views and representations of the data which can lead to a lack of research rigor and therefore directed findings and conclusions (Zainal, 2007).

3.3 Research Participants

This study took place at the Wits School of Education (WSoE) in Johannesburg. The participants of the study were pre-service Life Sciences teachers, specifically Post Graduate Certificate of Education (PGCE) PSTs who aimed to qualify to be Life Sciences teachers at the FET level (grades 10, 11 and 12). These were the participants as they were in their last year of study before qualifying to be Life Sciences teachers and since they were trained through a different model of education to the B Ed PSTs, it is important to assess their content knowledge and therefore their preparedness for the workplace. I targeted all 27 students who were registered for the Life Sciences PGCE program, however the final number of participants who gave their consent was 22.

3.4 Sources of data

Sources of data for this study were the CAPS documents, four objective tests based on grades 10 and 11 curriculums as well as the PSTs' responses to the tests and a questionnaire. I analysed the FET Life Sciences Curriculum and Assessment Policy Statement (CAPS) document in order to determine the content knowledge that the Life Sciences PSTs are expected to teach after qualification; PSTs' responses to the objective tests to determine the PSTs' content knowledge; as well as an online questionnaire in order to further understand the level of their content knowledge and their perspectives about their levels of content knowledge and their preparedness to teach.

3.4.1 Curriculum and Assessment Policy Statement (CAPS) document

In January 2012, amendments that were made to the National Curriculum Statement (NCS) in South Africa came into effect (DBE, 2011). These amendments gave rise to the Curriculum and Assessment Policy Statement (CAPS) document which provides subject statements, learning programme guidelines and subject assessments for each school grade (Grades R-12) (DBE, 2011). This new curriculum guides teachers to provide an active learning environment for learners where critical thinking is encouraged (DBE, 2011). As discussed in chapter 2, the CAPS document is used in all South African public schools and incorporates the knowledge, skills and values that all South African learners should learn despite their personal backgrounds (DBE, 2011). The CAPS document provides content as well as the context in which the content for the subject is taught. In this study I analysed the CAPS document for Life Sciences at FET level in order to determine the different categories of the content knowledge that is required by Life Sciences FET teachers.

3.4.2 Objective tests (See Appendix A)

When PGCE pre-service teachers enter the school of Education to train for a teaching qualification, they are required to complete subject tests so that the lecturers can determine their levels of content knowledge on the school subject that they will be teaching (personal communication). For example, students complete a Bachelor of Sciences (BSc) degree and come to the school of Education to complete a PGCE in order to qualify to be Life Sciences teachers. Since the PGCE does not focus on the teaching of content, it is important that lecturers are aware of the Life Sciences content knowledge that the PSTs have when entering the programme. Although the PSTs are training to be teachers for FET level (Grades 10, 11 and 12), in the beginning of their year of study, they are given tests in order for their content knowledge on Life Sciences for grades 10 and 11 only to be assessed (personal communication). This may be because the PSTs are expected to only teach at the grade 10 and 11 level as newly qualified teachers. For the year 2020, I used the students' responses to these tests to determine how the content knowledge that was assessed in the tests was aligned to what the PSTs are expected to teach at FET level. I also used the PSTs' responses to the tests in order to determine the strengths and weaknesses that could be seen in the PSTs' content knowledge of FET Life Sciences. Since the tests were set by a professional lecturer and not myself, they are objective and contain no bias towards this investigation.

3.4.2.1 Structure of the tests

The PSTs were given four short tests consisting of multiple choice, match the columns, fill in the blank and true or false questions. An example of each type of question can be seen in the excerpt below.

<table>
<tr><th>Type of question</th><th>Example</th></tr>
<tr><td>Multiple choice</td><td>Which of the following is NOT a function of mitosis?
A. Growth.
B. Repair.
C. Asexual reproduction in unicellular organisms.
D. The formation of sex cells.</td></tr>
<tr><td>Match the columns</td><td>Match the statements / descriptions in column one with the correct term in column two.
<table>
<tr><td>1. Opportunistic colonizer of barren or disturbed habitat</td><td>A. Geographical dispersal</td></tr>
<tr><td>2. Array of species at the end of successional stages in a habitat</td><td>B. Pioneer species</td></tr>
<tr><td>3. One species outcompetes a rival with the same resource needs, driving it to extinction</td><td>C. Climax community</td></tr>
<tr><td>4. The scientific study of how species are distributed in the natural world</td><td>D. Competitive exclusion</td></tr>
<tr><td>5. Individuals leave their home range, become established elsewhere</td><td>E. Biogeography</td></tr>
</table></td></tr>
<tr><td>Fill in the blank</td><td>For each of the items below, select the most appropriate answer option(s) above. Each answer option may be used once, more than once, or not at all.
1. The name of the part where anaerobic respiration occurs_____
2. The organelle in which aerobic respiration occurs_____
3. The organelle that contains chlorophyll _____
4. The organelle that keeps the cell turgid and stores salts _____
5. The living boundary of the cell that controls the movement of substances into and out of the cell. _____
6. Plays a part in heredity and controls all the functions of the cell._____</td></tr>
<tr><td>True or false</td><td>Osmosis is the movement of water molecules through a selectively permeable membrane from a region of low water potential to a region of high-water potential</td></tr>
</table>

3.4.2.2 Administration of the tests

The tests were administered one at a time (starting with grade 10 test 1). The tests were released to the PSTs on the Wits online platform of SAKAI and the PSTs were made aware when each test would be made available for them to complete. Once the first test was made available to the PSTs, the PSTs were given one hour to complete and submit the test. The second test was released two weeks after the first test, the third test was released two weeks after the second

test and the fourth test was released three weeks after the third test. The tests were linear, meaning that the PSTs were only able to see the questions one at a time and once they had submitted their answer to a question, they were unable to return to that question. The PSTs were given the opportunity to submit each test twice, however in this study, only the first attempts were analysed as I planned to analyse the PSTs' initial content knowledge on entry to the school of education

3.4.3 Online questionnaire (See Appendix B)

A questionnaire consists of a sequence of questions that aim at gathering information from participants (Kabir, 2016). Although questionnaires are often used for statistical analysis (Kabir, 2016), I used a questionnaire for qualitative analysis, specifically to find out the extent to which the participants felt that they were prepared to teach FET Life Sciences once they are qualified. There are three main forms of questionnaires, namely: close-ended (structured); open-ended (unstructured) or a mixture of the two (Zohrabi, 2013). Since I used the questionnaire primarily for qualitative analysis but also minimally for quantitative analysis, the questionnaire was open-ended or unstructured. It was therefore primarily made up of open-ended questions which allowed the participants to articulate their individual thoughts and feelings in their answers (Kabir, 2016). An example of an open-ended question from the questionnaire is: *What is your opinion about your ability to teach Life Sciences to school learners?* There was also a small amount of closed ended questions for quantitative analysis, for example: What are the Life Sciences topics/courses that you covered during your first degree? An advantage of using an open-ended questionnaire is that it allows for a greater level of insight and discovery (Zohrabi, 2013). Another advantage of questionnaires is that they are an efficient way for data collection on a large scale as they can be sent to a large number of people simultaneously (Debois, 2019). A disadvantage however is that the qualitative analysis and coding of participants' answers may be time consuming and difficult (Zohrabi, 2013). Another disadvantage is that ambiguous responses may be difficult to interpret (Debois, 2019).

3.4.3.1 Administration of the questionnaire

In this study, I uploaded the questionnaire for the PGCE PSTs (see appendix B) onto Google Forms and a link to the questionnaire was given to the PSTs through the Wits online platform SAKAI. The link was also sent to the PSTs via email. The PSTs were able to fill in the questionnaire online and submit them back to me for analysis. It should have taken them about 10 minutes to complete.

3.5 Data Analysis

I used four forms of data analysis in this study: document analysis of the CAPS document; deductive analysis of the objective tests as well as the PSTs' responses to the tests; and inductive analysis of the questionnaire.

Document analysis

Document analysis is an organised procedure whereby documents (either paper or electronic) are reviewed and evaluated (Bowen, 2009). During this process, a researcher aims to examine the document and develop empirical knowledge that will aid in their research. Document analysis involves the inspection of documents in order to find, select and review useful information found within the document (Bowen, 2009). The information found within the document can then be organised into central themes or categories that frame the results or findings of the study (Bowen, 2009). In this study I performed document analysis on the CAPS document for Life Sciences at FET level. I read through the document multiple times and coded the aspects of content knowledge (such as theories, facts and concepts) as discussed under the theoretical framework in order to determine the content knowledge that is required by the PSTs. An example of this coding can be seen below.

Topic: The Chemistry of Life (Main concept)

Content:

Molecules for Life (subordinate concept) - Organic molecules are made up of C, H, and O, and some contain other elements, such as N and P (fact). Cells are made up of proteins, carbohydrates, lipids, nucleic acids and vitamins (fact). (Only basic structural detail required.)

Analysis of the objective tests

I analysed the content knowledge that was assessed in these tests as well as the PSTs' responses to the objective tests through deductive analysis. A researcher performing deductive data analysis generally begins the analysis with prior theoretical knowledge or an analysis matrix that guides the analysis (Kyngäs & Kaakinen, 2020). This type of data analysis is primarily used for quantitative analysis (Hyde, 2000). In this study, I performed deductive analysis on the objective tests that were completed by the PGCE PSTs as I used my already existing conceptual framework to determine which aspects of content knowledge were assessed through these tests. Secondly, I used the classification system of Bloom's taxonomy in order to determine which cognitive levels were being assessed in these tests. An example of a coded question can be seen below.

*Each new cell produced by mitosis will have... (**Fact**) (**Remembering**)*

A. half the number of chromosomes.
B. a full set of chromosomes.
C. twice the number of chromosomes.
D. two new nuclei.

The red colour shows that the aspect of content knowledge that was assessed in this question was fact and the yellow highlight shows that the cognitive levels of Bloom's taxonomy was that of remembering.

The PSTs' responses to the tests

I also performed deductive analysis on the PSTs' responses to the tests as I had the answers to the tests before beginning the analysis. I scored the tests using a rubric scale system as an analysis matrix to analyse the performance of the PSTs and I then went further to find patterns in the PSTs' responses to see if there was alignment between the PSTs' prior knowledge from previous studies and their answers in the tests. For example, if the test responses showed that the PSTs correctly answered majority of the questions on the topic of biochemistry, I would consult the questionnaire to see how many PSTs had studied biochemistry in their previous degrees and whether that number aligned with the high performance. If a high number of PSTs had studied biochemistry previously then there would be alignment between that and the high performance in that topic.

Analysis of the questionnaires

Inductive data analysis focuses on forming themes from the data collected. The themes formed are guided by the research questions in order to give focus to the study (Gabriel, 2013). Inductive analysis can be done by organising data into categories and identifying patterns and relationships among the categories (Astalin, 2013). Inductive analysis therefore begins with a specific observation which leads to the formation of patterns, generalisations and conclusions (Gabriel, 2013). In this study, I used inductive data analysis to analyse the questionnaires from the PGCE PSTs in order to further explore the level of content knowledge as well as the PSTs' perspectives on their content knowledge and therefore their levels of preparedness to teach in terms of their content knowledge. The analysis was done question by question and the information that was contained in the students' responses determined the codes. An example of this coding can be seen in the excerpt below. The excerpt shows PSTs' responses to the question: Now that you are familiar with the CAPS document, to what extent would you say your first degree prepared you content wise for FET Life Sciences? This question allowed

me to analyse the PSTs' perspectives about their preparedness to teach in terms of their content knowledge. When analysing the responses, I noticed patterns of *indications of confidence* and *indications of lack of confidence*. This can be seen below.

I have a deeper understanding of most content (indication of confidence) but it did not prepare me on how to teach (indication of lack of confidence)
I think it really went beyond the mark (indication of confidence) because it was so detailed and discipline specific, thus I'm able to relate most of the content with what I teach in class. I'm also able to give learners a bit more than what the textbook says. It just makes it easier to explain (indication of confidence).
Over prepared (indication of confidence)

3.6 Research Rigor

Research rigor refers to the quality and precision of an investigation and it ensures the accuracy and validity of a study (Cypress, 2017). Research rigor therefore ensures objectivity and trustworthiness from a qualitative approach and reliability and validity from a quantitative approach (Cypress, 2017). I ensured research rigor in my study through data triangulation. Data triangulation occurs when more than one method of data collection is used to investigate a single phenomenon (Heale & Forbes, 2013). In this way, the analysis and interpretation of data aids in avoiding bias and it becomes more reliable and concrete than it would be through using a single method of data collection (Heale & Forbes, 2013). I achieved triangulation through using both a quantitative and a qualitative approach in my study with the expectation that the results from the objective tests (the quantitative approach) would converge with the results from the PST questionnaires (qualitative approach) to form a solid basis that would verify and increase the validity of the study (Heale & Forbes, 2013). Triangulation of data was achieved by combining the quantitative and qualitative approach in order to align the researcher's point of view with that of the participants. This allowed for the presentation of unbiased and reliable findings (Creswell & Clark, 2017).

The tests, as mentioned above, were already set by an objective lecturer and administered to the PSTs for a different purpose and in a different context before this investigation began. The tests were therefore unbiased as I did not set them or influence the way in which they were set. This therefore increases the rigor of this investigation as this source of data was objective and unbiased. In order to increase research rigor, I contacted an anonymous colleague and teacher and I asked them to cross check my coding. I sent the colleague a sample of questions from the

tests and asked them to code the questions in accordance with the cognitive levels of Bloom's taxonomy. The results of this cross coding showed 90% intercoder reliability as the colleague coded 90% of the questions in the same manner that I did.

When looking at the questionnaire, due to the challenges of COVID-19 and lockdown in 2020, I did not have access to students who I could use to pilot the questionnaire. I was therefore dependent on my supervisor only to assess the questions in the questionnaire, ensure that the questions were clear, and approve the questionnaire for online dispersal to the PSTs. Under different circumstance, I would have used a sample group of PSTs to pilot the questionnaire in order to determine the validation of each question and ensure that the questionnaire was suitable for the study. The suitability of the questionnaire was therefore approved by my supervisor only.

3.7 Ethical considerations

Since the participants in this study are human beings who can be affected, it was important for me to follow the correct ethical procedures so as to affect the participants in the smallest way possible. I therefore considered all of the ethical implications for this investigation and I applied for ethics clearance. The ethical procedures that I followed can be seen below.

Permission

As part of my ethics application, I sent a letter to the WSoE Head of School and registrar asking for permission to conduct this study with PGCE students at the institution.

Informed consent

Since I interacted indirectly with these students in this study through the tests and questionnaire, I wrote a cover letter in order to explain the purpose of my study to potential participants and to ask each student involved for their consent to participate in this study and for the use of their answers from the tests and questionnaire.

Anonymity

To ensure anonymity of the participants, they were not required to use their names throughout the data collection process and non-identifiable labels were used when responses were used in the final write up of the study.

Confidentiality

To ensure confidentiality, access of data was restricted to the researcher (myself) and my supervisor (Dr E Nyamupangedengu). Responses to the tests and questionnaire were not discussed by anyone other than the two of us. All data was stored on my password protected personal computer.

Risk

The only risk that this study posed to the participants was that participating in the questionnaire may have been time consuming. The students however were able to complete the questionnaire at their own pace and at their convenience.

3.8 Conclusion of the chapter

In this chapter I outlined the different research methodologies for this study. I then went to on to identify the research participants. My data collection procedures as well as the data analysis processes were then described. I then went on to describe my research rigor in order to ensure accuracy in my study. The ethics procedure for this study was then explained and outlined. In the next chapter, I present my analysis of the Life Sciences CAPS document and the objective test items and my findings.

Chapter 4

Analysis of the Life Sciences CAPS document and the objective content test items and presentation of findings

In this chapter, I show how I analysed my first set of data (the Life Sciences CAPs document) as well as my second set of data (the content test items given to the PSTs) and I present my findings. The purpose of this study was to investigate the content knowledge possessed by PGCE Life Sciences pre-service teachers by analysing the extent to which their content knowledge was assessed, how the PSTs' performed in those assessments, and the PSTs' perspectives about their content knowledge and their preparedness to teach.

The main question guiding this study was: To what extent are PGCE pre-service teachers prepared, in terms of their content knowledge, to teach at FET level? At the end of this chapter, I will answer my first and second sub-questions:

1. What is the content knowledge that pre-service teachers are expected to teach at FET level after qualification?
2. How is the content knowledge that is assessed in the PGCE programme aligned to what the PSTs are expected to teach at FET level?

4.1 The analysis process

4.1.1 My coding scheme

As described in chapter 3, I had four sources of data namely the CAPS document, objective test items, PGCE students' responses to the tests and completed questionnaires. Data analysis included document analysis of the CAPS document and the object tests; deductive analysis of students' responses to the tests and inductive analysis of the questionnaires. I used my conceptual framework, which describes Life Sciences content knowledge and the components that make it up, to inform my analysis. In Table 1 below, I explain the conceptual framework and indicate the codes that I used to analyse my data.

Table 1: My coding scheme for analysing my data

Subject matter content knowledge				**Curricular knowledge**	
Substantive knowledge (code-SbK) Descriptions of *facts*, *theories* and *concepts* of a subject • Facts – Any known truth that can be observed by individuals e.g. Organisms interact with other organisms and with the environments in which they live in order to survive and produce offspring • Concepts – Ideas or mental representations of events (observable and unobservable entities or processes) e.g. observable entities (such as mountains in nature), unobservable entities (such as genes or atoms) or processes (such as photosynthesis) • Theories - tested explanations that are informed by concepts and facts eg. the theory of Evolution • Descriptions pointing to an understanding of the History of the topic eg. Give a brief overview of the history of microscopy	**Syntactic knowledge (code-SK)** • Descriptions of the procedures pointing to the validity of different scientific facts and concepts e.g. the scientific method • Descriptions of different perspectives, disagreements and controversies on specific scientific topics e.g. Darwin's and Lamarck's different perspectives on the process of natural selection • Descriptions of any controversies within the field e.g. controversial topics in Life Sciences include evolution and biotechnology topics	**Common content knowledge (code-CCK)** Descriptions of the overall knowledge that individuals who have studied a subject would have on that specific subject; this is not necessarily specific to teaching eg. Overall knowledge on all of the topics that need to be taught in the Life Sciences subject • Descriptions of the knowledge about biology or a biology topic that learners must know eg. Learners must be able to recall and describe concepts, processes, phenomena, mechanisms, principles, theories, laws and models in Life Sciences • Descriptions of errors in text books eg. "**Only** those individuals that are adapted to their environment will survive and breed" • Descriptions of learner misconceptions eg. individual organisms purposefully evolve	**Specialised content knowledge (code-SCK)** Descriptions of knowledge on a specific subject (in this case Life Sciences) that is unique to the profession of teaching e.g. knowledge of how learner prior knowledge can be used to identify misconceptions • Descriptions of how to find patterns in errors eg. when learners continuously refer to adaptation as a conscious action from individual organisms • Descriptions of how to identify and understand different interpretations of content eg. Darwin's and Lamarck's different perspectives on the process of natural selection • Descriptions of applications of Life Sciences in Society eg. Learning about cells and cell division can lead to a career in Oncology	**Vertical curricular knowledge (code-VCK)** Knowledge of the biology topics that are taught in the same subject area but in the preceding or later years of the learners' schooling eg. Linking the explanation of chemical digestion by enzymes in grade 11 with the teaching of enzymes as organic compounds in grade 10	**Lateral curricular knowledge (code-LCK)** Knowledge of substantive knowledge in curricula of the other subjects that learners would need in order to learn and understand biology content knowledge eg. In Life Sciences experiments, learners need to understand independent and dependent variables, they will also learn this in the subject of mathematics when learning graphs

4.2 Analysis of the Curriculum and Assessment Policy Statement (CAPS) document

As described in chapter 3, I performed document analysis on the CAPS document for Life Sciences at FET level. This document analysis was performed in order to answer my first research sub question: What is the content knowledge that preservice teachers are expected to teach at FET level after qualification? From my initial perusal of the Life Sciences CAPS document, I was able to deduce that the document is divided into two sections essential for understanding the content knowledge that teachers need to know in order to teach Life Sciences. The first section is titled 'Introduction to Life Sciences'. This section outlines and describes the specific aims for teaching the Life Sciences FET syllabus. The second section is titled 'Content' and it describes the actual Life Sciences content that needs to be taught at FET level. In the next section, I present the analysis of the first section: The introduction to Life Sciences.

4.2.1 Analysis of the Introduction to Life Sciences section of the CAPS document

The CAPS document outlines and elaborates on three specific aims for teaching the subject of Life Sciences (DBE, 2011). These three aims are:

Specific aim 1: Knowing Life Sciences;
Specific aim 2: Investigating Phenomena in Life Sciences; and
Specific aim 3: Appreciating and Understanding the History, Importance and Applications of Life Sciences in Society (DBE, 2011).

I used my conceptual framework to code the details of the three aims. Table 2 below shows this coding of the three aims.

Table 2: Excerpt of coded specific aims section of the Life Sciences CAPS document

Coding of CAPS document
The science theory that is taught in schools has been tested and is generally accepted. A good teacher will inform learners of debates and arguments (Syntactic knowledge - SK) among the scientists who were the first to investigate a phenomenon.
Specific Aim 1: Knowing Life Sciences (Life Sciences concepts, processes, phenomena, mechanisms, principles, theories, laws, models, etcetera) (Substantive knowledge - SbK) Specific Aim 1 involves knowing, understanding, and making meaning of sciences, (SbK) thereby enabling learners to make many **connections** between the ideas and concepts (SK)
Specific Aim 2: Investigating Phenomena in Life Sciences Learners must be able to plan and carry out investigations as well as solve problems (SK) that require some practical ability. This ability is underpinned by an attitude of curiosity and an interest in wanting to find out how the natural world and living things in it work (SK)
Specific Aim 3: Appreciating and Understanding the History, Importance and Applications of Life Sciences in Society Learners must be exposed to the history of science (SbK) and indigenous knowledge systems from other times and other cultures. Scientific knowledge and understanding have been developed over time by people who were curious and who persevered with their quest for knowledge. Our present understanding of science will change and improve as modern scientists make new discoveries (SK). Science should therefore be taught in an integrated way in order to both enhance the subject and to clarify the relationship between the subject and society (SK) i.e., indigenous knowledge systems that relate to a specific topic, related history of scientific discoveries and the applications of science in everyday life (SK).
In the process of acquiring knowledge learners must: • recall facts (SbK); and • describe concepts, processes, phenomena, mechanisms, principles, theories, laws and models in Life Sciences (SbK)
The subject content provides the context for learning about the history of scientific discoveries (SbK) and their relevance for society (SK). These aspects, the history and relevance, should be linked to and taught in conjunction with the topics and content that are related to a particular discovery or a particular scientist.
The Value and Application of Life Sciences Knowledge in the Industry in Respect of Career Opportunities (SbK) and in Everyday Life Knowledge of Life Sciences is applied in and relevant to various aspects of society.

The coding scheme: Red colour shows coding of syntactic content knowledge and purple colour shows coding of substantive content knowledge

4.2.2 Analysis of the three specific aims and presentation of findings

Six categories of content knowledge form my conceptual framework. Below, I have used these categories as subheadings in the presentation of my findings.

4.2.2.1 Substantive and syntactic content knowledge

The Life Sciences CAPS document's introduction shows that **Specific aim 1** describes substantive knowledge as it refers to knowledge of Life Sciences content including the concepts, theories and facts relating to the subject. **Specific aim 2** describes both scientific procedures as well as facts and concepts. This is because **Specific aim 2** refers to the practical activities in the Life Sciences. In order to carry out practical activities or scientific experiments in the classroom, teachers need to understand the procedures such as the scientific method that point to the validity of different facts and concepts. Since practical activities are about how

facts and concepts are validated, it means this specific aim aligns with scientific procedures, facts and concepts and hence it describes both substantive and syntactic knowledge.

My analysis shows that **Specific aim 3** aims to teach learners the relevance of Life Sciences outside of school. This involves engaging learners with the history of science and indigenous knowledge systems, which according to the conceptual framework, aligns with substantive knowledge. This aim goes further to say that in order for learners to understand the relevance of Life Sciences, it is necessary for teachers to teach them about how modern scientists make new discoveries and their relevance to society. This goes even further to include the different opinions of different scientists on certain topics, controversies within the field and the validity of old and new discoveries. These descriptions of content knowledge to be taught, align with syntactic knowledge. Therefore, specific aim 3 is about both substantive and syntactic knowledge.

As can be seen above, the three specific aims in the CAPS document which form the basis on which the rest of the document is constructed, reflect the content knowledge that teachers need to know which is explicitly linked to substantive and syntactic content knowledge. *Therefore, according to the CAPS document, in order to effectively teach Life Sciences at FET level after qualification, pre-service teachers need to have predominantly substantive and syntactic content knowledge.*

4.2.2.2 The Common Content Knowledge (CCK) and Specialised Content Knowledge (SCK)

Although I could identify CCK in the CAPS document, the term CCK was not used to code any sections of the document. This is because as described in my coding scheme, CCK encompasses both substantive and syntactic knowledge. The reason for this is that CCK involves the overall knowledge that individuals have on a specific topic or subject and that overall knowledge includes both substantive as well as syntactic knowledge (Ball *et al*., 2008).

Specialised Content Knowledge is a type of content knowledge that is more easily noticed and assessed through observing a teacher in practice (Ball *et al*., 2008). Therefore, this type of knowledge could not be identified in the CAPs document. This type of content knowledge is what is taught in methodology courses and it is the type of knowledge that PGCE PSTs are taught as they are considered to already have mastered the disciplinary content knowledge that they need to know in order to teach.

4.2.2.3 The CAPS document and vertical and lateral curricular knowledge

Vertical curricular knowledge encompasses both substantive and syntactic knowledge. This category of knowledge is explicit in the CAPS document as one can see the content that needs to be taught for grades 10, 11 and 12 but I could not code it because this type of knowledge is described with reference to teachers' knowledge. It is the teachers who should possess it and as such it is normally assessed on teachers and this was outside the scope of this research. Lateral curricular knowledge is knowledge of other subjects or topics and concepts in other subjects that are related to Life Sciences and could not be seen in the Life Sciences CAPS document.

The analysis of the descriptions of the three specific aims using my framework shows that the CAPS document presents mainly substantive and syntactic components of the Life Sciences content knowledge. With this in mind, I present the analysis of the rest of the Life Sciences CAPS document.

4.2.3 How I analysed the Content section of the CAPS document

I began the analysis by analysing the grade 10 Life Sciences curriculum for substantive knowledge. After identifying and coding the substantive content knowledge (concepts, facts and theories) for the grade 10 curriculum, I analysed the same content for the syntactic knowledge. I read through the document twice to familiarise myself with the content, starting with the content for grade 10 and then moving on to the content for grade 11. After reading through the content twice, I slowly read through the document for the third time, coding different aspects of content knowledge such as descriptions of theories, facts and concepts. After coding the CAPS document, I tabulated the different aspects of content knowledge or content categories (such as theories, facts and concepts) which should be taught at FET level in order to determine the content knowledge that is required by PSTs to teach FET Life Sciences. The content categories include concepts, facts and theories (which fall under substantive content knowledge) as well as practical investigations and activities (including the performance of experiments, calculations and the use of practical equipment) (which fall under syntactic content knowledge). Below I present the results.

4.2.4 Presentation of the results of my analysis of the CAPS document

4.2.4.1 Substantive knowledge to be taught in grade 10

Table 3 below shows the main concepts as well as examples of the subordinate concepts and of the facts that are to be taught throughout the grade 10 year. The full list of subordinate concepts in the grade 10 curriculum can be seen in appendix C and the full list of facts to be taught in the grade 10 curriculum can be seen in appendix D.

Table 3: Main concepts, subordinate concepts and facts to be taught in grade 10

Main Concepts to be taught in grade 10	Excerpt of subordinate concepts to be taught in grade 10	Excerpt of facts to be taught in grade 10
Organic and inorganic compounds (**Biochemistry**)*	Carbohydrates, Lipids, Proteins, Enzymes, Nucleic enzymes, Vitamins	Organic molecules are made up of C, H, and O, and some contain other elements, such as N and P
Cell structure and function (**Biochemistry/cell biology**)	Microscopy, Fluid mosaic model, Diffusion, Osmosis, Organelles	Cells are made up of proteins, carbohydrates, lipids, nucleic acids and vitamins Chromosomes are found in nuclei of all cells
The cell cycle and mitosis (**Biochemistry/cell biology**)	Cell division, Chromosomes	The continuous process of Mitosis involves the division of a cell to form two identical cells Chromosomes are found in nuclei of all cells
Cancer **(Biochemistry/Biotechnology)**	Causes of cancer, Medical biotechnology	Cancer can be defined as uncontrolled cell division and growth Treatments of cancer and medical biotechnology include: radiotherapy and chemotherapy
Plant and animal tissues **(Botany/Zoology)**	Xylem, phloem, parenchyma, collenchyma, sclerenchyma, epidermis, meristematic tissues	Tissues are a group of similar cells adapted for a particular function
Organs **(Botany)**	Leaf structure	Organs consist of a number of tissues
Biotechnology and Indigenous Knowledge **(Biotechnology)**	Traditional technology, healers, medical biotechnology, immunity, vaccines, cloning, stem cell research	Applications of Indigenous Knowledge Systems and Biotechnology include: traditional technology; medical biotechnology; and the cloning of plant and animal tissues and stem cell research
Transpiration **(Botany)**	Relationship between water loss and leaf structure, wilting and guttation	Factors that affect the rate of transpiration are: temperature; light intensity; wind; humidity
Skeletons **(Animal/human anatomy)**	Hydrostatic skeleton, endoskeleton, exoskeleton	The human Skeleton consists of: the axial skeleton (facial bones, cranium, foramen magnum, palate and jaws) and the appendicular skeleton Functions of the Skeleton include: movement, protection, support, storage of minerals and hearing
Joints **(Animal/human anatomy)**	Fixed joints, Partly movable joints, Freely movable (synovial) joints	Synovial joints include: ball and socket, hinge, pivot and gliding
Human locomotion **(Animal/human anatomy)**	Bones; joints; ligaments; tendons; antagonistic muscles, Voluntary skeletal muscles: Myofibrils and muscle contraction	Bones, joints, ligaments, tendons and antagonistic muscles (biceps/triceps) play a role in human locomotion
Diseases that affect the skeleton **(Animal/human anatomy)**	Rickets, osteoporosis, arthritis	Diseases that affect the skeleton include: Rickets in children, osteoporosis and arthritis
Blood circulation systems **(Animal/human physiology)**	Pulmonary and systemic (double, closed) circulatory systems	The blood circulation system includes the pulmonary and systemic (double, closed) circulatory systems

Blood flow, the cardiac cycle and heart rate **(Human physiology)**	The heart and associated blood vessels	The blood circulatory system includes: the heart and associated blood vessels; heart internal and external structure related to functioning; and the cardiac cycle (the flow of blood through the heart)
Diseases of the heart and cardiovascular system **(Human physiology)**	High and low blood pressure, heart attacks and strokes, treatment	Diseases of the heart and circulatory system include: high and low blood pressure, heart attacks and strokes The treatments of heart diseases include stents, valve replacements, bypass surgery, pacemakers, and heart transplants
The biosphere and biomes **(Environmental studies)**	The biosphere, hydrosphere, lithosphere and atmosphere, Biomes in South Africa	There are terrestrial and aquatic biomes of southern Africa and climate, soils and vegetation influence the organisms found in each
The environment and Ecosystems **(Environmental studies)**	Ecosystem structure and function, Abiotic factors, Biotic factors, Trophic structures and energy flow, Trophic levels	Abiotic factors include physiographic factors (aspect, slope, and altitude); soil (pH, humus content, texture, water retention capacity and air content); light (day length and seasonal changes); temperature (effect of day/night and seasons); water (water cycle and the importance of wetlands); atmospheric gases; and wind
Biodiversity and classification **(Environmental studies)**	Indigenous and endemic species	There is enormous biodiversity on Earth (large variety of species, different ecosystems and genetic differences) Classification schemes are a way of organising biodiversity
History of life forms **(Socio-biology)**	The atmosphere and Climate change, Geological events, Biogeography, Geological timescale, Cambrian Explosion, Mass extinctions	There have been five mass extinctions throughout history, two of which are particularly important: 250 mya (the extinction of about 90% of all life on Earth) and 65 Mya (the extinction of many species, including the dinosaurs). The rate of extinction on the Earth at present is higher than at any time in the past. The present time has been called the sixth extinction
Fossil formation **(Socio-biology)**	The impact of humans on biodiversity and the natural environment Fossil Tourism	Scientists use deductive reasoning (inference) to understand fossils and the history of life on Earth. Fossil Tourism Fossil tourism is a source of income and employment in some localities

***** *The bolded words in brackets indicate the larger overall topics under which the concepts and facts fall. This is further elaborated on below.*

The concepts and facts in Table 3 above outline what should be taught in grade 10 Life Sciences. All of these concepts and facts fit into the broader context of FET Life Sciences and they fall under the larger topics of **zoology** (including animal physiology, anatomy, genetics, and, classification), botany (including plant physiology, anatomy, genetics, and, classification) **biochemistry**; **cell biology**; **biotechnology**; **environmental studies**; and **socio-biology**.

Table 4 below shows the theories to be taught throughout the grade 10 year. While the concepts and facts are clearly identifiable in the CAPS documents, the theories were not as explicitly mentioned and therefore there are not many theories listed below.

Table 4: Theories to be taught in grade 10

Theories to be taught in grade 10
Cell Theory (Biochemistry/cell biology)
Evolution (Environmental studies/socio-biology)
Meteorite impact theory (Environmental studies)

Although not explicitly written in the CAPS document, the three theories in Table 4 above fall under the larger Life Sciences topics of biochemistry; cell biology; environmental studies; and socio-biology.

4.2.4.2 Syntactic knowledge to be taught in grade 10

When analysing the CAPS document for grade 10, I noticed that the syntactic knowledge in the CAPS grade 10 curriculum manifested as practical investigations for the learners to perform. This is because, in order to carry out practical activities or scientific experiments in the classroom, teachers need to understand the procedures such as the scientific method that point to the validity of different facts and concepts. Table 5 below therefore contains an excerpt of the syntactic knowledge included in the grade 10 curriculum as manifested through practical investigations and activities which aim to describe the procedures pointing to the validity of different scientific facts and concepts. The full list of practical activities and investigations can be seen in appendix E.

Table 5: Excerpt of the practical investigations and activities for grade 10

Practical investigations and activities for grade 10
Food tests for starch, glucose, lipids and proteins (Experiment)
Investigate the working of a 'biological' washing powder (containing enzymes) OR Hydrogen Peroxide and chicken liver to demonstrate the effect of enzymes OR Fresh pineapple juice and solid egg white in a plastic drinking straw AND Observe, measure and record results of the experiment done at different temperatures (Investigation)
Investigate the history of microscopy: from lens and light microscopes and to electron microscopes. How these instruments enabled people to see cells and then structures within cells which led to cell theory (Investigation/practical equipment)
Explain and demonstrate how a light microscope works. Use a light microscope to observe and record (draw) the structure of a: plant cell (wet mount of onion epidermis) and an animal cell (cheek cells). If microscopes are not available, use micrographs. Calculate magnification of drawing by measuring the field of view under a microscope OR Calculate the size of specimen on a micrograph using the scale line provided (Practical equipment/calculation)
Research and present information on ONE of the cancers. This must include causes, prevalence and treatment. Information can be presented verbally or as a written report (Investigation)
Examine and identify some plant tissues using microscope, biostrips, micrographs or posters. Draw cells that make up these tissues to show specialised structure (Practical equipment)

Observe annual rings in a cut tree to assess age and climatic conditions (Fieldwork/observation)
Design an investigation to discover the effect of temperature, light intensity or humidity on transpiration rate (using a simple potometer). Identify variables and control variables (Investigation)
Dissection of mammal heart (sheep, cow or pig) obtained from a butchery. Identify chambers, valves, muscle, and blood vessels (Dissection)
Fieldwork: Choose ONE ecosystem (close to the school) within a local biome for special study. The study must: • deal with abiotic and biotic factors and the interactions between them; • investigate the trophic relationships in an ecosystem; • record and describe seasonal changes over two terms either Terms 1 and 2 or Terms 3 and 4 • investigate biodiversity within the ecosystem using field guides and keys •investigate positive and/or negative human impact on the ecosystem Different groups should investigate different factors. Each group must plan, collect, record and present, analyse and evaluate data. (This serves as an introduction/link to human influences on the environment in Grade 11.) (Fieldwork)
Classify a selection of familiar organisms into groups based on visible evidence. Use keys and identification guides (Fieldwork)
Various hypotheses have been proposed for the extinction, 65 million years ago, such as the meteorite impact theory and the volcanism evidence (in India) theory. Select ONE of these hypotheses and describe the evidence scientists have gathered in support of it. (Nature of science) (Investigation)

The practical investigations and activities in Table 5 above outline a variety of practical aspects that should be covered in grade 10 Life Sciences. These practical aspects fall under the larger subsections of **experiments**; **investigations**; **observations**; the use of **practical equipment**; **calculations**; **dissections**; and **fieldwork**.

After constructing these tables, I then repeated this process for the grade 11 curriculum. Table 6 below shows a summary of the broader topics that should be taught in grade 11 FET Life Sciences.

Table 6: The broader substantive and syntactic topics that should be taught in grade 11 FET Life Sciences

Broad topic
Microbiology
Plant and animal physiology
Botany
Zoology
Animal taxonomy
Environmental studies
Human physiology

Environmental studies
Socio-biology
Experiments
Investigations
Fieldwork
Drawing
Dissection
Calculation
Observation
Case study

Table 6 above shows just a summary of the results. The detailed results showing the main concepts, the subordinate concepts, the facts and theories to be taught in grade 11 as well as the practical investigations and activities to be performed in grade 11 can be seen in appendix F.

4.2.5 What is absent from the CAPS document in terms of substantive and syntactic knowledge

Table 2 outlines the aspects of substantive and syntactic knowledge that should be included in the Life Sciences FET curriculum. Tables 3, 4 and 5 outline the aspects of substantive and syntactic content knowledge that are present in the CAPS Life Sciences curriculum for grade 10 and Table 6 shows a summary of the aspects of substantive and syntactic content knowledge that are present in the CAPS Life Sciences curriculum for grade 11. There are however aspects of both types of content knowledge that are absent from the CAPS Life Sciences curriculum for grades 10 and 11. These aspects are outlined below.

Grade 10

The CAPS document states that "a good teacher will inform learners of debates and arguments among scientists who were the first to investigate a phenomenon" (DBE, 2011, p 8). My analysis of the description of the grade 10 Life Sciences content however revealed that there is no mention of any scientific debates that teachers should make mention of. Although specific debates may be found in certain textbooks, they are not informed by the CAPS document for grade 10 Life Sciences. The CAPS document also makes mention of the "value and application

of Life Sciences knowledge in the industry in respect of career opportunities and in everyday life knowledge" (DBE, 2011, p 17). Although certain applications of Life Sciences in society are implicit in the practical investigations and activities recommended in the CAPS document for grade 10 (such as investigating the working of a 'biological' washing powder containing enzymes), that is the full extent to which this is mentioned. There is no explicit reference to applications of Life Sciences in society such as career opportunities or jobs related to the different fields of Life Sciences. Although career opportunities may be mentioned in certain textbooks, they are absent from the CAPS curriculum for grade 10.

Grade 11

The same aspects of content knowledge that are absent from the grade 10 CAPS curriculum are also absent from the grade 11 CAPS curriculum. For grade 11 there is no mention in the CAPS document for Life Sciences of scientific debates that teachers should make mention of or of career opportunities related to the different fields of Life Sciences. Despite the facts that these aspects of content knowledge are mentioned as being necessary for teachers to teach, there is no clear instruction in the CAPS document as to how teachers should go about doing so.

4.2.6 Implications of the content knowledge that is missing from the CAPS document

The absence of some aspects of content knowledge is significant because the CAPS document guides teachers on what to teach and how to teach it. If the document states that the specific aims for teaching Life Sciences include informing learners of scientific debates or career opportunities related to the different fields of Life Sciences, it is important that teachers (especially new teachers) are provided with guidance or resources to teach those aspects of the subject. Despite the fact that many teachers expect to be given these resources, it is important to remember that the aspects of content knowledge that are absent from the CAPS document (scientific debates and career opportunities related to the different fields of Life Sciences) are not fixed, and as science evolves and expands, so do the debates and the career opportunities. It is therefore understandable that these aspects are absent from the CAPS document. The problem still stands however that if new teachers do not have guidance, they may not know or understand how to teach those aspects that are absent from the CAPS document. In situations such as these, instead of the CAPS document changing and updating whenever a new debate or career opportunity is discovered, it is important to provide teachers with the training or resourcefulness to uncover these aspects themselves. Higher education institutions can

therefore aim to train teachers in their teacher preparation programmes not only to understand and use what is in the CAPS document but to also equip PSTs with the knowledge and ability to find and update themselves on the latest scientific debates and career opportunities within the field of Life Sciences. If PSTs gain that skill during their training, once they are qualified as teachers, they will still be able to teach about scientific debates and career opportunities despite the fact that this information is absent from the CAPS document.

4.3 Analysis of the objective tests

4.3.1 Structure of the tests

Four tests were given to the PGCE PSTs who were studying to be Life Sciences teachers at the FET level. As mentioned in chapter 3, PGCE PSTs are required to complete subject tests in order for the lecturers to determine if they have satisfactory content knowledge on the school subject that they will be teaching (personal communication). I downloaded the tests from the PGCE e-learning site. I surveyed each of the four tests twice, first round to familiarise myself with the structure of the tests and the test items and second round to gather and record information about each test. Below is a summary of the structure of the four tests. In 2020, the four tests consisted of four types of questions namely multiple-choice questions, fill in the blanks, match the columns and true or false questions. Test 1 had 38 items in total all of which focused on grade 10 content for terms 1 and 2. Test 2 had a total of 29 items and focused on grade 10 content for terms 3 and 4. Test 3 focused on grade 11 content for terms 1 and 2 (30 items) and Test 4 focused on grade 11 content for terms 3 and 4 (30 items). The PSTs were not given any content tests for grade 12. Table 7 summarises the structure of the four tests.

Table 7: A summary of the structure of each test

	Type of questions making up the test and the number of those questions found in the test			
Test	**Multiple choice**	**Fill in the blanks**	**Match the columns**	**True or false**
Test 1	17	6	8	7
Test 2	17	0	12	0
Test 3	30	0	0	0
Test 4	20	0	10	0

4.3.2 Analysis of the test items

To analyse the test items, I read through all of the tests twice and coded the test items using the different aspects of content knowledge outlined in Table 1 such as theories, facts and concepts as codes.

The coding process

I coded each test item in accordance with the coding scheme. The code 'concept' was given to items that were testing content knowledge of a concept i.e., ideas or mental representations of events including observable entities, unobservable entities or processes. An example of an item testing content knowledge of a concept can be seen below.

Which is the most important force causing water to rise up the xylem vessels in plants? (concept)

A. *Root pressure.*
B. *Cohesion forces.*
C. *Transpiration pull.*
D. *Capillarity.*

The code 'fact' was used for items that were testing a known truth that can be observed by individuals. An example of a question testing content knowledge of a fact can be seen below.

The centromere is a region in which...(fact)

A. *chromatids remain attached to one another until anaphase.*
B. *metaphase chromosomes become aligned at the metaphase plate.*
C. *chromosomes are grouped together during telophase.*
D. *the nucleus is located prior to mitosis.*

The code 'history' was used for items that had a description pointing to an understanding of the history of Life Sciences. An example of test items testing content knowledge of history can be seen below.

Match the statements / descriptions in column one with the correct term in column two. (History)(Remembering)

1. A type of dating that involves studying the horizontal layers of extinction sedimentary rock.	A. background
2. The oldest living fossil.	B. relative dating
3. One of the earliest forms of life found in the Barberton district of Mpumalanga	C. Bacteria
4. The animal that is generally accepted as the link between dinosaurs and birds.	D. Archaeopteryx
5. The kind of event that is responsible for the greatest loss of large numbers of species.	E. Coelacanth
6. The natural rate at which species die out.	F. Mass extinction

The code ‘experiment’ was used to code the questions that represented scientific experiments. An example of a question testing content knowledge of experiments can be seen below.

Which of the following is used as a test for glucose? (experiment)

A. Ether
B. Benedict’s solution
C. Iodine solution
D. Millon’s reagent

The code ‘practical equipment’ was used to code items that required knowledge about practical equipment in Life Sciences. An example of a question testing content knowledge of practical equipment can be seen below.

The instrument that allows you to magnify a cell 50000x is called:(practical equipment)

A. a light microscope.
B. an electron microscope.
C. a dissecting microscope.
D. a hand lens.

The code calculation was used for items that required a calculation in order to arrive at the correct answer. An example of a question testing content knowledge of calculations can be seen below.

If a cell divides by mitosis, how many cells will there be after three divisions? (calculation)

A. 3 cells.
B. 4 cells.
C. 8 cells.
D. 16 cells.

During the coding process, I found that certain questions appeared to belong to more than one code, such as theory and history or fact and concept. When this occurred, I chose the code that most appropriately represented the question. The coded tests can be seen in Appendix A.

4.3.2.1 Coding the test items for cognitive demand

As part of the analysis process, I also coded for the cognitive skills that were being assessed through the questions in these tests. I used Bloom’s taxonomy in order to classify the cognitive demand of the test items. The revised Bloom’s taxonomy is made up of six cognitive skill categories which range from the skills that involve a lower level of cognitive processing (lower-order skills) to the skills that involve a higher or deeper level of cognitive processing (higher-order skills) (Adams, 2015). The six categories (from lower-order skills to higher-order skills)

are: Remember; Understand; Apply; Analyse; Evaluate; and Create. Remembering is the lowest level of Bloom's taxonomy and it therefore requires the lowest level of cognitive processing (Adams, 2015). This type of knowledge focuses on the ability to recall or recognise facts or basic concepts (factual recall or conceptual recall) (Forehand, 2010). This recall is usually tested through multiple choice questions or short answer questions that require the recognition or retrieval of information (Adams, 2015). In order to determine which levels of cognitive processing were being assessed in these tests, I coded all four tests using Bloom's taxonomy as the framework. This coding can be seen alongside my initial coding of the tests in Appendix A.

The code 'Remembering' was used to code items that involved the recall of facts or basic concepts. An example of a question testing this cognitive level can be seen below.

Each new cell produced by mitosis will have... (remembering)

E. half the number of chromosomes.
F. a full set of chromosomes.
G. twice the number of chromosomes.
H. two new nuclei.

The code 'Understanding' was used to code items that involved an explanation; classification; description; discussion; or recognition of ideas or concepts. An example of a question testing this cognitive level can be seen below.

Chimpanzees have a relatively low birth rate. They take good care of their young, and most chimps live a long life. The chimp survivorship curve would look like... (understanding)

A. a line that slopes gradually upward.
B. a relatively flat line that drops steeply at the end.
C. a line that drops steeply at first, then flattens out.
D. a line that slopes gradually downward.

The code 'application' was used to code items that involved differentiation; organisation; examinations; or calculations. An example of a question testing this cognitive level can be seen below.

If a cell divides by mitosis, how many cells will there be after three divisions?

A. 3 cells.
B. 4 cells.
C. 8 cells.
D. 16 cells.

These were the only cognitive levels that were tested in these tests.

4.3.3 Presentation of the results of my analysis of the objective tests

4.3.3.1 Results of the analysis of the structure of the tests

As summarised in Table 7 above. The four tests consisted of four types of items namely multiple choice, fill in the blanks, match the columns and true and false items. This is significant as these types of items often test the PSTs' abilities to recall specific facts or concepts.

4.3.3.2 Results of the analysis of the grade 10 tests

Some aspects of both the substantive and syntactic knowledge were examined by the grade 10 tests. I provide details below.

Substantive knowledge

Table 8 below shows the proportions (%) of the different aspects of substantive knowledge that were tested for grade 10.

Table 8: Proportions of the different aspects of substantive knowledge tested for grade 10 (total number of questions (n) = 67)

Aspect of substantive knowledge	Proportion of questions asked (%)
Facts (n = 25)	37
Concepts (n = 32)	48
Theories (n = 0)	0
History (n =6)	9

From this table it can be seen that the aspect of substantive knowledge for grade 10 that was tested the most was concepts. While knowledge of concepts was tested throughout the tests, it was mostly tested in the match the columns questions where the name of a concept needs to be matched with its definition as well as the fill in the blanks question where the concepts of organelles was tested. Facts also made up a large portion of the knowledge tested for grade 10. Facts were primarily tested in the multiple-choice questions of the tests as well as the true or false questions. The tests went further to ask a match the columns question that tested the PSTs' knowledge on the history of the Earth (including fossils and mass extinctions), therefore testing the history aspect of substantive knowledge.

Although there is evidence of the testing of facts, concepts and history, there were no questions asked in this test that tested the PSTs' knowledge of theories. In grade 10 terms 1 and 2, the

cell theory should be taught, however there were no questions related to the cell theory in this test. In grade 10 terms 3 and 4, the theory of Evolution is introduced. Although there were questions in the tests that related to the theory of Evolution (such as questions about natural selection and fossils) the link to the theory is implicit and these questions were better related to the History of the Earth instead of the theory of evolution. Therefore, knowledge of theories was not explicitly tested for grade 10.

Syntactic knowledge

The grade 10 tests tested some aspects of the practical investigations or activities that are performed in the Life Sciences subject such as calculations, experiments and general practical equipment. Table 9 below shows the proportions (%) of the different aspects of syntactic knowledge that were tested for grade 10.

Table 9: Proportions of the different aspects of syntactic knowledge tested for grade 10 (total number of questions (n) = 67)

Aspect of syntactic knowledge	Proportion of questions asked (%)
Calculation (n = 1)	1.5
Experiment (n = 2)	3
Practical equipment (n = 1)	1.5

From the table it can be seen that PSTs' knowledge of basic experiments is briefly tested as there were questions in only one test that related to syntactic knowledge. The test asked questions relating to testing for glucose or proteins which are practical activities that can be performed in term 1 of grade 10. One of the tests also tested knowledge of some equipment used in Life Sciences practical activities such as the different types of microscopes and which microscopes are used for specific magnifications. The table also shows that the PSTs' ability to perform basic calculations based on their Life Sciences content knowledge was also tested as they were asked to determine the number of cells present after three divisions by mitosis. In order to correctly answer this question, PSTs need to have been aware of the exponential division of cells by mitosis. Although there was evidence of the testing of PSTs' content knowledge of the practical aspects of the subject, there were no questions testing the PSTs' knowledge of any controversies within the field of Life Sciences such as indigenous treatments of cancer which is taught in term 1 or 2 of grade 10.

4.3.3.3 Results of the analysis of the grade 11 tests

Some aspects of substantive knowledge were tested however there was no evidence of any questions testing the PSTs' syntactic knowledge for grade 11. The tests included questions that tested knowledge of facts and concepts however the other aspects of substantive knowledge were absent from the tests. Table 10 below shows the proportions (%) of the different aspects of substantive knowledge that were tested for grade 11.

Table 10: Proportions of the different aspects of substantive knowledge tested for grade 11 (total number of questions (n) = 60

Aspect of substantive knowledge	Proportion of questions asked (%)
Facts (n = 31)	52
Concepts (n = 29)	48
Theories (n = 0)	0
History (n = 0)	0

From this table it can be seen that the aspect of substantive knowledge for grade 11 that was tested the most was facts. Concepts also made up a large amount of the tests. While the tests were made-up of multiple-choice questions and match the columns, knowledge of facts was only tested in multiple choice questions while concepts were tested in multiple choice questions and match the columns questions. There were no questions that tested the PSTs' knowledge of theories such as germ theory which would be taught in term 1 of grade 11. There were also no questions in the tests that tested the PSTs' knowledge on the history of Life Sciences topics and questions testing the syntactic knowledge of PSTs were also absent from these tests.

From the analysis of all four of the tests, it can be seen that various aspect of substantive and syntactic content knowledge were tested in these tests. While all of the tests asked questions that tested the PSTs' knowledge on the facts and concepts throughout the Life Sciences curriculum for grades 10 and 11, only the theory of evolution was implicit in one test while theories such as germ theory and cell theory were absent. The history of Life Sciences topics was also only tested on occasion but not throughout the tests. It could also be seen from this analysis that syntactic content knowledge was only tested briefly for grade 10 and questions related to syntactic knowledge were absent from grade 11. This analysis shows that the common content knowledge of PSTs (including aspects of substantive and syntactic knowledge) was tested in these tests however the other aspects of content knowledge such as specialised content knowledge and curricular knowledge were not assessed.

4.4 Discussion of the results

In this chapter I analysed the CAPS document for FET Life Sciences and the content tests that were given to the pre-service teachers in order to answer my first two research sub-questions:

1. What is the content knowledge that pre-service teachers are expected to teach at FET level after qualification?
2. How is the content knowledge that is assessed in the PGCE programme aligned to what the PSTs are expected to teach at FET level?

4.4.1 Content knowledge that is expected to be taught at FET level

The analysis of the CAPS document showed that the content knowledge that Pre-service teachers are expected to teach at FET level consists mainly of substantive content knowledge (knowledge of facts, concepts, theories and history) and syntactic content knowledge (knowledge of procedures pointing to the validity of different scientific facts and concepts e.g., the scientific method; different perspectives and controversies on specific topics; and controversial topics within the subject). These findings are in alignment with Deng (2015), who argued that a subject curriculum should include the academic knowledge of the subject such as knowledge of theories, concepts and facts (substantive knowledge) as well as the knowledge on modes of enquiry and an understanding of why and how that academic knowledge was included in the curriculum (syntactic knowledge) (Deng, 2015).

Teachers need to have deep knowledge and understanding of both substantive and syntactic content knowledge in order to demonstrate effective PCK (Anderson & Clark, 2012). As mentioned in Chapter 1, in order to develop PCK a teacher must have four knowledge bases namely: knowledge of subject matter/content; general pedagogical knowledge; knowledge of the students and knowledge of context (Rollnick *et al.*, 2008). Although all four knowledge domains are important for effective teaching, this study focused on content knowledge and investigating the content knowledge of PGCE PSTs.

Schwab (1964), stated that knowledge of content knowledge can be divided into substantive content knowledge and syntactic content knowledge. Anderson and Clark (2012), discuss the importance of substantive and syntactic content knowledge in school curricula.

Researchers such as Shulman recognised the importance of both the syntactic and substantive aspects of content knowledge when educating others (Shulman, 1986). While many individuals are aware that facts, concepts, theories and history (substantive knowledge) make up content

knowledge of a discipline such as Life Sciences, the syntactic aspects of content knowledge such as the nature of science are often not explicitly defined and recognised as content knowledge. Therefore, pre-service teachers without a background in science may not understand the importance of syntactic content knowledge in their teaching (Anderson & Clark, 2012). It is therefore important, as outlined in the CAPS document that, when teaching and learning Life Sciences, substantive and syntactic content knowledge are both explicitly taught. In teacher education programmes, it is therefore important that this be made explicit to the PSTs in order for them to understand the significance of both aspects of content knowledge in the Life Sciences curriculum.

4.4.2 Aspects of content knowledge that were assessed in the content tests

The analysis of the four objective tests that were used to determine the content knowledge of PGCE students at the university in this study in 2020 consisted only of certain aspects of both substantive and syntactic knowledge.

Substantive content knowledge

The substantive content knowledge that was covered in the tests included knowledge of facts, concepts and history (however history was only briefly assessed in one test).

Knowledge of Life Sciences facts and concepts can also be considered to be common content knowledge which, as mentioned in Chapter 2, refers to the overall knowledge that teachers must have in order to teach their chosen subjects (Ball *et al.,* 2008). It is essential for Life Sciences pre-service teachers to have knowledge of the facts and concepts in Life Sciences as this is will be what they will need to teach and what they will expect their learners to learn (Ball *et al.,* 2008). This knowledge can also enable teachers to recognise errors in textbook definitions as well as gaps in the knowledge of their learners (Ball *et al.,* 2008). If a learner gives an incorrect response or has a misconception, a teacher with common content knowledge will be able to identify the incorrect response or misconception and correct it (Ball *et al.,* 2008). It is therefore essential that these aspects of content knowledge were assessed in the content tests.

Knowledge of the history of Life Sciences is essential for teachers to be able to teach as an understanding of the historical background behind certain theories, laws, concepts and facts can give both teachers and learners a more comprehensive and in-depth interpretation of the content and its social context (Dagher, 2014). An understanding of science history in the Life

Sciences classroom not only promotes a deeper understanding of the scientific reasoning and inquiry behind the scientific knowledge, it also has the potential to grasp the interest of learners as they begin to understand how certain knowledge and content originated (Dagher, 2014). It is therefore essential that teachers have knowledge of facts, concepts and history in FET Life Sciences and therefore it is appropriate that these aspects of substantive content knowledge were assessed in the content tests.

Syntactic knowledge

The syntactic content knowledge that was covered in the tests included knowledge of practical investigations, practical equipment and calculations (however syntactic knowledge was only tested in four questions in one test).

It is essential for teachers to be able to demonstrate knowledge of practical investigations and the equipment used in practical investigations as the practical aspect of Life Sciences can allow for learners to learn the science content while also learning how to do science (Hart, 2018). This is important as certain learners are able to learn more easily through the action of performing the activities (Hart, 2018). In other words, when learning abstract concepts, learners may better understand the content through active participation in their learning and this can be achieved through practical activities (Millar, 2004). Scientific skills are therefore learned through practical activities and this can introduce learners to science as a profession. Through practical investigations and the use of practical equipment, learners can develop skills such as critical thinking and problem solving (Hart, 2018). Through practical activities, learners can construct their own meaning of the content through their actions, allowing to develop further skills (Millar, 2004). Practical activities are time consuming and teachers may prefer to teach content instead. It is therefore important that pre-service teachers are trained and have knowledge of how to use practical equipment and conduct practical activities for their future learners (Hart, 2018).

It is also important to assess the PSTs' abilities to perform calculations as the CAPS document for FET Life Sciences includes many instances where teachers need to teach learners to perform calculations (DBE, 2011). For example, in microscopy, learners should be taught how to use a scale line to calculate the size of a specimen on a micrograph. Learners should also be taught to calculate the nutritional values of meals and calculate population size in population ecology (DBE, 2011). PSTs therefore need to be able to perform these calculations in order to properly teach these skills to their future learners.

4.4.3 Aspects of content knowledge that were not assessed in the content tests

The aspects of the substantive and the syntactic content knowledge that were not covered in the tests were theories, different perspectives and controversies on specific topics and controversial topics within the subject.

Although there are not many theories in the Life Sciences curriculum, it is important for PSTs to understand and be able to teach the theories that are present in the curriculum (Shou, Bergstrom, Chakraborty & Skinner, 2015). Theories are important because they form a larger framework through which concepts and facts are explained (Shou *et al.*, 2015). For example, it is important for PSTs to understand the content behind the theory of evolution as this leads to an understanding of concepts such as natural selection and fossils. It is also important for PSTs to be knowledgeable on how to teach different perspectives and controversial topics within the subject of Life Sciences and their knowledge on these aspects of content knowledge should therefore be assessed (Soley, 1996). Engaging learners in discussions over controversial topics is important as it this allows learners to think critically about their social environments through making thoughtful judgements and decisions about their beliefs (Soley, 1996). Engaging in controversial topics allows learners to perform their own research on the topic while thinking deeply about their own values and those of others. It can be difficult to teach controversial topics and it is therefore important for PSTs to learn these skills in their teacher education programmes (Soley, 1996).

4.4.4 Final remarks about the results of Chapter 4

It can be seen that most of the aspects of content knowledge were assessed in the content tests at the beginning of the PGCE programme in 2020. The analysis of the tests also showed that the cognitive levels that were assessed in these tests were remembering, understanding and application. The cognitive levels of analysing, evaluating and creating were not assessed in the tests. The cognitive level of remembering was the dominant cognitive level of assessment in these tests as most of the questions throughout all four tests were testing the PSTs' abilities to remember or recall content.

As mentioned in Chapter 2, Bloom's taxonomy is a classification system that defines the different cognitive levels that students should display (Adams, 2015). The different cognitive levels in the revised Bloom's taxonomy (ranging from the lowest level to the highest level) are: remember; understand; apply; analyse; evaluate; and create (Adams, 2015). Using Bloom's taxonomy in teaching and assessment allows teachers to expand the levels and depth of the

learning that takes place in their classrooms (Eber & Parker, 2007). In order to achieve this however, all six levels of the classification system need to be taught and assessed. As indicated by Eber and Parker (2007), college assessments often only or predominantly assess the cognitive level of remembering and this was the case with the content tests in this study. The problem however is that all six levels need to be taught and assessed in order to promote critical thinking and mastery of skills (Eber & Parker, 2007). By assessing all of the cognitive levels, teachers can determine the learners' knowledge and abilities within each level (Eber & Parker, 2007). PSTs need the ability to teach and assess all six cognitive levels in order to ensure that their future learners develop accordingly and master each level. It is therefore important for the PSTs to be assessed on all six cognitive levels instead of just the first and lowest level.

4.5 Conclusion of the chapter

In this chapter, I presented my analyses of the Life Sciences CAPs document and the content tests given to the pre-service teachers and the findings from these data sets. I performed the analyses by using my conceptual framework on content knowledge and Bloom's taxonomy as a lens. In the next chapter, I present the analysis and results that enable me to answer my third and fourth research sub-question.

Chapter 5

Analysis of the PGCE pre-service teachers' performance in the content tests and presentation of findings

In this chapter, I present my analysis of the PSTs' responses to the four tests. I also make use of the responses from the questionnaire to further make sense of the content knowledge that the PSTs possess as well as the PSTs' perspectives about their content knowledge and teaching abilities. The findings that are presented in this chapter will help me to answer my third and fourth sub-questions:

3. What strengths and weaknesses can be seen in the PGCE PSTs' content knowledge of FET Life Sciences?
4. To what extent are PGCE PSTs confident about their content knowledge?

5.1 Analysis of the PGCE pre-service teachers' performance in the content tests

Twenty-two PGCE PSTs out of a class of 29 gave their consent for me to analyse their test responses. I therefore analysed all 22 PST's written tests. As indicated in chapter 3, a total of 4 objective tests were written by each student to assess their content knowledge. My analysis took place in 3 stages. I outline these stages below.

Stage 1: I analysed the overall performance of the PSTs for each test. I began this analysis by going through each PST's response to each question, indicating correct and incorrect responses and then recording the final mark (%). After analysing all of the responses, I created a frequency distribution table of 10% range from 0% to 100% to show the range of the students' final marks for each test (see Table 11 and Figure 2).

Stage 2: I calculated the students' average marks for each of the four tests in order to see where the content knowledge of the PSTs was the strongest and where it was the weakest (see Table 12).

Stage 3: I grouped the questions according to the various aspects of content knowledge (i.e., facts, theories, concepts, history, calculations, experiments or practical equipment) and calculated the average number and proportions (%) of correct and incorrect responses given by

the PSTs for each aspect of the content knowledge as indicated. My aim was to determine the students' performance for each content knowledge aspect.

The results of the PGCE PSTs' test responses are presented below.

5.2 Presentation of the results

5.2.1 Results from stage 1: Analysis of the pre-service teachers' responses to all four tests

As mentioned above, I began my analysis of the test responses by calculating each PST's final mark (%) for each of the four tests. Of the 22 participants, only 20 completed Grade 10 test 1 while all 22 completed the other three tests (Grade 10 test2, Grade 11 test 1, Grade 11 test 2). The range of the marks achieved for each test are shown in Table 11 and figure 2 below.

Table 11: Overall ranges of marks achieved by the PSTs for each test

	Grade 10 test 1	Grade 10 test 2	Grade 11 test 1	Grade 11 test 2
Percentage range (%)	**Number of PSTs in the range**			
0-9	0	0	0	0
10-19	0	0	0	0
20-29	0	0	0	0
30-39	0	0	0	0
40-49	0	0	0	0
50-59	3	0	0	0
60-69	0	0	2	1
70-79	1	0	1	0
80-89	10	0	9	5

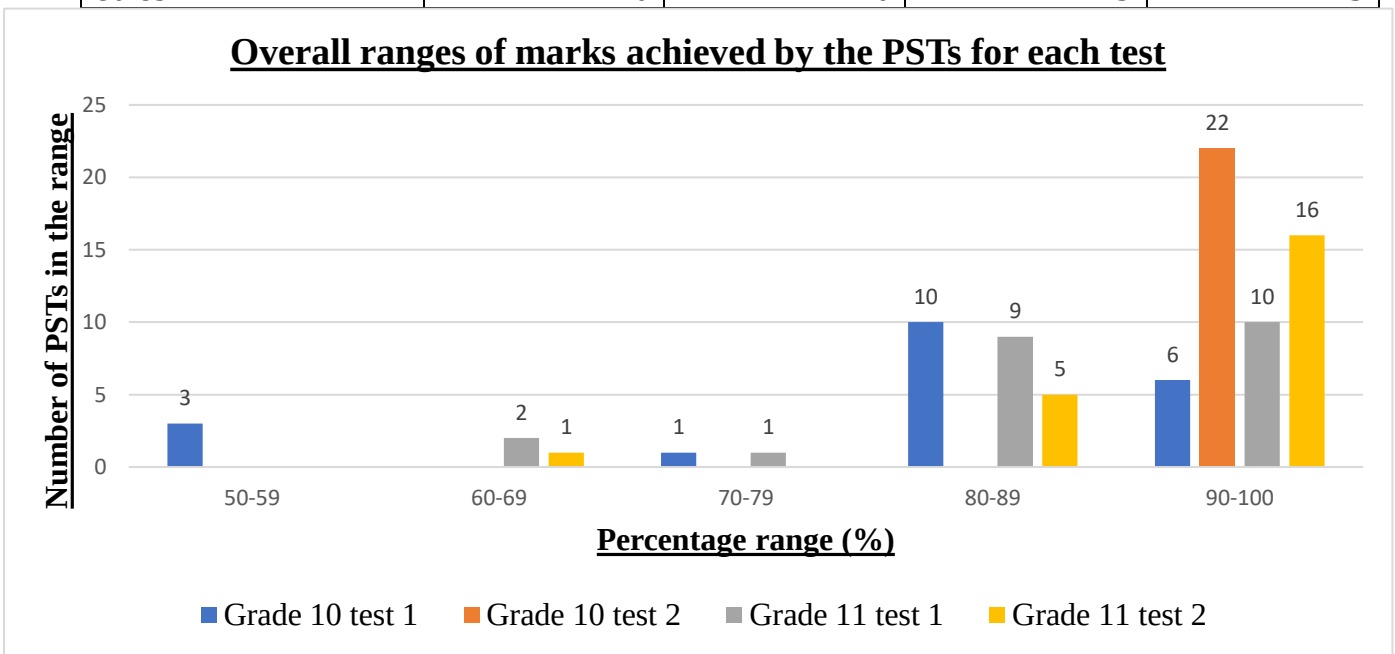


Figure 2: Overall ranges of marks achieved by the PSTs for each test

As can be seen in Table 11 and Figure 2 above, the results show that the 20 PGCE PSTs who completed Grade 10 test 1 scored between 50% and 100% with the majority of PSTs scoring within the 80-89 percentage range which is high. For Grade 10 test 2, all 22 PSTs scored within the highest percentage range (90%-100%), with 7 out of the 22 PSTs scoring 100%. For Grade 11 test 1, all 22 PGCE PSTs scored between 60% and 100%, with 10 PSTs scoring within the percentage range of 90%-100%; 9 PSTs scoring within the percentage range of 80%-89%; 1 PST scoring within the percentage range of 70%-79% and 2 PSTs scoring within the percentage range of 60%-69%. For Grade 11 test 2, the PGCE PSTs scored between 60% and 100%, with 16 PSTs scoring within the percentage range of 90%-100%; 5 PSTs scoring within the percentage range of 80%-89%; and 1 PST scoring within the percentage range of 60%-69%. All results show that the PSTs achieved primarily high marks for all four tests. Considering that the content knowledge that these tests were assessing falls primarily under the lowest cognitive processing level of remembering, the high marks indicate that the PSTs could recall/remember the knowledge about the content that the questions were testing.

5.2.2 Results from stage 2: Comparison of the pre-service teachers' overall performance in each of the four tests

As mentioned above, after analysing the students' responses for all four tests, I calculated the average mark for each test. The aim was to compare the averages to one another in order to see where the content knowledge of the PSTs was the strongest and where it was the weakest. The results are shown in Table 12 and Figure 3 below.

Table 12: Comparison of the overall average marks for all four tests

Test	Average final mark (%)
Grade 10 test 1	83
Grade 10 test 2	98
Grade 11 test 1	86
Grade 11 test 2	92

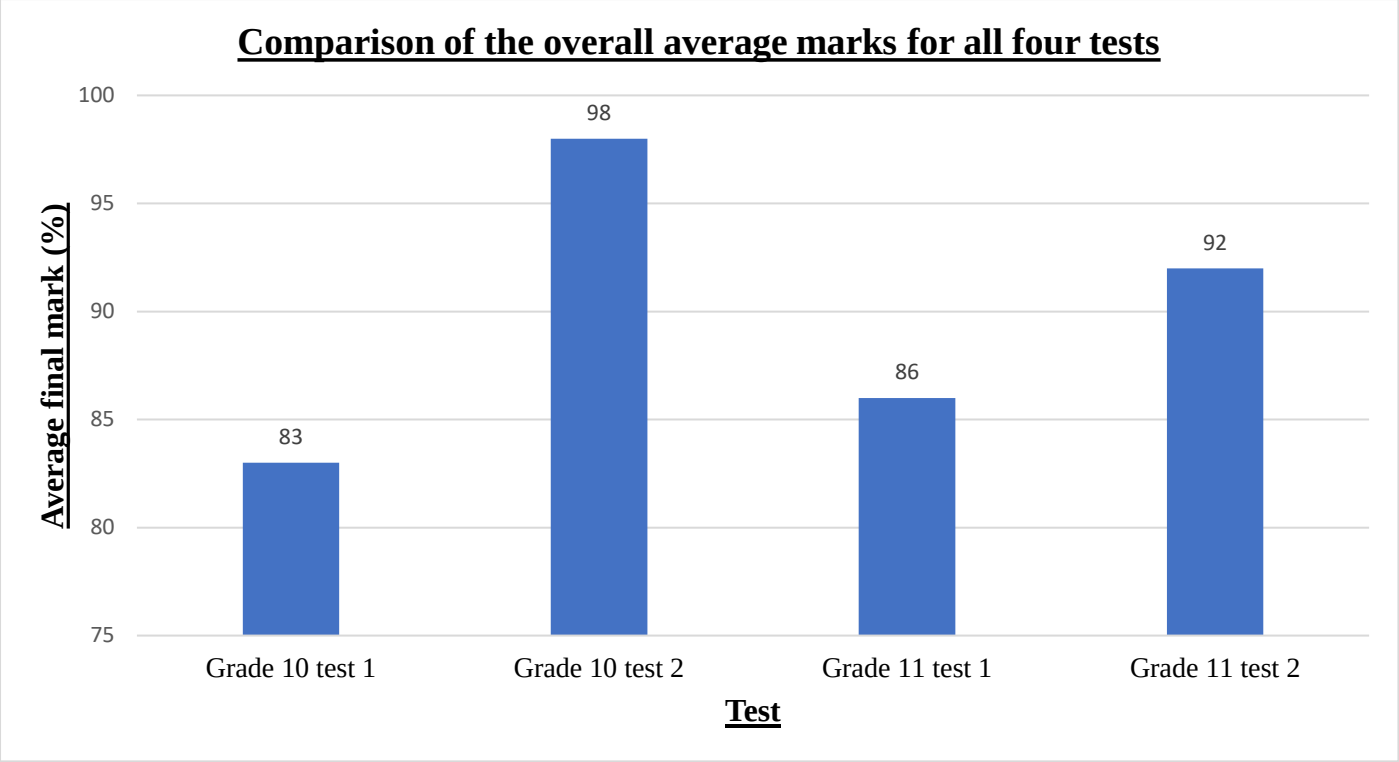


Figure 3: Bar graph comparing the overall average marks (%) for all four tests

From the above results, it can be seen that the PSTs' performance was strongest in the Grade 10 test 2 which tested for content knowledge for terms 3 and 4. The topics that are covered in grade 10 terms 3 and 4 include: transport systems in mammals (human); Biosphere to ecosystems; Biodiversity and classification; and History of Life on Earth. The PSTs' performance was the weakest in the Grade 10 test 1 which tested for content knowledge for terms 1 and 2. The topics that are covered in grade 10 terms 1 and 2 include: The chemistry of Life; Cells: the basic units of life; Cell division: mitosis; Plant and animal tissues; organs; support and transport systems in plant; and support systems in animals.

Overall, the above results show a high-level performance in all four tests. The reason for this high performance throughout all four tests may be a result of the simplicity of the questions asked. The questions in the tests were either multiple choice, fill in the blanks, match the columns and true or false questions. All of these types of questions are simplified so that the answers are visible as part of the question. For example, in multiple choice questions, the correct answer to the question is one of the options given as part of the question. In match the columns questions, the answers to the statements in one column are present in the other column. Once more PSTs can see the answer. For fill in the blank questions, the possible words that fill the blanks are given to the PSTs and for true or false questions, the PSTs only have to look at

the statement on the page to give one of two answers. As mentioned in chapter 4, most of the questions in the tests assessed the lowest cognitive level of remembering or recall and in conjunction with the simplicity of the type of question, this can lead to a high performance by the PSTs.

The fact that the PSTs showed the weakest performance in grade 10 test 1 may be because the PSTs were unprepared for their first content test upon entry into the school of education. However, the PSTs still achieved high marks for this test and this may be due to the simplicity of the questions in the test. The PSTs showed the strongest performance in the grade 10 test 2 and a reason for this can be the simplicity of the questions and the low cognitive levels that the test assessed. However, another reason for the high performance in this test may be that after experiencing the grade 10 test 1, the PSTs may have read and studied more for the next test so as to be more prepared.

5.2.3 Results from stage 3: Analysis of the performance of the pre-service teachers for the different aspects of content knowledge

This analysis focused on how the PSTs performed in the specific aspects of content knowledge. In order to perform this analysis, I first grouped the questions according to the different aspects of content knowledge. For each aspect of content knowledge (in each test individually), I calculated the PSTs' average performance by looking at each question that tested for that aspect of content knowledge, calculating the number of PSTs who gave correct answers for each question, calculating the average number of PSTs who gave correct answers over all of the questions in that specific group, and then calculating the average proportions (%) of correct answers given by the PSTs. For example, there were 2 questions in Grade 10 test 1 that tested for knowledge of experiments. For the first question, 19 out of the 20 PSTs who completed the test gave correct answers. For the second question, 18 out of the 20 PSTs gave correct answers. The average number of PSTs who gave correct answers for questions testing for knowledge of experiments is therefore 18.5, which is rounded up to 19 PSTs out of 20. Therefore, the total proportion of PSTs who gave correct answers is 95%.

The number of questions present in all four tests relating to each aspect of content knowledge can be seen below.

Table 13: Number of questions for each aspect of content knowledge in each test

Test description	Questions on Facts	Questions on Concepts	Questions on History	Questions on Syntactic knowledge	Questions on Theories	Total
Grade 10 test 1	13	21	0	4	0	38
Grade 10 test 2	11	12	6	0	0	29
Grade 11 test 1	19	11	0	0	0	30
Grade 11 test 2	12	18	0	0	0	30

When grouping the questions according to the different aspects of content knowledge, the analysis showed that all four tests tested for knowledge of facts and concepts; none of the tests tested for knowledge of theories; one test (Grade 10 test 2) tested for knowledge of history; and one test (Grade 10 test 1) tested for knowledge of the different aspects of syntactic knowledge (calculations, experiments and practical equipment).

Knowledge of facts and concepts

Due to the fact that all four tests tested for knowledge of facts and concepts, when comparing the overall results of the PSTs' test responses for all four tests, the analysis focused on the PSTs' performance in questions that tested for knowledge of facts and concepts. The results of this analysis can be seen below. As mentioned above, the numbers and proportions used are the average numbers and proportions of PSTs who gave correct answers for facts and concepts. It is also important to remember that 20 PSTs completed Grade 10 test 1 while 22 PSTs completed the other 3 tests.

Table 14: A comparison of the average number and proportions of correct answers given for facts and concepts for all four tests

Aspect of content knowledge	Average number (and proportion %) of students who got correct answers for Grade 10 test 1	Average number (and proportion %) of students who got correct answers for Grade 10 test 2	Average number (and proportion %) of students who got correct answers for Grade 11 test 1	Average number (and proportion %) of students who got correct answers for Grade 11 test 2
Facts	17 (85)	21 (95)	20 (91)	20 (91)
Concepts	17 (85)	21 (95)	18 (82)	20 (91)

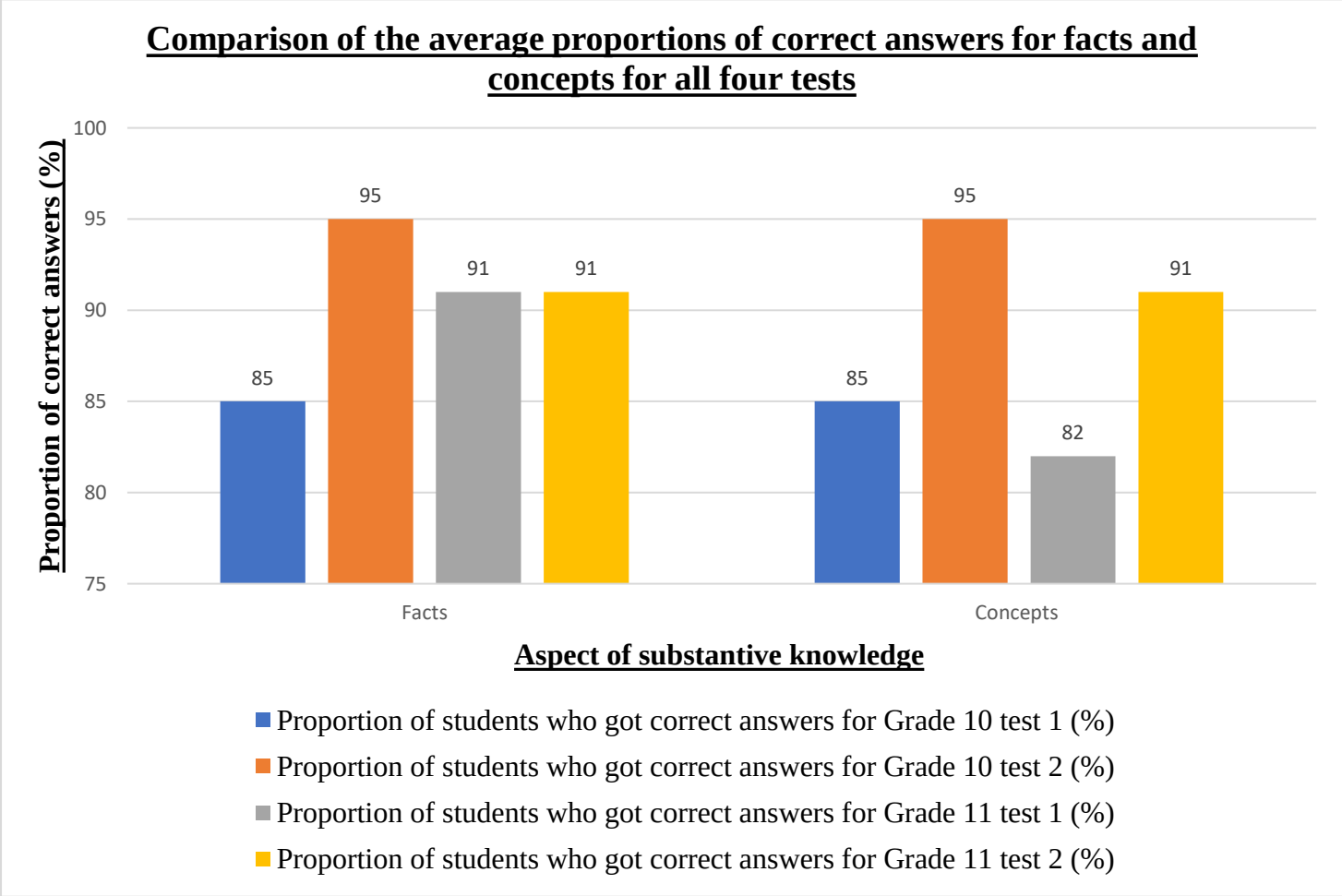


Figure 4: Comparative bar graph showing a direct comparison of the proportions of correct answers for facts and concepts for all four tests

The above results show a high level of achievement in all four tests, thereby showing strength in the PSTs' content knowledge for both grades 10 and 11. In addition, the PSTs show more strength in their content knowledge of facts and concepts that are taught in grade 10 terms 3 and 4. The content that is covered in these terms (3 and 4) falls under the following topics: the human circulatory system; biosphere and ecosystems; biodiversity and classification; and history of life on Earth. It is important to remember however that the questions in all four tests were predominantly testing the cognitive process of remembering, the results therefore show that the PSTs were highly capable of recalling the correct facts and concepts that they need to know for grades 10 and 11.

After analysing the PSTs' content knowledge for facts and concepts by looking at the number of questions that they answered correctly and incorrectly, I went further in my analysis. I first analysed the questions on facts and concepts that the highest number of PSTs answered correctly in order to determine the Life Sciences topics under which the question items fell. I then did the same for the questions that the highest number of PSTs answered incorrectly. By looking at the specific topics that each question was focused on and by analysing the PSTs' responses to those questions, I was able to determine the areas or content topics where the PSTs performed highly and the areas or content topics where the PSTs performed poorly. Since the PSTs' performances for facts and concepts were almost equal to one another, I will present the results for facts and concepts together.

The results show that, when tested for knowledge of facts and concepts, the PSTs performed well in questions on molecular and cell biology (which includes topics such as biochemistry, cell structure and function and biotechnology); Zoology – with an emphasis on human physiology (including topics such as the human circulatory system, gaseous exchange in humans, human excretion and human respiration); environmental studies (including topics such as ecology and species); and microbiology (including topics such as classification and antibiotics). PSTs were able to give correct responses to most of the questions that were related to these topics. Examples of these questions can be seen in the excerpt below.

Topic	Question
Molecular and cell biology	*In eukaryotes, the electron transport chain is a series of electron carrier molecules embedded in which organelle?* *A. The smooth endoplasmic reticulum.* *B. The rough endoplasmic reticulum.* *C. The mitochondria.* *D. The Golgi apparatus.*
Zoology/human physiology	*The double membrane surrounding the heart is called the ...* *A. epithelium.* *B. pericardium.* *C. endothelium.* *D. exocardium.*
Environmental studies	*The biosphere is* *A. the gaseous layer that surrounds the earth.* *B. part of the earth's crust.* *C. the layer where are all living organisms are found.* *D. the gaseous layer that surrounds the earth.*
Microbiology	*Bacteria are prokaryotic and belong to the kingdom:* *A. Monera* *B. Fungi* *C. Protista* *D. Plantae*

It is not a surprise that the PSTs were able to answer questions that required factual and conceptual knowledge based on the above topics because the questionnaire that the PSTs completed showed that 9 out of the 15 PSTs who completed the questionnaire had studied molecular and cell biology in their previous degrees. The questionnaire also showed that 10 out of the 15 PSTs who completed the questionnaire had studied human physiology or degrees related to the study of humans in their previous degrees; 9 out of the 15 PSTs had studied ecology or environmental studies; and 9 out of the 15 PSTs had studied microbiology or molecular biology in their previous degrees. What is also significant is that when the PSTs were asked in the questionnaire which topic they felt was the easiest to learn, human physiology was the topic that was mentioned the most as being the easiest to learn. This is in alignment with the above results as the PSTs showed that they were highly capable of answering the questions that focused on content knowledge of human physiology and the highest number of PSTs who completed the questionnaire had studied human physiology in their previous degrees.

The analysis of the questions that students got correct and those they got wrong also showed that most of the questions that PSTs got wrong were based on the broader topics of botany

(including plant physiology, anatomy, genetics, and, classification) and animal physiology (excluding humans). Examples of these questions can be seen in the excerpt below.

Topic	Question
Botany	*True or false:* *Plasmolysis is the pulling away of the cell membrane from the cell wall.*
Animal physiology (excluding humans)	*Which of the following types of skeletons does a snail have?* *A. Endoskeleton.* *B. Hydrostatic skeleton.* *C. Exoskeleton.* *D. Radial skeleton*

The fact that the PSTs incorrectly answered most of the questions that required knowledge of plants and animal physiology (excluding humans) shows a possible lack of knowledge about these topics by the PGCE students. This result aligns with the information gathered from the questionnaire that the PSTs completed which shows that only 6 PSTs out of the 15 who completed the questionnaire had completed a module based on botany during their previous degrees and furthermore, only 6 PSTs out of the 15 had completed a module based on zoology or animal physiology (excluding humans). This shows that there could potentially be a lack of content knowledge in these areas due to the fact that many of the PSTs had not studied plants or animals previously in their degrees.

There were 2 questions among the 4 tests that did not align with the previous results on the PSTs' content knowledge of facts for grades 10 and 11 Life Sciences. These were outliers because the PSTs showed a weakness in their abilities to recall facts based on content knowledge of molecular and cell biology and human physiology despite the fact that the previous trends showed that a great number of the PSTs who completed the questionnaires had studied these topics and the PSTs showed strengths in answering majority of the questions on these topics.

The first outlier question was based on content knowledge of molecular and cell biology (specifically biochemistry) and only 7 out of the 22 PSTs were able to answer this question correctly. This question can be seen below.

The electrons removed from glucose in cellular respiration end up in ...

A. ATP.
B. Heat.
C. Water.
D. Chlorophyll.

The second outlier question was based on content knowledge of human physiology (specifically human respiration) and only 11 out of the 22 PSTs were able to answer this question correctly. This question can be seen below.

What is the order of passage as air is inhaled into the lungs in a typical mammal?

A. nasal cavity, pharynx, larynx, bronchiole, bronchus, trachea, alveolus
B. nasal cavity, pharynx, larynx, trachea, bronchiole, bronchus, alveolus
C. nasal cavity, larynx, pharynx, trachea, bronchus, bronchiole, alveolus
D. nasal cavity, pharynx, trachea, larynx, bronchus, bronchiole, alveolus

Since both of these questions are based on content knowledge of facts on topics that are seen as strengths of the PSTs, these questions are outliers that require deeper levels of recall than the other recall question items in the tests. The first question above is about the complicated biochemical process of cellular respiration. This focus on biochemistry may be difficult for biology focused students. The complexity of the biochemical reactions that take place during cellular respiration may require PSTs to go beyond superficial recall and focus more deeply on their understanding of cellular respiration in order to recall the content about the process of cellular respiration.

The second question above is about respiration in humans however it once more goes beyond superficial factual recall. This question requires students to recall all of the components of the human respiratory system and then recall the order in which air is inhaled through each component. This requires a deeper level of recall than most of the other test items in the tests. Therefore, it can be seen that while these two questions fall under the topics that are seen as strengths, they require a deeper level of factual recall than the other questions in the tests and are therefore more difficult to answer.

Knowledge of history

As mentioned above, only one test (Grade 10 test 2) tested for content knowledge of history. There was only one question in the test however that tested for this aspect of content knowledge and this question belonged to one set of match the columns questions. The question can be seen below.

Match the statements / descriptions in column one with the correct term in column two.

1. A type of dating that involves studying the horizontal layers of extinction sedimentary rock.	*A. background*
2. The oldest living fossil.	*B. relative dating*
3. One of the earliest forms of life found in the Barberton district of Mpumalanga	*C. Bacteria*
4. The animal that is generally accepted as the link between dinosaurs and birds.	*D. Archaeopteryx*
5. The kind of event that is responsible for the greatest loss of large numbers of species.	*E. Coelacanth*
6. The natural rate at which species die out.	*F. Mass extinction*

All 22 PSTs correctly answered items 1, 4, 5 and 6. Least performance was seen with item 2 where only 18 PSTs (which is still a high number) were able to answer correctly. Basing on students' performance on these six items, I can say PSTs showed knowledge of the content on history in Life Sciences. The fact that this was the only question that tested for this aspect of content knowledge for grades 10 and 11 shows that the PSTs were not properly assessed on their content knowledge of history for FET Life Sciences and therefore their strengths and weaknesses on this aspect of content knowledge cannot be confidently confirmed.

Syntactic content knowledge

As mentioned above, there was only one test (Grade 10 test 1) that tested for knowledge of the different aspects of syntactic content knowledge (calculations, experiments and practical equipment). Note that only 20 out of the 22 PSTs completed this test. The results of the analysis of the PSTs' responses to the questions testing for these aspects of syntactic knowledge can be seen below.

Table 15: A comparison of the average number and proportions of correct answers given for each aspect of syntactic content knowledge (total number of questions testing syntactic content knowledge (n) = 4)

Aspect of syntactic content knowledge	**Average number (and proportion %) of students who got correct answers**	**Average number (and proportion %) of students who got incorrect answers**
Calculation (n =1)	15 (75)	5 (25)
Experiment (n = 2)	19 (95)	1 (5)
Practical equipment (n = 1)	18 (90)	2 (10)

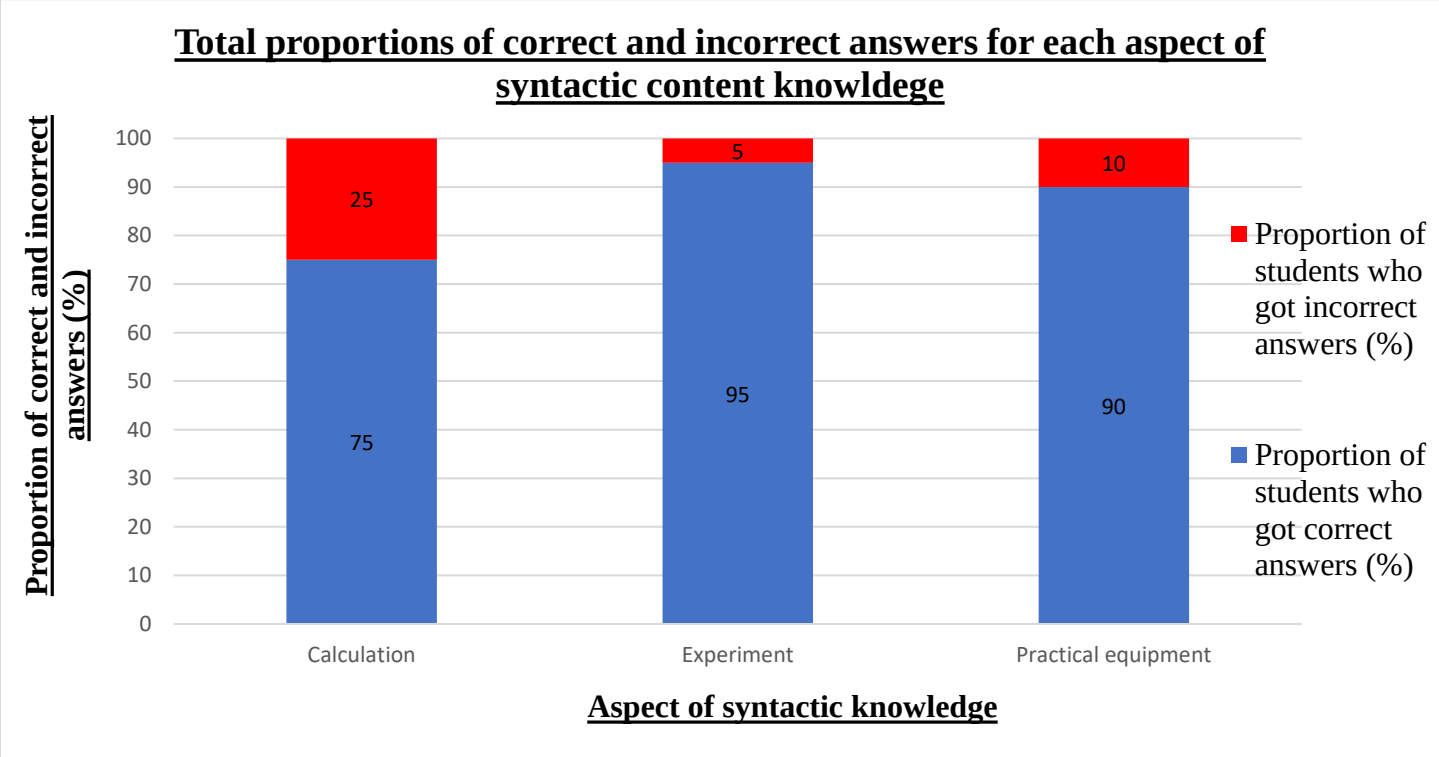


Figure 5: Bar graph showing the total proportions of correct and incorrect answers for each aspect of syntactic content knowledge

Only four questions in Grade 10 test 1 tested for syntactic content knowledge and they were predominantly assessing the cognitive level of remembering. The above results show that the PSTs performed well in these questions. The fact that there were only four questions that tested for syntactic content knowledge for grades 10 and 11 however shows that the PSTs were not properly assessed on this aspect of content knowledge for FET Life Sciences.

The aspects of syntactic knowledge that were tested were calculations, experiments and practical equipment. Most of the PSTs were able to give correct answers to all four questions, however it can be seen that the weakest aspect of content knowledge was calculations which required a higher cognitive level of application of knowledge while their strongest aspect of content knowledge was knowledge of experiments which required factual recall/remembering.

5.2.4 Concluding remarks about the tests and the PSTs' responses to the tests

As mentioned above, all four tests (covering content knowledge of grade 10 and grade 11 Life Sciences) were predominantly testing the cognitive process of remembering. The above results show that the PSTs performed highly in all the four. Despite the fact that the PSTs' were not adequately assessed on their content knowledge of history and syntactic knowledge, the PSTs

performed well in the few questions that covered these aspects. The PSTs therefore showed an overall high performance over all four tests. Although the tests were mostly at factual recall/remembering level, this is a strength on the side of the PSTs because, in the classroom, teachers often need to recall content at a moment's notice depending on what is asked of them by their learners. The PGCE PSTs have therefore shown that they are highly capable of recalling content for grades 10 and 11 Life Sciences. The problem however is that the four tests primarily assessed the first cognitive level of remembering and they did not go further to properly assess the other cognitive levels of Bloom's taxonomy that are equally important for teachers to master. Therefore, in order to properly assess the content knowledge of the PSTs, all of the cognitive levels of Bloom's taxonomy would need to be properly assessed.

As mentioned previously, because of COVID-19, the format of the tests was changed so that the tests could be easily completed online. This may be the reason why the tests consisted of simple questions that predominantly assessed the lowest cognitive level of Bloom's taxonomy. The simplicity of the questions and the online format would also have given the PSTs opportunities to find the correct answers to the questions from their notes or online. Although this was not expected of the PSTs, there was still a possibility that this could have happened. These factors may have contributed to the high marks and therefore the high levels of content knowledge that the PSTs displayed.

5.3 Analysis of the PGCE pre-service teachers' questionnaire answers and presentation of findings

In order to further make sense of the PSTs' content knowledge, I performed further analyses through analysing their questionnaire responses. I performed my analyses in both a quantitative and a qualitative manner in order to further make sense of the knowledge of the PGCE PSTs as well as their perspectives on their content knowledge and their teaching abilities. As mentioned above, 15 PGCE PSTs completed the questionnaire.

5.3.1 Testing the pre-service teachers' abilities to recognise content knowledge and what it is made up of

A question in the questionnaire (see Appendix B, question 10) aimed to assess participants' abilities to recognise what counts as content knowledge. The PSTs were presented with statements linked to the different aspects of substantive content knowledge (facts, concepts, theories and history), syntactic content knowledge (calculations, practical investigations, practical equipment, different perspectives and controversies within the subject) and curricular

knowledge. An example of a statement given is: *knowledge of organic and inorganic molecules* – which is knowledge of facts. For each statement, the PSTs were asked whether the knowledge mentioned in the statement was an aspect of content knowledge or not. The PSTs were also asked to state whether they were sure or not sure of their answers. The results can be seen below.

Table 16: The number of PSTs who correctly identified the presence or absence of content knowledge from each statement

Statement given to the PSTs	Correct answer	Number of PSTs who gave correct answers
Knowledge of organic and inorganic molecules	Yes – Substantive content knowledge	13
Knowledge of links between Natural Sciences (GET) and Life Sciences (FET)	Yes – curricular knowledge	15
Knowledge of cancer is uncontrolled cell division and growth	Yes – Substantive content knowledge	13
Knowledge of the limitations of scientific evidence	Yes – Syntactic content knowledge	12
Knowledge of different ethical opinions about cloning	Yes – Syntactic content knowledge	12
Knowledge of patterns and relationships in data	Yes – Syntactic content knowledge	10
Knowledge of cell theory	Yes – Substantive content knowledge	14
Knowledge of how to use scientific equipment	Yes – Syntactic content knowledge	14
Knowledge of biodiversity of plants	Yes – Substantive content knowledge	15
Knowledge of the procedures and how to safely use apparatus in laboratories and classrooms	Yes – Syntactic content knowledge	15
Knowledge that cells produce food or obtain food from elsewhere	Yes – Substantive content knowledge	15
Knowledge that humans have two systems: nerves and hormones that enable them to respond to the environment.	Yes – Substantive content knowledge	15
Knowledge of the relationships between food intake, energy, growth and health	Yes – Syntactic content knowledge	14
Knowledge of how to use a light microscope to observe cells	Yes – Syntactic content knowledge	13
Knowledge of history of life on Earth	Yes – Substantive content knowledge	14
Knowledge of the theory of Evolution	Yes – Substantive content knowledge	15

From Table 16 above it can be seen that the majority of the PGCE PSTs who completed the questionnaire answered most of the questions correctly and were therefore able to recognise the different aspects of content knowledge as mentioned in the conceptual framework.

PSTs were highly able to recognise substantive knowledge components of concepts, facts, theories and history. This is because, for each statement that made reference to one of these aspects of substantive content knowledge, at least 13 out of the 15 PSTs were able to correctly

answer that these components were aspects of content knowledge. A great number of the PSTs stated that they were sure of their answers to these statements. This therefore shows a strength in their understanding of what makes up substantive content knowledge.

When looking at syntactic content knowledge, the PSTs showed above average abilities in recognising that the different facets of syntactic knowledge as defined by the conceptual framework were components of content knowledge. This is because, for each statement that made reference to one of these aspects of syntactic content knowledge, at least 10 out of 15 PSTs were able to identify that those statements were aspects of content knowledge.

There was one statement in the question that made reference to vertical curricular knowledge and all 15 PSTs were able to identify it as an aspect of content knowledge. This therefore showed strength in the PSTs' abilities to recognise that aspect of content knowledge.

The above analysis show strengths in the ability of PGCE PSTs to recognise what constitutes content knowledge.

5.3.2 Analysis of the pre-service teachers' perspectives and confidence with regards to their content knowledge

In this study, I also decided to assess their confidence levels with regards to life science content knowledge. In the questionnaire, the PSTs were asked a question about their level of confidence in their Life Sciences content knowledge. This question can be seen below.

On a scale of 1 to 5 where one is NOT confident and 5 is VERY confident, how confident are you in your Life Sciences content knowledge?

I noted the different confidence levels of the PSTs by looking at the number of PSTs who responded to the different levels on the scale of 1 to 5. The PSTs' responses to this question can be seen below.

Table 17: Analysis of the PSTs' confidence levels of their Life Sciences content knowledge

Scale level	Number of PSTs (n=15) who responded for this level
1	0
2	1
3	3
4	7
5	4

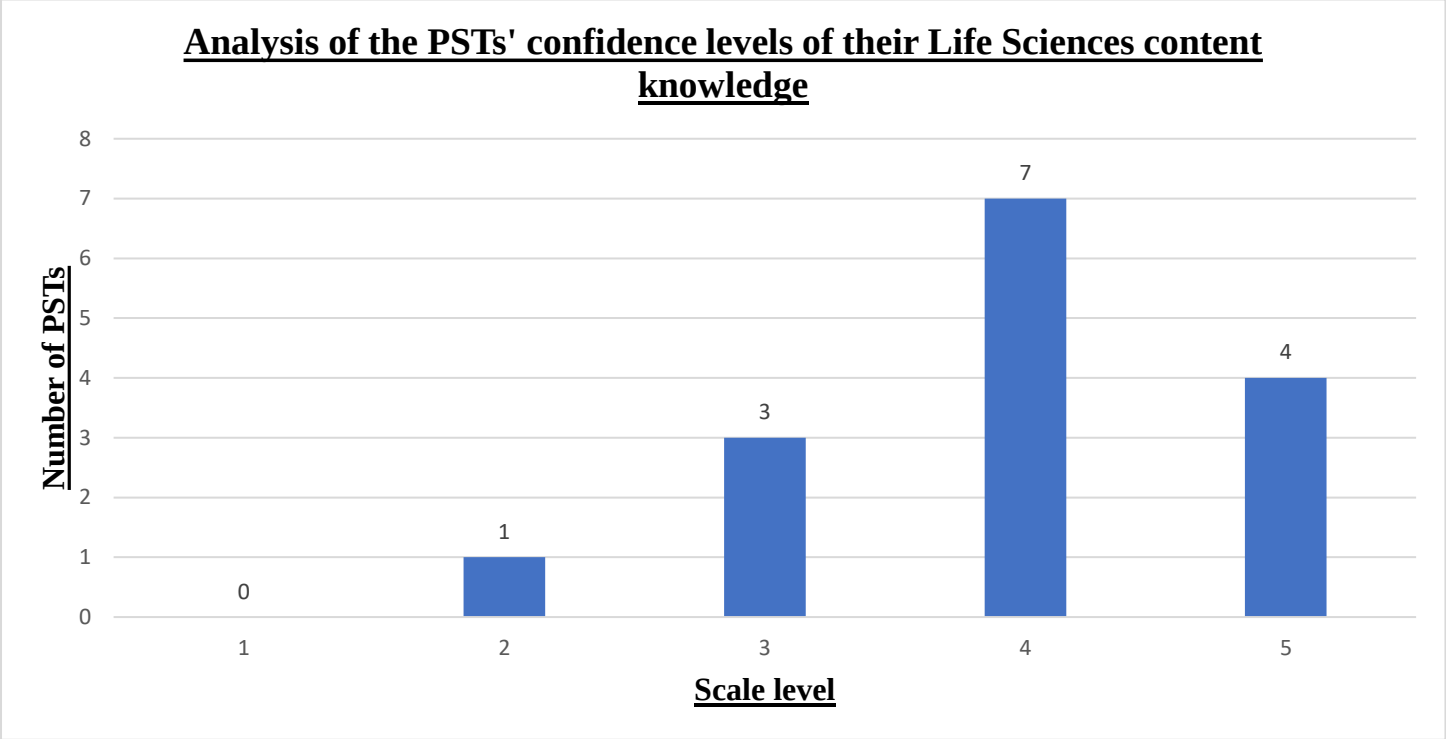


Figure 6: Analysis of the PSTs' confidence levels of their Life Sciences content knowledge

The above answers show that most of the PSTs felt confident in their Life Sciences content knowledge as a significant number of the PSTs who participated (11) showed that their confidence levels were either a 4 or a 5, with majority of the PSTs choosing a confidence level of 4. 3 PSTs stated that their confidence levels were at level 3 which shows an average or neutral level of confidence while only 1 PST stated that their level of confidence was below average at level 2 and no PSTs chose level 1.

In order to further justify this statement, I analysed another question that the PSTs were asked in the questionnaire which was on their preparedness to teach Life Sciences content. The question can be seen below.

Now that you are familiar with the CAPS document, to what extent would you say your first degree prepared you content wise for FET Life Sciences?

The PSTs showed a lot of confidence in their content knowledge when answering this question as 10 out of the 15 PSTs who completed the questionnaire responded to this question with confidence with statements such as:

"It prepared me extremely well (indication of confidence). My first-year biology course essentially covered all major topics in the CAPS document and went more into depth (such as studying the cytoskeleton in addition to cells). My second, third, and honours years went into depth in biodiversity and whole ecosystem ecology. My honours year in particular

taught me about the nature of science and research, which I think will help me develop my future learners' critical thinking (indication of confidence) in the sciences."

"I think it really went beyond the mark (indication of confidence) because it was so detailed and discipline specific, thus I'm able to relate most of the content with what I teach in class (indication of confidence). I'm also able to give learners a bit more than what the textbook says (indication of confidence). It just makes it easier to explain."

"Very much (indication of confidence) as I got used to reading scientific articles so that I do not perpetuate misconceptions that I was taught in school which I found to be incorrect explanations of scientific phenomena"

As can be seen above, as the PSTs were explaining their perspectives on their levels of confidence in their content knowledge, I coded their responses and underlined the specific words or statements that indicated that the PSTs were confident in their content knowledge and their abilities to teach. The above PSTs showed confidence in their content knowledge and abilities to teach by saying that they felt extremely well prepared to teach and that their previous degrees "went beyond the mark" to prepare them to teach. Certain PSTs even went further to mention that they were confident enough in their content knowledge to move beyond teaching only from the textbook and one PST felt that their level of content knowledge would allow them to develop critical thinking in their future learners, while another PST was confident that they understood the content well enough to avoid passing misconceptions on to their learners. These above indicators therefore show that a great number of the PSTs were highly confident in their content knowledge and how that content knowledge would influence their teaching.

Although a great number of the PSTs stated that their previous degrees prepared them well for teaching FET Life Sciences, with one PST saying that they felt "*over prepared",* there were a few PSTs (5 out of the 15 who completed the questionnaire) who did not feel the same way as they answered with statements such as:

"*I believe that my degree prepared me for Life Science content in terms of human anatomy and physiology. However, my degree did not cover plants and animals nor did it cover space. My content knowledge on those topics thus solely depends on my learnt knowledge from high school (indication of lack of confidence).*"

"*Not very much at all (indication of lack of confidence). BSc is so complicated and in depth compared to CAPs doc."*

"With the exception of plant biology, my degree has prepared me quite well. Not 100%, but quite well (indication of lack of confidence)."

As can be seen above, as the PSTs were explaining their perspectives on their levels of confidence in their content knowledge, I coded their responses and underlined the specific

words or statements that indicated that the PSTs were not very confident in their content knowledge and their preparedness to teach. The statements from the above PSTs show that these PSTs felt that their previous degrees did not properly prepare them to teach in terms of content knowledge. The reason for this is that the PGCE PSTs in this study had completed science degrees before moving to the school of education. Most of those science degrees would have focused in depth on specific science topics and they most likely would not have focused on every topic that is taught in FET Life Sciences. Because of this, these PSTs felt that their degrees did not adequately prepare them to teach that content and therefore their confidence levels were not as high as other PSTs. The third statement above specifically indicated a lack of confidence in the topic on botany which is significant as it is in alignment with the results from the test responses.

This explanation links with the above results with regards to the PSTs' test responses as the PSTs who have shown low levels of confidence in their content knowledge have specified that their lack of confidence came from a lack of knowledge on plants and animals. The PSTs made mention of the fact that their degrees did not cover plants and animals and as was seen above, the PSTs performed poorly in questions related to the topics of botany and animals (excluding humans). This therefore further shows that the lack of focus on these topics during the PSTs' academic degrees led to gaps in the PSTs' content knowledge on these topics as well a lack of confidence by the PSTs in their own content knowledge and readiness to teach.

Two interesting responses to note from two PGCE PSTs can be seen below.

"*I have a deeper understanding of most content but it did not prepare me on how to teach"*

"I think I have the content that I need but I am not so confident in teaching that content. I feel like the micro- teaching should have had more than two lesson presentations per student especially PGCE students."

These PSTs emphasised that they had a lack of confidence in their preparedness to teach Life Sciences, however this was not due to a lack of content knowledge but rather pedagogical knowledge. This is important to note as PGCE PSTs may not feel confident in their abilities to teach despite the fact that they feel that their content knowledge may be of a high standard. From these responses, and the above responses, I conclude that majority of the PGCE PSTs felt like their previous degrees prepared them well in terms of content knowledge to teach FET Life Sciences whilst only a small number of PSTs did not feel as prepared or as confident.

5.4 A commentary on the depth of the PSTs' content knowledge

Despite the fact that the PSTs have shown a high level of content knowledge, it is once more important to remember that the content tests given to the PSTs did not cover all of the facets that make up content knowledge. Furthermore, it is important to note that because the PGCE PSTs completed a science-based degree before coming to the WSoE, they did not cover every topic that is taught at FET level for Life Sciences in their previous degrees. Each PST would therefore most likely display a more in-depth level of content knowledge on topics that fall under the content that they covered in their specific previous degrees. As can be seen from the results above, this can lead to strengths in the PSTs' content knowledge when it comes to the content and topics that they did cover in their previous degrees and gaps in the PSTs' content knowledge when it comes to the content and topics that they did not cover in their degrees. This is a challenge when training PGCE PSTs. Despite these challenges, the PSTs still showed a high capability of recalling the content that was assessed in the tests that they submitted. The PSTs' also showed confidence in their content knowledge and teaching abilities when asked about it in the questionnaire.

5.5 Discussion of the results

In this chapter I analysed the pre-service teachers' performance in the four content tests as well as the PSTs' responses to the questionnaire in order to answer my third and fourth sub-questions:

3. What strengths and weaknesses can be seen in the PGCE PSTs' content knowledge of FET Life Sciences?
4. To what extent are PGCE PSTs confident about their content knowledge?

5.5.1 Strengths and weaknesses of the pre-service teachers' content knowledge

The analysis of the PSTs' responses to the content tests showed that overall, the PSTs achieved primarily high marks for all four tests. Considering that the content knowledge that these tests were assessing fell primarily under the lowest cognitive processing level of remembering, the high marks indicated that the PSTs could recall/remember the knowledge about the content that the questions were testing. As mentioned in Chapter 4, PSTs need the ability to teach and assess all six cognitive levels in order to ensure that their future learners develop accordingly and master each level. It is therefore important for the PSTs to be assessed on all six cognitive levels instead of just the first and lowest level.

When looking at the PSTs' strengths and weaknesses, my analysis of the PSTs' performance showed that the PSTs' performance was strongest in the Grade 10 test 2 which tested for content knowledge for terms 3 and 4. The topics that are covered in grade 10 terms 3 and 4 include: transport systems in mammals (human); Biosphere to ecosystems; Biodiversity and classification; and History of Life on Earth. The PSTs' performance was the weakest in the Grade 10 test 1 which tested for content knowledge for terms 1 and 2. The topics that are covered in grade 10 terms 1 and 2 include: The chemistry of Life; Cells: the basic units of life; Cell division: mitosis; Plant and animal tissues; organs; support and transport systems in plant; and support systems in animals.

A further analysis showed that the PSTs showed strengths in their knowledge of molecular and cell biology (which includes topics such as biochemistry, cell structure and function and biotechnology); Zoology – with an emphasis on human physiology (including topics such as the human circulatory system, gaseous exchange in humans, human excretion and human respiration); environmental studies (including topics such as ecology and species); and microbiology (including topics such as classification and antibiotics). It was also seen that the PSTs performed poorly in questions based on the broader topics of botany (including plant physiology, anatomy, genetics, and, classification) and animal physiology (excluding humans). The PSTs also showed strength in their knowledge of the content on history in Life Sciences, however this aspect of content knowledge was not properly assessed. The analysis of the PSTs' syntactic content knowledge showed that the PSTs were able to give correct answers to all four questions on syntactic knowledge that were asked, however the weakest aspect of content knowledge was calculations which required a higher cognitive level of application of knowledge while their strongest aspect of content knowledge was knowledge of experiments which required factual recall/remembering.

These results align with the data as the PGCE students completed science-based degrees before coming to the WSoE and they did not cover every topic that is taught at FET level for Life Sciences in their previous degrees. Each PST would therefore most likely display a more in-depth level of content knowledge on topics that fall under the content that they covered in their specific previous degrees. The above results above show that the PSTs' content knowledge on the topics that they did cover in their previous degrees was strong while there were gaps in the PSTs' content knowledge of the topics that they did not cover in their degrees. This is a challenge when training PGCE PSTs.

5.5.2 PSTs' responses to the questionnaire

The quantitative aspect of the questionnaire aimed to test the PSTs' abilities to recognise the different aspects of content knowledge as mentioned in the conceptual framework. The PSTs were highly able to recognise substantive knowledge components of concepts, facts, theories and history. When looking at syntactic content knowledge, the PSTs showed above average abilities in recognising that the different facets of syntactic knowledge as defined by the conceptual framework were components of content knowledge. There was one statement in the question that made reference to vertical curricular knowledge and all 15 PSTs who completed the questionnaire were able to identify it as an aspect of content knowledge. This therefore showed strength in the PSTs' abilities to recognise that aspect of content knowledge. This analysis therefore showed strengths in the ability of PGCE PSTs to recognise what constitutes content knowledge.

5.5.3 Pre-service teachers' perspectives and confidence with regards to their content knowledge

In this study, I also assessed the PSTs' confidence levels with regards to life science content knowledge. It is important to consider the preparedness and confidence levels of pre-service teachers because the transition from student to teacher can often be disappointing and difficult (Tuner, Jones, Davies & Ramsay, 2004). PGCE PSTs have spent multiple years achieving their previous academic degrees and therefore when they leave university and move to the workplace, they may be overwhelmed by the change and the working environmental may not meet their expectations (Turner *et al.,* 2004). Transitional difficulties may cause anxiety in individuals and it therefore important to understand how the PSTs feel about their abilities before they undergo this transition (Turner *et al.,* 2004). As students enter the school of education, they enter as participants of the community of practice of teaching where, over time, they will learn to develop and demonstrate the knowledge and skills needed to be a teacher (Swabey, Castleton & Penney, 2010). They way in which the PSTs learn and develop in this community will affect the way that PSTs feel about their skills and abilities. Therefore, it is important that the PSTs are properly trained during their teacher preparation programmes (Swabey *et al.*, 2010).

The results showed that most of the PSTs felt confident in their Life Sciences content knowledge as many PSTs responded by saying that they felt extremely well prepared to teach and that their previous degrees "went beyond the mark" to prepare them to teach. There were however a small number of PSTs who felt less confident and stated that they felt unprepared to teach once they are qualified. This links with the above results with regards to the PSTs' test responses as the PSTs who showed low levels of confidence in their content knowledge specified that their lack of confidence came from a lack of knowledge on plants and animals. The PSTs made mention of the fact that their degrees did not cover plants and animals and as was seen above, the PSTs performed poorly in questions related to the topics of botany and animals (excluding humans). This therefore further shows that the lack of focus on these topics during the PSTs' academic degrees led to gaps in the PSTs' content knowledge on these topics as well a lack of confidence by the PSTs in their own content knowledge and readiness to teach.

5.6 Conclusion of the chapter

In this chapter I presented my analysis and results of the PGCE PSTs' tests whilst also making use of answers from the PST questionnaire in order to further understand the content knowledge of the PSTs. From my analyses I was able to answer my third and fourth sub questions and conclude that the PSTs showed a high level of ability to recall content knowledge of facts and concepts for Life Sciences grades 10 and 11 and this is in alignment with their confidence levels and perspectives about their content knowledge and their abilities. It is important however to remember that this analysis only covered the aspects of content knowledge that were assessed in the tests. While knowledge of facts and concepts were extensively assessed, assessment of knowledge of history and syntactic knowledge was limited and knowledge of theories and curricular knowledge were not assessed at all. Therefore, the analysis could not cover and assess every aspect of the PSTs' content knowledge.

Chapter 6

Conclusions and recommendations

This study investigated the content knowledge that the 2020 cohort of PGCE PSTs possessed when they enrolled at the Wits School of Education by analysing the extent to which their content knowledge was assessed, how the PSTs' performed in those assessments, and the PSTs' perspectives about their content knowledge and their preparedness to teach. The problem that motivated this study was that in the PGCE course, PSTs are considered to have mastered the content of their chosen subjects (in their previously completed academic degrees). The content that the PSTs learned in their academic degrees however does not necessarily align with the content that they need to know in order to teach at school level. The purpose of this study was therefore to investigate PGCE PSTs' content knowledge when entering the School of Education and their preparedness to teach at school level in terms of that content knowledge.

Although the content knowledge of PGCE PSTs is assessed at the beginning of the course, their performance in those assessments is often only seen by the lecturer involved in the course (personal communication). This is because the assessments are put in place in order to determine whether the PSTs can continue with the methodology aspect of the course and their performance is not necessarily documented for further purposes (personal communication). As a result, the PSTs' preparedness to teach in terms of their content knowledge has not been properly documented and therefore their abilities to teach FET Life Sciences in terms of their content knowledge has not been determined.

The purpose of this case study was therefore to investigate the content knowledge possessed by PGCE Life Sciences pre-service teachers. This was done by analysing how their content knowledge was assessed, their performance in the assessments as well as their personal perspectives about their content knowledge and their preparedness to teach in terms of content knowledge whilst also observing any issues that may manifest from this process of assessment. The main question guiding this study was: To what extent are PGCE pre-service teachers prepared, in terms of their content knowledge, to teach at FET level?

The sub-questions guiding this study were:

1. What is the content knowledge that pre-service teachers are expected to teach at FET level after qualification?

2. How is the content knowledge that is assessed in the PGCE programme aligned to what the PSTs are expected to teach at FET level?
3. What strengths and weaknesses can be seen in the PGCE PSTs' content knowledge of FET Life Sciences?
4. To what extent are PGCE PSTs confident about their content knowledge?

In this chapter, I answer the research questions above focusing on how the results present insights into the problem.

6.1 Answering sub-question 1 – What is the content knowledge that pre-service teachers are expected to teach at FET level after qualification?

In order to determine the content knowledge that PSTs are expected to teach at FET level after qualification, I performed document analyses (using my conceptual framework as a lens) on the CAPS document for Life Sciences at FET level. I used this document for the document analysis as it provides content as well as the context in which the content for the subject is taught. My analysis of the CAPS document showed that the content knowledge that pre-service teachers are expected to teach at FET level consists mainly of knowledge of facts (for example, organisms interact with other organisms and with the environments in which they live in order to survive and produce offspring); concepts (for example, the concept of genes or atoms); theories (for example, the theory of Evolution); and history (for example, an overview of the history of microscopy) – this is what is called substantive content knowledge. PSTs are also expected to have content knowledge of procedures pointing to the validity of different scientific facts and concepts (for example, the scientific method and practical investigations); different perspectives and controversies on specific topics (for example, Darwin's and Lamarck's different perspectives on the process of natural selection); and controversial topics within the subject (for example, evolution and biotechnology topics) – this is what is called syntactic content knowledge. Since the document analysis showed that these are the categories that should be taught at FET level, PSTs are expected to know the content that falls under these categories in order to teach Life Sciences at FET level.

6.2 Answering sub-question 2 - How is the content knowledge that is assessed in the PGCE programme aligned to what the PSTs are expected to teach at FET level?

The PSTs were given four tests, based on the Life Sciences content for grades 10 and 11 at the beginning of 2020 in order for their content knowledge to be assessed. I analysed these tests in order to determine the specific content knowledge that was being assessed and whether that knowledge that was assessed aligned with the content that the PSTs needed to know in order to teach Life Sciences at FET level. The analysis showed that the tests assessed only certain aspects of substantive and syntactic content knowledge. The substantive knowledge that was covered in the tests included knowledge of facts, concepts and history (however history was only briefly assessed in one test). The syntactic knowledge that was covered in the tests included knowledge of practical investigations, calculations and practical equipment (however syntactic knowledge was only tested in four questions in one test). The aspects of the substantive and the syntactic knowledge that were not covered in the tests were theories (there are not many theories that are taught at FET level), different perspectives and controversies on specific topics and controversial topics within the subject. Therefore, it can be seen that most of the aspects of content knowledge were assessed in the tests at the beginning of the PGCE programme in 2020. However, aspects such as history and syntactic content knowledge (practical investigations, calculations and practical equipment) were not assessed on a wide enough scale and theories and certain aspects of syntactic knowledge (different perspectives and controversies on specific topics and controversial topics within the subject) were not assessed at all. As a result, the content knowledge that was assessed is mostly, but not completely aligned with what the PSTs are expected to teach at FET level.

6.3 Answering sub-question 3 - What strengths and weaknesses can be seen in the PGCE PSTs' content knowledge of FET Life Sciences?

The science-based degrees that the PSTs completed before beginning the PGCE course were specialised with a focus on specific topics within the field (such as cell biology or environmental studies). The PSTs therefore would not have covered every topic of Life Sciences that is taught at FET level. Through the questionnaire that was given to the PSTs, I was able to determine which topics many of the PSTs covered in their previous degrees and which topics many did not cover in their previous degrees. As a result of the specialised nature of their previous degrees, the PSTs showed strengths in content knowledge of the topics that many of them had studied in their previous degrees such as molecular and cell biology; human physiology; environmental studies; and microbiology. It was also seen that the PSTs showed

weaknesses in the topics that many of them did not study in their previous degrees such as botany and animal physiology (excluding humans). Despite the fact that the PSTs displayed certain weaknesses in their content knowledge, overall, my analyses of the PSTs' test responses across all four tests showed a high performance by the PSTs and revealed that the PGCE Life Sciences PSTs have a high level of content knowledge of facts and concepts and a respectable ability to recall content in terms of facts and concepts for Life Sciences grades 10 and 11.

6.4 Answering sub-question 4 - To what extent are PGCE PSTs confident about their content knowledge?

The PSTs' answers to the questionnaire showed that a great number of the PSTs who completed the questionnaire were confident in their content knowledge and felt that their degrees had prepared them well to teach in terms of their content knowledge. Only 5 PSTs showed low levels of confidence and felt that their previous degrees did not properly prepare them in terms of content knowledge to teach. The responses to the questionnaire showed that many of the PSTs who expressed high levels of confidence felt that the in-depth and specialised nature of their degrees gave them a deeper understanding of the content that they would need to teach and allowed them to draw from knowledge beyond what is found in text books. The questionnaire responses also showed that the PSTs who expressed a lack of confidence felt that as a result of the specialised nature of their degrees, they were not properly prepared to teach the topics that were not covered in their specific degrees (such as botany and animal physiology (excluding humans)).

6.5 Answering the main research question and concluding remarks - To what extent are PGCE pre-service teachers prepared, in terms of their content knowledge, to teach at FET level?

The PSTs have shown high levels of performance in their content knowledge and their abilities to recall content of facts and concepts for Life Sciences grades 10 and 11 and this is in alignment with their confidence levels and perspectives about their content knowledge and their abilities. I would therefore conclude to say that when looking overall at the preparedness of the PSTs to teach in terms of the different aspects of content knowledge, the PSTs have shown that they are well prepared to teach content of facts and concepts for grades 10 and 11. However, because the tests only covered certain aspects of content knowledge, their preparedness to teach the aspects that were not assessed in the tests cannot be determined from this investigation. Furthermore, when looking at the preparedness of the PSTs to teach in terms of the cognitive levels of Bloom's taxonomy, the PSTs have shown strength in their abilities to recall or remember content for grades 10 and 11. Since the tests primarily assessed the lowest

cognitive level of remembering, the PSTs' abilities to understand, apply, analyse, evaluate or create content cannot be determined from this investigation. The PSTs' content knowledge for grade 12 was also not assessed and their preparedness to teach grade 12 Life Sciences can therefore not be determined from this investigation.

6.6 Limitations of the study

Due to the COVID-19 pandemic, there were multiple limitations when carrying out this study. The first limitation was in relation to the objective tests that the PSTs were given at the beginning of the PGCE course in 2020. Although it is not known for certain that the pandemic was responsible for the change in structure and format of the tests, the tests were adjusted so that they could be easily completed online. This may be the reason why the tests consisted of simple questions that predominantly assessed factual and conceptual recall - the lowest cognitive level of Bloom's taxonomy. The simplicity of the questions, the online format, and the fact that the PSTs were not invigilated during completion of the tests would also have given the PSTs opportunities to easily find the correct answers to the questions from their notes or online. Although this was not expected of the PSTs, there was still a possibility that this could have happened. These factors may have contributed to the high marks and therefore the high levels of content knowledge that the PSTs displayed.

Since the PSTs are usually on assessed on their content knowledge on grades 10 and 11, my initial plan at the beginning of this study was to create and prepare my own test instruments that would have sufficiently covered and assessed all of the aspects of content knowledge and all of the cognitive levels of Bloom's taxonomy for grades 10, 11 and 12. However, due to the challenges of the pandemic, I was unable to do so. I therefore had to make use of the tests that were already administered to the PSTs in a different context. This is therefore a further limitation in this investigation.

The structure of the tests however was not the only limitation. The fact that there was no face-to-face contact meant that the PSTs could not be assessed on how quickly they were able to recall the content. As mentioned previously, it is important for teachers to have the ability to quickly recall content as learners can ask many questions that would require instant recall from a teacher. As the PSTs completed the tests online with no supervision, their speed at recalling content could not be determined.

A further limitation was my inability to communicate with the participants of this study in a face-to-face manner. Most communications with the participants occurred through email where

I would have to wait for the PSTs to respond to me. This was a time-consuming process and many PSTs who had signed consent forms and agreed to complete the questionnaire did not respond. I originally planned to conduct focus group interviews with the PSTs in order to gain a further understanding of their content knowledge, however, due to the pandemic, the online nature of a questionnaire was favourable. A questionnaire can be limiting however as the PSTs do not have the same ability to engage in discussion as they would with a semi-structured focus group interview.

6.7 Recommendations

The simplified nature of the tests resulted in the primary assessment of the PSTs' abilities to recall content, meaning that the lowest cognitive level of Bloom's taxonomy was mostly assessed in these tests while the other levels were either only briefly assessed or not assessed at all. In addition, the aspects of content knowledge that were primarily assessed were facts and concepts while history and certain aspects of syntactic content knowledge were only briefly assessed and theories and other aspects of syntactic knowledge were not assessed at all. I would therefore recommend that future assessments are made more complex by including long answer and essay questions in addition to the multiple choice, fill in the blanks, match the columns, and true or false questions that were asked in these assessments. It is understandable that higher order and long questions increase the demands of marking the tests, and if one lecturer is marking all of the tests then the demands may be too great. However, the demand of marking should not determine the complexity of the tests. I further recommend that that the institution provide assistance to lecturers in marking these tests so that the tests are set with assessment criteria in mind and not with marking demands in mind. I give this recommendation because knowing if the PGCE candidates are adequately prepared to teach in terms of CK is crucial in any institution and more complex, higher order tests can aid in investigating that content knowledge.

I would also recommend that the tests are structured so as to include questions that assess PSTs thoroughly on all of the cognitive levels of Bloom's taxonomy and all of the aspects of substantive and syntactic content knowledge. In this manner, one can more comprehensively determine the content knowledge of the PSTs for FET Life Sciences and therefore their preparedness to teach once they have qualified.

As mentioned above, it is not certain that the tests were changed to an online format because of the pandemic. PGCE lecturers may have changed the format in order to accommodate larger

numbers of PSTs and for ease of marking. I therefore recommend that if the tests continue to be administered online then the PSTs should complete the tests on campus, in a computer lab where they can be invigilated. In this way, the PSTs will not be able to search on the internet for answers to the questions and high performances will therefore not be doubted or assumed to have been achieved by cheating.

6.8 Reflections on the research process

From this study, I learned valuable information with regards to the complexities of content knowledge and how it is assessed. Before this study, I had a limited understanding of what makes up content knowledge of a science subject. I thought that it was only made up of facts, concepts and theories. I essentially thought that content knowledge was made up of the content found in textbooks. I therefore thought only of substantive content knowledge when considering the aspects of content knowledge. During my research however, I learned about syntactic content knowledge and its components as well as curricular knowledge. I learned that knowledge of procedures pointing to the validity of different scientific facts and concepts and therefore the ability to perform scientific experiments, knowledge of how to use scientific equipment and knowledge of how to complete calculations are aspects of content knowledge. I also learned that content knowledge further includes knowledge of different perspectives and controversies on specific topics (for example, Darwin's and Lamarck's different perspectives on the process of natural selection); knowledge of controversial topics within the subject (for example, evolution and biotechnology topics) and knowledge of the Life Sciences FET curriculum as a connected continuum as well as curricula from other subjects that may link with Life Sciences content. This knowledge allowed me to reflect that content knowledge is more complex than one may initially think and it is vital for teachers to understand and be able to teach every aspect of content knowledge, including those that may not appear to be obvious aspects of content knowledge.

My analysis of the CAPS document showed me that not every aspect of syntactic content knowledge (such as debates and arguments among scientists, newly discovered phenomena, and application of Life Sciences knowledge in the industry in respect of career opportunities and in everyday life knowledge) can be included in the CAPS document. The reason that these are not included in the CAPS document is because science is ever changing and evolving and as it expands and evolves, so do the debates and career opportunities. Furthermore, just as with COVID-19, new phenomena are occurring continuously and the CAPS document cannot

change each time science evolves. I had thought that new teachers would need every aspect of content knowledge to be included in the CAPS document so as to give them guidance, however the absence of these aspects gives teachers the opportunity to be proactive and gain the ability to keep up to date and find this information for themselves.

I further learned how deeply one has to think when creating tests in order to assess content knowledge. One would need to design an assessment that includes and properly assesses each aspect of content knowledge as well as all of the cognitive levels of Bloom's taxonomy. This is difficult to achieve and requires thought and hard work. It is only once one breaks down and analyses each assessment that one can see what is present and what is missing. Therefore, in the process of doing my research, I have learnt a lot about content knowledge and why it is important for teachers to be lifelong learners.

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Appendix A

Coded objective Tests

Grade 10 content test 1 (terms 1 and 2)

Codes:
Fact
Concept
Theory
History
Experiment
Practical equipment
Calculation

Bloom's taxonomy codes:
Remembering
Understanding
Applying
Analysing
Evaluating
Creating

Part 1: Multiple Choice

1. Which of the following is used as a test for glucose? (**Experiment**) (**Remembering**)
   A. Ether
   B. Benedict's solution
   C. Iodine solution
   D. Millon's reagent

2. Which of the following is used as a test for proteins? (**Experiment**) (**Remembering**)
   A. Ether
   B. Benedict's solution
   C. Iodine solution
   D. Millon's reagent

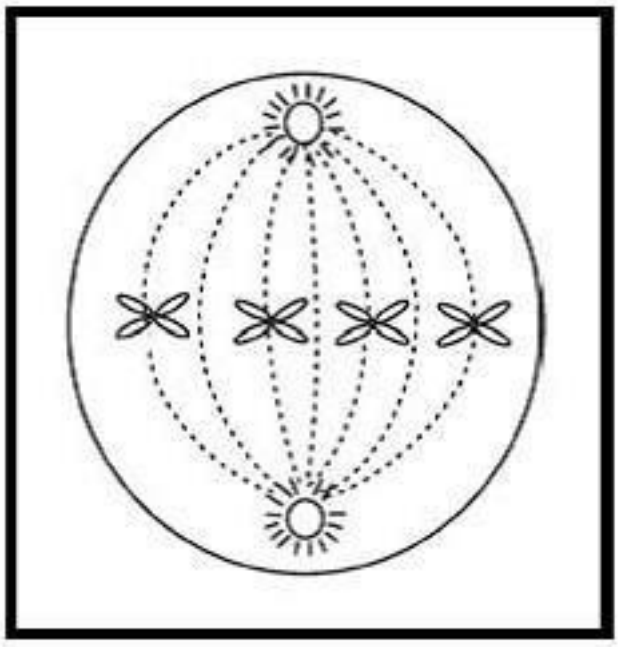
3. The instrument that allows you to magnify a cell 50000x is called: (**Practical equipment**) (**Remembering**)
   A. a light microscope.
   B. an electron microscope.
   C. a dissecting microscope.
   D. a hand lens.

4. Each new cell produced by mitosis will have... (**Fact**) (**Remembering**)
   A. half the number of chromosomes.
   B. a full set of chromosomes.
   C. twice the number of chromosomes.
   D. two new nuclei.

5. Which of the following is NOT a function of mitosis? (**Fact**) (**Remembering**)
   E. Growth.
   F. Repair.
   G. Asexual reproduction in unicellular organisms.
   H. The formation of sex cells.

6. If a cell divides by mitosis, how many cells will there be after three divisions? (Calculation) **(Applying)**
   A. 3 cells.
   B. 4 cells.
   C. 8 cells.
   D. 16 cells.

6. Study the following diagram. The chromosome number of the cell is… (**Fact**) (Understanding)



   A. 2.
   B. 4.
   C. 6.
   D. 8.

8. The centromere is a region in which... (**Fact**) (**Remembering**)
   A. chromatids remain attached to one another until anaphase.
   B. metaphase chromosomes become aligned at the metaphase plate.
   C. chromosomes are grouped together during telophase.
   D. the nucleus is located prior to mitosis.

9. The organelles that synthesize proteins are called… (**Fact**) (**Remembering**)
   A. ribosomes.
   B. mitochondria.
   C. chloroplasts.
   D. nucleoli.

10. What important biomolecule is composed of a sugar, a phosphate and a nitrogenous base? (**Fact**) (**Remembering**)
   A. An amino acid.
   B. A nucleotide.
   C. A saturated fat.
   D. A quaternary protein.

11. Which of the following shows the correct sequence of tissues through which water moves from the soil to the root? (**Concept**) (**Remembering**)
   A. Root hair, cortex, phloem, xylem.
   B. Root hair, pericycle, cortex, endodermis, xylem.
   C. Epidermis, cortex, endodermis, pericycle, xylem.
   D. Epidermis, cortex, xylem, phloem.

12. Which structure is incorrectly paired with its tissue system? (Concept) (Remembering)
    A. root hair - dermal tissue
    B. palisade parenchyma - ground tissue
    C. guard cell - dermal tissue
    D. companion cell - ground tissue

13. Which of the following have unevenly thickened primary walls that support young, growing parts of the plant? (Fact) (Remembering)
    A. Parenchyma cells.
    B. Collenchyma cells.
    C. Tracheids and vessel elements.
    D. Sieve-tube elements.

14. Which is the most important force causing water to rise up the xylem vessels in plants? (Concept) (Remembering)
    A. Root pressure.
    B. Cohesion forces.
    C. Transpiration pull.
    D. Capillarity.

15. Which of the following types of skeletons does a snail have? (Concept) (Remembering)
    A. Endoskeleton.
    B. Hydrostatic skeleton.
    C. Exoskeleton.
    D. Radial skeleton

16. Which of the following does not form part of the axial skeleton? (Concept) (Remembering)
    A. Skull
    B. Clavicle
    C. Sternum
    D. Vertebrae
17. The smallest unit of muscle contraction is the... (Fact) (Remembering)
    A. sarcolemma.
    B. sarcoplasm.
    C. sarcomere.
    D. sacrofibril.

Part 2: Matching

Cell Organelles (Concept) (Remembering)

A. Cell wall
B. Cell membrane
C. Nucleus
D. Cytoplasm
E. Chloroplast
F. Mitochondrion
G. Vacuole

For each of the items below, select the most appropriate answer option(s) above. Each answer option may be used once, more than once, or not at all.

1. The name of the part where anaerobic respiration occurs_____
2. The organelle in which aerobic respiration occurs_____
3. The organelle that contains chlorophyll _____
4. The organelle that keeps the cell turgid and stores salts _____
5. The living boundary of the cell that controls the movement of substances into and out of the cell. _____
6. Plays a part in heredity and controls all the functions of the cell._____

1. Vacuoles or vesicles that contain enzymes that break down old or dead cells.	A. Endocytosis
2. The study of cells and tissues.	B. Phospholipids.
3. Organelles that refine proteins and package them to be transported	C. Casparian strip.
4. Mammalian tissue that has become specialized as a storage tissue	D. Histology
5. A transport process that involved bulk movement of material into the cell.	E. Golgi apparatus
6. A waxy waterproof band in the cell walls of the cells of the endodermis.	F. Lysosomes.
7. A major structural component of cell membranes.	G. Meristematic tissue.
8. Tissue consisting of cells that can differentiate to form various tissue types.	H. Adipose tissue.

Part 3: Matching (Concepts) (Remembering)

Match the statements / descriptions in column one with the correct term in column two.

Part 4: True or false
For each statement: state weather it is true or false

Osmosis is the movement of water molecules through a selectively permeable membrane from a region of low water potential to a region of high-water potential. (**Concept**) (**Remembering**)

Plasmodesmata are small strands of cytoplasm that pass through the cell walls and connect the cytoplasm of adjoining cells. (**Fact**) (**Remembering**)

Plasmolysis is the pulling away of the cell membrane from the cell wall. (**Fact**) (**Remembering**)

Root pressure develops as a result of osmosis. (**Fact**) (**Remembering**)

Ring barking is destructive process that removes xylem and subsequently causes the tree to die. (**Concept**) (**Remembering**)

The main difference between woody and herbaceous dicotyledons is the activity of the vascular cambium. (**Fact**) (**Remembering**)

A plant will wilt faster on a hot, still day than a hot, windy day. (**Fact**) (**Understanding**)

Grade 10 content test 2 (terms 3 and 4)

Codes:
Fact
Concept
Theory
History
Experiment
Practical aspect
Calculation

Bloom's taxonomy codes:
Remembering
Understanding
Applying
Analysing
Evaluating
Creating

Part 1: Multiple choice

1. The blood vessel that carries oxygenated blood from the lungs to the heart is the... (**Fact**) (**Remembering**)
   A. Pulmonary artery
   B. Aorta
   C. Inferior vena cava
   D. Pulmonary vein

2. Which of the following is the correct sequence of blood flow in mammals? (**Concept**) (**Remembering**)
   A. Vena cava - right atrium - right ventricle - pulmonary circuit.
   B. Left ventricle - aorta - lungs - systemic circulation.
   C. Pulmonary vein - left atrium - left ventricle - pulmonary circuit.
   D. Right atrium - pulmonary artery - left atrium - ventricle.

3. The tissue layer common to all blood vessels is... (**Fact**) (**Remembering**)
   A. circular smooth muscle.
   B. longitudinal, striated muscle.
   C. endothelium.
   D. connective tissue.

4. Veins do not require thick walls... (**Fact**) (**Remembering**)
   A. as they do not have to work hard.
   B. they are required only occasionally.
   C. blood pressure declines as it gets into veins.
   D. blood pressure increases as it gets into veins.

5. Damage to the sinoatrial node in humans ... (**Fact**) (**Understanding**)
   A. is a major contributor to heart attacks.
   B. would block conductance of the Purkinje fibres.
   C. would disrupt the rate and timing of cardiac muscle contractions.
   D. would have a direct effect on the blood pressure monitors in the aorta.

6. The set of blood vessels with the lowest velocity of blood flow is ... (**Fact**) (**Remembering**)
   A. the arteries.
   B. the arterioles.
   C. the veins.
   D. the capillaries.

7. A component of blood that is involved in clotting is called… (Fact) (Remembering)
   A. blood plasma.
   B. red blood cells.
   C. blood platelets.
   D. white blood cells.

8. The left atrium receives oxygenated blood from the... (Fact) (Remembering)
   A. right atrium.
   B. lungs.
   C. left ventricle.
   D. right atria.

9. The double membrane surrounding the heart is called the ... (Fact) (Remembering)
   A. epithelium.
   B. pericardium.
   C. endothelium.
   D. exocardium.

10. The best definition of an ecosystem is: (Concept) (Remembering)
A. The community of plants and animals that live in a particular area, and the interactions between them and the environment.
B. The place where animals and plants co-exist.
C. A small area where animals rely on each other to survive.
D. The mix of abiotic and biotic factors in a trophic level.

11. Migration and hibernation are most common in which two biomes? (Fact) (Remembering)
   A. deciduous forest and desert
   B. tropical rain forest and arctic tundra
   C. arctic tundra and desert
   D. deciduous forest and arctic tundra

12. The biosphere is (Concept) (Remembering)
   A. the gaseous layer that surrounds the earth.
   B. part of the earth's crust.
   C. the layer where are all living organisms are found.
   D. the gaseous layer that surrounds the earth.

13. The variety of life across the biosphere is called: (Concept) (Remembering)
   A. Biodiversity
   B. Biomes
   C. Ecosystems
   D. Ecology

14. A group of organisms that have the same structure and can reproduce with one another are considered to be (Fact) (Remembering)
   A. order.
   B. family.
   C. genus.
   D. species.

15. Although the same species may have the same basic structure, variations exist within the same species. Variations among members of a population are referred to as …(Concept) (Remembering)
   A. biotic diversity
   B. species diversity
   C. genetic diversity
   D. living diversity

16. Bacteria are prokaryotic and belong to the kingdom: (Fact) (Remembering)
   B. Monera
   C. Fungi

D. Protista
E. Plantae

17. How is natural selection in the evolution of long necks in giraffes best explained? (**Concept**) (Understanding)
A. Shorter-necked giraffes were killed by long-necked giraffes.
B. Giraffe necks grew longer because of the bone structure of the animals.
C. Giraffes with longer necks survived because they were better suited to the environment.
D. Long-necked giraffes mated only with other long-necked giraffes.

Part 2: Matching (Concept) (Remembering)

Match the statements / descriptions in column one with the correct term in column two.

1. Linked food chains showing the energy flow in an ecosystem	A. Biome.
2. A measure of the variety of different animal and plant species in an area.	B. Food web
3. Extremely high levels of nutrients in a river leading to increased algal growth.	C. Global warming
4. The rise in average temperature of the earth.	D. Deforestation
5. The removal of many trees from a forested area to plant crops.	E. Eutrophication
6. A large area consisting of many ecosystems.	F. Biodiversity

Part 3: Matching (History) (Remembering)

Match the statements / descriptions in column one with the correct term in column two. (History)

1. A type of dating that involves studying the horizontal layers of extinction sedimentary rock.	A. background
2. The oldest living fossil.	B. relative dating
3. One of the earliest forms of life found in the Barberton district of Mpumalanga	C. Bacteria
4. The animal that is generally accepted as the link between dinosaurs and birds.	D. Archaeopteryx
5. The kind of event that is responsible for the greatest loss of large numbers of species.	E. Coelacanth
6. The natural rate at which species die out.	F. Mass extinction

Grade 11 content test 1 (terms 1 and 2)

Codes:
Fact
Concept
Theory
History
Experiment
Practical aspect
Calculation

Bloom's taxonomy codes:
Remembering
Understanding
Applying
Analysing
Evaluating
Creating

Part 1: Multiple choice

1. A prophage is a(n)... (**Fact**) (**Remembering**)
   A. virus that infects bacteria.
   B. phage genome that has been integrated into a bacterial cell's chromosome.
   C. viral genome that has been incorporated into a bacterial cell's chromosome.
   D. emerging virus that infects fungi.

2. How do retroviruses such as HIV differ from other viruses? (**Fact**) (**Understanding**)
   A. They contain DNA that is used as a template to make RNA.
   B. They can reproduce only inside living cells.
   C. They have much simpler reproductive cycles than other RNA viruses.
   D. They contain the enzyme reverse transcriptase.

3. An antibiotic is a drug that selectively kills... (**Fact**) (**Remembering**)
   A. viruses.
   B. bacteria.
   C. fungi.
   D. viruses and bacteria.

4. The main function of cellular respiration is... (**Fact**) (**Remembering**)
   A. to break down toxic molecules.
   B. to synthesize macromolecules from monomers.
   C. to extract usable energy from glucose.
   D. to extract CO2 from the atmosphere.

5. An electron carrier acts as an energy storage molecule when it is... (for example, ...) (**Concept**) (**Remembering**)
   A. reduced; NAD
   B. oxidised; NAD
   C. reduced; NADH
   D. oxidised; FADH2

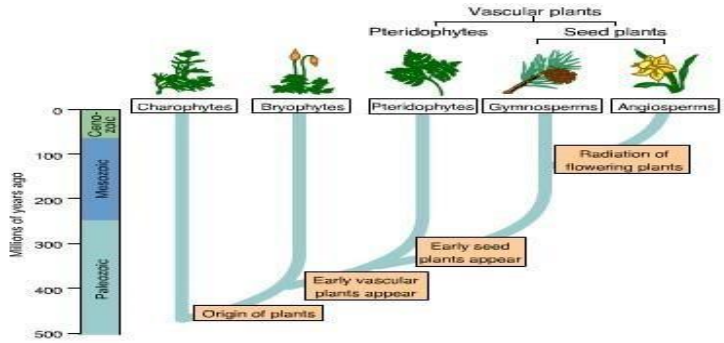
6. In eukaryotes, the electron transport chain is a series of electron carrier molecules embedded in which organelle? (**Fact**) (**Remembering**)
   A. The smooth endoplasmic reticulum.
   B. The rough endoplasmic reticulum.
   C. The mitochondria.
   D. The Golgi apparatus.

7. During respiration in a eukaryotic cell, reactions of glycolysis occur... (**Concept**) (**Remembering**)
   A. in the cytosol.
   B. on the inner mitochondrial membrane.
   C. within the nucleus.
   D. across the inner membrane of the mitochondrion.

8. The electrons removed from glucose in cellular respiration end up in ... (**Fact**) (**Remembering**)
   A. ATP.
   B. Heat.
   C. Water.
   D. Chlorophyll.

9. What is the name of the process in which pyruvic acid is converted to lactic acid? (**Concept**) (**Remembering**)
   A. Aerobic respiration.
   B. Glycolysis.
   C. Fermentation.
   D. Kreb's cycle.

10. According to this phylogenetic tree below, angiosperms are most closely related to... (**Fact**) (Understanding)



   A. Charophytes.
   B. Bryophytes
   C. Pteridophytes
   D. Gymnosperms.

11. Pollination is the transfer of pollen grains to the _____ of a flower on the same plant or another plant of the same species. (**Concept**) (**Remembering**)
   A. stigma
   B. anther
   C. stamen
   D. style

12. Vascular tissues of plants include ... (**Fact**) (**Remembering**)
   A. xylem for conducting sugars, and phloem for conducting water and minerals.
   B. lignin for conducting organic molecules, and phloem for conducting sugars.
   C. xylem for conducting water and minerals, and phloem for conducting sugars.
   D. phloem for conducting water and minerals, and lignin for conducting sugars.

13. Bryophytes are small because... (**Fact**) (**Remembering**)
   A. they exist in areas of limited nutrients.
   B. they reproduce by spores.
   C. they lack vascular tissue.
   D. they evolved in moist areas.

14. Alternation of generations... (**Concept**) (**Remembering**)
   A. is unique to plants.

B. consists of a diploid gametophyte stage alternating with a haploid sporophyte stage.
C. occurred only in extant plants, between stages with similar appearance.
D. consists of a haploid gametophyte stage and a diploid sporophyte stage.

15. Unlike most angiosperms, grasses are pollinated by wind. Consequently, unnecessary parts of typical flowers have almost disappeared in grasses. Which of the following would you expect to be most reduced in a grass flower? (**Concept**) (**Applying**)
A. anthers
B. stamens
C. ovaries
D. petals

16. Which one of the following best describes the function of fruits? (**Concept**) (**Remembering**)
A. To protect and disperse the seeds.
B. To reward pollinators.
C. To store food for the germinating plant to use.
D. To distract herbivores from eating the leaves.

17. The evolutionary advance that made possible the colonisation of dry environments by seed plants is most likely the evolution of ... (**Concept**) (**Remembering**)
A. seeds.
B. ovules.
C. pollen.
D. fruit.

18. The animal phylum most like the protists that gave rise to the animals is... (**Fact**) (**Remembering**)
A. Echinodermata.
B. Cnidaria.
C. Platyhelminthes
D. Porifera.

19. Consider the following list of animals: squid, earthworm, largemouth bass, snail, tapeworm, coral, sea star. The two that belong to the same phylum are the ...., and this phylum is ... (**Fact**) (**Remembering**)
A. bass and squid; Chordata.
B. coral and sea star; Echinodermata.
C. squid and snail; Mollusca.
D. snail and coral; Annelida.

20. The phylum .... includes the largest number of species. (**Fact**) (**Remembering**)
A. Mollusca
B. Arthropoda
C. Chordata
D. Echinodermata

21. In arthropods, moulting is necessary because... (**Fact**) (**Remembering**)
A. arthropod appendages generally increase in number as the animal ages.
B. the environment degrades the exoskeleton, which must therefore be shed and replaced.
C. the exoskeleton cannot grow and must be replaced as the organism grows.
D. the exoskeleton is progressively resorbed by body tissue.

22. A distinguishing feature of vertebrates is the presence of ... (**Fact**) (**Remembering**)
A. a post-anal tail.
B. a gastrovascular cavity.
C. segmentation.
D. a backbone.

23. The synthesis of glucose by photosynthesis requires energy. The source of energy for the excited electrons is... (**Fact**) (**Remembering**)
A. chlorophyll.
B. water.

C. light.
D. glucose.

24. In photosynthesis, what is the fate of the oxygen atoms present in CO2? (**Concept**) (**Remembering**)
A. They end up in water.
B. They end up in sugar molecules and water.
C. They end up in sugar molecules.
D. They end up released as O2.

25. What effect does photosynthesis have on the greenhouse effect? (**Concept**) (**Remembering**)
A. It reduces atmospheric CO2 and thus reduces greenhouse warming.
B. It increases atmospheric CO2 and thus reduces greenhouse warming.
C. It has no impact on the greenhouse effect.
D. It reduces atmospheric CO2 and thus increases greenhouse warming.

26. Identify the correct statement about nutrition and digestion. (**Concept**) (**Remembering**)
A. Feeding and "digestion" are synonyms.
B. Chemical digestion precedes mechanical digestion.
C. Absorption involves nutrients passing through intestinal walls.
D. Elimination rids the body of overly large nutrient molecules.

27. Enzymes play a direct role in... (**Fact**) (**Remembering**)
A. ingestion.
B. chemical digestion.
C. peristalsis.
D. emulsification.

28. Intracellular digestion occurs within... (**Fact**) (**Remembering**)
A. digestive sacs.
B. digestive tubes.
C. food vacuoles.
D. mitochondria.

29. A mutation in the genes for salivary amylase will greatly affect the chemical digestion of ... (**Fact**) (**Remembering**)
A. proteins.
B. fats.
C. carbohydrates.
D. nucleic acids.

30. The largest variety of digestive enzymes function in the ... (**Fact**) (**Remembering**)
A. oral cavity.
B. stomach.
C. small intestine.
D. large intestine.

Grade 11 content test 2 (terms 3 and 4)

Codes:
Fact
Concept
Theory
History
Experiment
Practical aspect
Calculation

Bloom's taxonomy codes:
Remembering
Understanding
Applying
Analysing
Evaluating
Creating

Part 1: Multiple choice

1. In insects, most gaseous exchange occurs at... (**Fact**) (**Remembering**)
   A. the body surface.
   B. the tips of the tracheal tubes.
   C. the gills.
   D. the aveoli of the lungs.

2. In human lungs, gas exchange occurs at the … (**Fact**) (**Remembering**)
   A. two bronchi.
   B. pleural sacs.
   C. alveolar sacs.
   D. trachea.

3. Which of the following normally contains the highest concentration of oxygen? (**Fact**) (**Remembering**)
   A. inhaled air
   B. air in the alveoli
   C. body cells
   D. air leaving the lungs

4. What is breathing? (**Concept**) (**Remembering**)
   A. Transport of gases by the circulatory system.
   B. The exchange of gases between the circulatory system and interstitial fluid.
   C. The exchange of gases in mitochondria.
   D. The exchange of gases in the lungs.

5. In order for a body surface to be a respiratory surface, it must be... (**Fact**) (**Remembering**)
   A. thin and moist.
   B. moist and glandular.
   C. thick, dry, and covered with hair.
   D. expansive.

6. What is the order of passage as air is inhaled into the lungs in a typical mammal? (**Fact**) (**Remembering**)
   A. nasal cavity, pharynx, larynx, bronchiole, bronchus, trachea, alveolus
   B. nasal cavity, pharynx, larynx, trachea, bronchiole, bronchus, alveolus
   C. nasal cavity, larynx, pharynx, trachea, bronchus, bronchiole, alveolus
   D. nasal cavity, pharynx, trachea, larynx, bronchus, bronchiole, alveolus

7. Bowman's capsule, the start of the tubular part of the nephron, is located in the... (**Fact**) (**Remembering**)
   A. renal cortex.
   B. renal pelvis.
   C. renal artery.
   D. renal medulla.

8. Fluid that enters Bowman's capsule flows directly into the... (**Fact**) (**Remembering**)
   A. renal artery.
   B. proximal tubule.
   C. distal tubule.
   D. loop of Henle.

9. Blood pressure forces water and small solutes into the Bowman's capsule during... (**Fact**) (**Remembering**)
   A. glomerular filtration.
   B. tubular reabsorption.
   C. tubular secretion.
   D. both a and c.

10. Kidneys return most of the water and small solutes back to the blood by way of... (**Concept**) (**Remembering**)
   A. glomerular filtration.
   B. tubular reabsorption.
   C. tubular secretion.
   D. both A and B.

11. ADH binds to receptors on distal tubules and collecting ducts, making them ... permeable to... (**Fact**) (**Remembering**)
   A. more; sodium.
   B. less; sodium.
   C. less; water.
   D. more; water.

12. To determine the human population density of your community, you would need to know the number of people living there and ... (**Concept**) (**Remembering**)
   A. the birth rate of the population.
   B. the size of the area in which they live.
   C. the dispersion pattern of the population.
   D. the carrying capacity.

13. Pine trees in a forest tend to shade and kill pine seedlings that sprout nearby. This causes the pine trees to ... (**Fact**) (Understanding)
   A. increase exponentially.
   B. grow in a clumped pattern.
   C. grow in a uniform pattern.
   D. grow in a random pattern.

14. The dispersion pattern of a population refers to... (**Concept**) (**Remembering**)
   A. the distribution of resources within the environment.
   B. the social interactions among population members.
   C. the spatial distribution of species.
   D. the spatial distribution of individuals.

15. When birth rate equals death rate, _____. (**Fact**) (**Remembering**)
   A. a population grows rapidly.
   B. density-dependent limiting factors do not affect the population.
   C. the size of a population remains constant.
   D. a population is in danger of extinction.

16. A newly mated queen ant establishes a nest in an unoccupied patch of suitable habitat. Assuming that no disasters strike the nest, which type of equation is likely to best describe its population growth? (**Concept**) (**Understanding**)
   A. linear
   B. logistical
   C. circular
   D. quadratic

17. No population can grow indefinitely. The ultimate size of any population is limited by… (**Concept**) (**Remembering**)
   A. its mortality rate.
   B. its birth rate.
   C. reproductive isolation.
   D. the carrying capacity of its environment.

18. Which one of the following would most likely be an example of an abiotic factor that limits population growth? (**Concept**) (**Understanding**)
   A. food availability
   B. diseases
   C. daily temperature extremes
   D. parasites

19. Chimpanzees have a relatively low birth rate. They take good care of their young, and most chimps live a long life. The chimp survivorship curve would look like ... (**Concept**) (**Understanding**)
   A. a line that slopes gradually upward.
   B. a relatively flat line that drops steeply at the end.
   C. a line that drops steeply at first, then flattens out.
   D. a line that slopes gradually downward.

20. What is the ultimate source of energy for nearly all surface terrestrial and shallow water ecosystems? (**Fact**) (**Remembering**)
   A. water
   B. organic compounds
   C. sunlight
   D. hydrothermal vents.

Part 2: Matching

Match the statements/descriptions in column 1 with the correct term in column 2 (**Concept**) (**Remembering**)

1. Two species interact and both species benefit from the interaction	A. Predation
2. Two species interact and one benefits while the other is not harmed nor helped	B. Mutualism
3. Two species attempt to use the same resource	C. Commensalism
4. One species feeds on another but usually does not kill it	D. Parasitism
5. One free-living species feeds on another and usually kills it	E. Interspecific competition

Part 3: Matching (Concept) (Remembering)

Match the statements / descriptions in column one with the correct term in column two.

1. Opportunistic colonizer of barren or disturbed habitat	A. Geographical dispersal
2. Array of species at the end of successional stages in a habitat	B. Pioneer species
3. One species outcompetes a rival with the same resource needs, driving it to extinction	C. Climax community
4. The scientific study of how species are distributed in the natural world	D. Competitive exclusion
5. Individuals leave their home range, become established elsewhere	E. Biogeography

Appendix B

Questionnaire

The purpose of this questionnaire is to find out to what extent you feel you are prepared to teach FET Life Sciences next year after your qualification.

1. When did you complete your first degree?
2. What is the name of your first degree?
3. What are the Life Sciences topics/courses that you covered during your first degree?
4. Which topic would you consider to be the most difficult to learn?
5. Which topic would you consider to be the easiest to learn?
6. Do you find it easy or difficult to learn the content of a new topic? Please elaborate on your answer.
7. What did you do after your first degree if you did not enrol immediately for PGCE?
8. Now that you are familiar with the CAPS document, to what extent would you say your first degree prepared you content wise for teaching FET Life Sciences
9. On a scale of 1 to 5 where one is NOT confident and 5 is VERY confident, how confident are you in your Life Sciences content knowledge?
10. Please tick the options that you think are part of the **content** knowledge that you need to know in order to teach Life Sciences at FET level. Leave the boxes blank if you think that it is not part of the **content** knowledge that you need to know. For each option, please also state (by ticking a box) whether you were sure of your answer, or whether you guessed.

- Knowledge of organic and inorganic molecules
- Knowledge of links between Natural Sciences (GET) and Life Sciences (FET)
- Knowledge of cancer is uncontrolled cell division and growth
- Knowledge of the limitations of scientific evidence
- Knowledge of different ethical opinions about cloning
- Knowledge of patterns and relationships in data
- Knowledge of cell theory
- Knowledge of how to use scientific equipment
- Knowledge of biodiversity of plants
- Knowledge of the procedures and how to safely use apparatus in laboratories and classrooms
- Knowledge that cells produce food or obtain food from elsewhere
- Knowledge that humans have two systems: nerves and hormones that enable them to respond to the environment.

- Knowledge of the relationships between food intake, energy, growth and health
- Knowledge of how to use a light microscope to observe cells
- Knowledge of the history of life on Earth
- Knowledge of the theory of Evolution

11. On a scale of 1 to 5 where one is NOT confident and 5 is VERY confident, how confident are you with your knowledge of the Life Sciences curriculum? Justify your answer?
12. What is your opinion about your ability to teach Life Sciences to school learners?

Appendix C

Full list of subordinate concepts to be taught in grade 10

Subordinate concepts for grade 10
Carbohydrates – Monosaccharides, Disaccharides, Polysaccharides
Lipids
Proteins
Enzymes
Lock and Key Model of enzymes
Nucleic acids
Vitamins
Deficiency diseases
Eutrophication
Microscopy – light microscopes, electron microscopes
Cell wall
Cell membrane – Fluid mosaic model
Diffusion
Osmosis
Active transport
Nucleus, Cytoplasm, Ribosomes, Protein synthesis, Endoplasmic reticulum (rough and smooth)
Golgi body, Plastids, Vacuoles, Lysosomes, vesicles - storage, digestion and osmoregulation
The cell cycle
Cell division
Chromosomes
Mitosis
Causes of cancer
Medical biotechnology and cancer
Xylem, phloem, parenchyma, collenchyma, sclerenchyma, epidermis, meristematic tissues
Leaf Structure
Photosynthesis, gas exchange and transport in plants
Root and stem: • Distribution of different tissues • Structure of cells in different tissues
Secondary growth
The relationship between water loss and leaf structure
Wilting and Guttation
Transport of water and minerals to leaves
Translocation
Hydrostatic skeleton
Endoskeleton
Exoskeleton
Axial skeleton
Appendicular skeleton
Long bones
Human locomotion
Bones; joints; ligaments; tendons; antagonistic muscles
Fixed joints; Partly movable joints; Freely movable (synovial) joints
Voluntary skeletal muscles: Myofibrils and muscle contraction
Pulmonary and systemic (double, closed) circulatory systems
The heart and associated blood vessels
The cardiac cycle
Oxygenated and deoxygenated blood
Blood vessels
Lymph
The biosphere, hydrosphere, lithosphere and atmosphere
Biomes in South Africa

Ecosystem structure and function
Abiotic factors
Biotic factors
Trophic structures and energy flow
Trophic levels
Biodiversity
Indigenous and endemic species
Classification
The atmosphere and Climate change
Geological events
Biogeography
Geological timescale
Cambrian Explosion
Mass extinctions
Radiometric dating and relative dating
Key Events from South Africa in life's history
Fossils
The impact of humans on biodiversity and the natural environment
Fossil Tourism

Appendix D

Full list of facts to be taught in grade 10

Facts for grade 10
Organic molecules are made up of C, H, and O, and some contain other elements, such as N and P
Cells are made up of proteins, carbohydrates, lipids, nucleic acids and vitamins and water
Different types of carbohydrates include: monosaccharaides (single sugars) e.g. glucose and fructose; disaccharides (double sugars) e.g. sucrose and maltose; polysaccharides (many sugars) e.g. starch, cellulose and glycogen
Lipids (fats and oils) are made up of 1 glycerol and 3 fatty acids
Fats can be saturated or unsaturated
Proteins are sensitive to temperature and pH in terms of of structure and function
Enzymes play a role in breaking down/synthesising molecules
Temperature and pH levels influence enzyme action
The Lock and Key Model describes how enzymes work
Enzymes are used in everyday life (for instance using washing powders)
Nucleic acids include DNA and RNA
Types of vitamins include: A, B, C, D and E
Where crops are grown and regularly harvested, fertilizers are washed away into rivers, and eutrophication can take place
Cell Organelles and their functions include: cell wall - support structure in plant cells only; cell membrane - fluid mosaic model, boundaries and transport: movement across membranes: diffusion, osmosis and active transport; nucleus, chromatin material, nuclear membrane, nucleopores, nucleolus: the control centre, heredity; cytoplasm - storage and circulation of materials; mitochondria - release energy during cell respiration; ribosomes - protein synthesis; endoplasmic reticulum (rough and smooth) - transport systems; Golgi body - assembles secretions; plastids - production and storage of food and pigments; and vacuole, lysosomes, vesicles - storage, digestion and osmoregulation
Cells differ in size, shape and structure in order to carry out specialised functions
The Cell Cycle involves: Interphase, mitosis, cytokinesis and growth
The continuous process of Mitosis involves the division of a cell to form two identical cells
Telophase differs between plant and animal cells
Chromosomes are found in nuclei of all cells
Chromosomes can be made up of two chromatids connected by a centromere
The roles of Mitosis are growth and repair or reproduction in some simple organisms
Cancer can be defined as uncontrolled cell division and growth
Treatments of cancer and medical biotechnology include: radiotherapy and chemotherapy
Tissues are a group of similar cells adapted for a particular function
Plant Tissues include: Xylem, phloem, parenchyma, collenchyma, sclerenchyma, epidermis and meristematic tissues
The Four basic types of animal tissues include: epithelial tissue; connective tissue; muscle tissue; and nerve tissues
Applications of Indigenous Knowledge Systems and Biotechnology include: traditional technology, e.g. traditional medicines and healers; medical biotechnology, e.g. immunity, vaccines, antibiotics and blood transfusions; and the cloning of plant and animal tissues and stem cell research (ethics and legislation)
Organs consist of a number of tissues
Factors that affect the rate of transpiration are: temperature; light intensity; wind; humidity
Different types of skeletons include: hydrostatic skeletons, endoskeletons and exoskeletons
The human Skeleton consists of: the axial skeleton (facial bones, cranium, foramen magnum, palate and jaws) and the appendicular skeleton
Functions of the Skeleton include: movement, protection, support, storage of minerals and hearing
Synovial joints include: ball and socket, hinge, pivot and gliding
Bones, joints, ligaments, tendons and antagonistic muscles (biceps/triceps) play a role in human locomotion
Diseases that affect the skeleton include: Rickets in children, osteoporosis and arthritis
The blood circulation system includes the pulmonary and systemic (double, closed) circulatory systems
The blood circulatory system includes: the heart and associated blood vessels; heart internal and external structure related to functioning; and the cardiac cycle (the flow of blood through the heart)

Diseases of the heart and circulatory system include: high and low blood pressure, heart attacks and strokes
The treatments of heart diseases include stents, valve replacements, bypass surgery, pacemakers, and heart transplants
The biosphere is interconnected with the hydrosphere, lithosphere and atmosphere
There are terrestrial and aquatic biomes of southern Africa and climate, soils and vegetation influence the organisms found in each
Abiotic factors include physiographic factors (aspect, slope, and altitude); soil (pH, humus content, texture, water retention capacity and air content); light (day length and seasonal changes); temperature (effect of day/night and seasons); water (water cycle and the importance of wetlands); atmospheric gases; and wind
Biotic factors include producers, consumers (carnivores, herbivores and omnivores) and decomposers
Energy flows through ecosystems through trophic structures
Trophic levels include: producers, consumers (herbivores and carnivores and omnivores) and decomposers
There is enormous biodiversity on Earth (large variety of species, different ecosystems and genetic differences)
Classification schemes are a way of organising biodiversity
Scientists attempt to classify organisms based on shared features. As information increases classification changes. One of the currently accepted classification systems is the five-kingdom system: Animalia, Plantae, Fungi, Protista and Monera (Bacteria)
Changes in the composition of the atmosphere include increases in the levels of oxygen; changes in climate include ice ages; geological events include movements of continents and their effect on the distribution of living organisms is known as biogeography
Evidence for changing sea level and rise and fall of the land includes: bivalves and ammonites found on the Makhatini Flats in Northern KZN, whale fossils in the Sahara, trilobites in the Karoo
The three eras: Paleozoic, Mesozoic and Coenozoic eras are each divided into periods
The Cambrian Explosion gives us insights into the origins of the major forms of all animal groups. In the last four million years, significant changes have occurred in species occurring in Africa (e.g., humans)
There have been five mass extinctions throughout history, two of which are particularly important: 250 mya (the extinction of about 90% of all life on Earth) and 65 Mya (the extinction of many species, including the dinosaurs). The rate of extinction on the Earth at present is higher than at any time in the past. The present time has been called the sixth extinction
There is evidence from South Africa of certain key events in life's history: origins of the earliest forms of life: evidence of single celled fossilised bacteria (stromatolites) from many parts of South Africa; soft-bodied animals in Namibia, Northern Cape; early land plants in the Grahamstown area; forests of primitive plants such as Glossopteris near Mooi River and Estcourt; location of coal deposits in South Africa (map only); the coelacanth as a 'living fossil' found on the Northern KwaZulu-Natal coast; mammal-like reptiles found in the Karoo (e.g. Lystrosaurus and Thrinaxodon); dinosaurs (in the foothills of Drakensberg and Maluti mountains), as well as cone-bearing plants; early mammals (Eastern Cape and Lesotho); humans and pre-humans (eg Gauteng, (Cradle of Humankind) Namibia, North West (Taung), Free State (Florisbad), KwaZulu-Natal (Border Cave) and, Limpopo (Makapansgat))
Scientists use deductive reasoning (inference) to understand fossils and the history of life on Earth. Fossil Tourism Fossil tourism is a source of income and employment in some localities

Appendix E

Full list of practical activities and investigations for grade 10

Practical activities and investigations for grade 10
Analyse nutritional content indicated on food packaging: vitamins, minerals and other nutritional content
Food tests for starch, glucose, lipids and proteins
Investigate the working of a 'biological' washing powder (containing enzymes) OR Hydrogen Peroxide and chicken liver to demonstrate the effect of enzymes OR Fresh pineapple juice and solid egg white in a plastic drinking straw AND Observe, measure and record results of the experiment done at different temperatures
Compare the Recommended Daily Allowance (RDA) with usual diet of individual learners. Draw a pie chart of the food types and discuss implications of the usual diet of learners
Investigate the history of microscopy: from lens and light microscopes and to electron microscopes. How these instruments enabled people to see cells and then structures within cells which led to cell theory
Explain and demonstrate how a light microscope works. Use a light microscope to observe and record (draw) the structure of a: plant cell (wet mount of onion epidermis) and an animal cell (cheek cells). If microscopes are not available, use micrographs. Calculate magnification of drawing by measuring the field of view under a microscope OR Calculate the size of specimen on a micrograph using the scale line provided
Investigate diffusion
Investigate osmosis
Use suitable resources to examine cell division, e.g., microscope slides, micrographs, posters and models. Record observations as drawings
Research and present information on ONE of the cancers. This must include causes, prevalence and treatment. Information can be presented verbally or as a written report
Examine and identify some plant tissues using microscope, biostrips, micrographs or posters. Draw cells that make up these tissues to show specialised structure
Examine and identify some animal tissues using microscope, biostrips, micrographs or posters. Draw the cells that make up these tissues to show specialised structure
Collect information on ONE field of biotechnology related to plant or animal tissues e.g., cloning, stem cell research or in vitro fertilisation
Observe and draw a section of a dicotyledonous leaf. Options: • Observe prepared slides of a cross section of a leaf OR • Observe micrographs OR • Observe bioviewer slide strips
Use a microscope or micrographs to observe and draw cross sections of root and stem (plan only)
If microscopes are available, make mounts of, and draw, whole xylem vessels from celery or pumpkin stalks to see secondary thickening patterns
Observe annual rings in a cut tree to assess age and climatic conditions
Design an investigation to discover the effect of temperature, light intensity or humidity on transpiration rate (using a simple potometer). Identify variables and control variables
Investigate water uptake through the roots
Investigate water movement through xylem (use Impatiens if possible)
Observe the human skeleton (model or photographs)
Observe and draw a typical long bone: longitudinal section
Observe as many of these tissues - bone, cartilage, tendons, ligaments – as possible: fresh material from a butcher
Observe and describe the movement which occurs at each of these types of joints – fixed joints, partly movable joints, freely movable (synovial joints). If possible, observe an X-ray of ball and socket and hinge joints
Dissection of mammal heart (sheep, cow or pig) obtained from a butchery. Identify chambers, valves, muscle, and blood vessels
In pairs, measure the pulse of one learner before and after exercise. Record, interpret and explain the data presented as a graph
Observe and draw prepared microscope slides or micrographs of blood cells and blood vessels as seen in cross section

Fieldwork: Choose ONE ecosystem (close to the school) within a local biome for special study. The study must: • deal with abiotic and biotic factors and the interactions between them; • investigate the trophic relationships in an ecosystem; • record and describe seasonal changes over two terms either Terms 1 and 2 or Terms 3 and 4 • investigate biodiversity within the ecosystem using field guides and keys •investigate positive and/or negative human impact on the ecosystem Different groups should investigate different factors. Each group must plan, collect, record and present, analyse and evaluate data. (This serves as an introduction/link to human influences on the environment in Grade 11.)
Investigate the principles of classification by grouping everyday objects on the basis of shared similarities into a simple nested hierarchy
Classify a selection of familiar organisms into groups based on visible evidence. Use keys and identification guides
Construct a timeline showing the history of life on Earth. The timeline should show key events from the emergence of the earliest life forms to the present day to emphasise the long history of life
Research ‘missing link’ between dinosaurs and birds eg. Archaeopteryx
Coelacanth as an example of a "living" fossil found off the coast of South Africa Present a verbal or written report
Various hypotheses have been proposed for the extinction, 65 million years ago, such as the meteorite impact theory and the volcanism evidence (in India) theory. Select ONE of these hypotheses and describe the evidence scientists have gathered in support of it. (Nature of science)
Examine fossils at a museum or fossil site or study photographs of fossils

Appendix F

Full lists of main concepts, subordinate concepts, the facts, and he theories to be taught in grade 11 as well as the practical investigations and activities to be performed in grade 11

Main concepts for grade 11
Biodiversity and Classification of Microorganisms (Microbiology)
Immunity (plant and animal immune responses against infecting microorganism) (Microbiology/plant and animal physiology)
Biodiversity of Plants (Botany)
Reproduction in Plants (Botany)
Biodiversity of Animals (Zoology)
Animal phyla (Zoology/animal taxonomy)
Photosynthesis (Botany/environmental studies)
Animal Nutrition (Mammals) (Zoology/animal physiology)
Homeostatic Control (Animal/human physiology)
Cellular respiration (Animal/human physiology)
Gaseous Exchange (Animal/human physiology)
Excretion in Humans (Human physiology)
Population Ecology (Environmental studies/socio-biology)
Human Impact on the Environment: Current Crises for Human Survival: Problems to be Solved Within the Next Generation (Environmental studies/socio-biology)
The atmosphere and climate change (Environmental studies)
Water (Environmental studies)
Food Security (Environmental studies/socio-biology)
Loss of Biodiversity (Environmental studies/socio-biology)
Solid Waste Disposal (Environmental studies/socio-biology)

Subordinate concepts for grade 11
Microorganisms: viruses; bacteria, protists, fungi
Microorganisms and symbiotic relationships
Effect of drugs on microorganisms
Microorganisms producing medicines
Microorganisms and traditional technology
Asexual and sexual reproduction in plants
Flowers as reproductive structures
Pollination
The Significance of Seeds
The concept of a phylum
Body plans: symmetry and cephalisation the number of tissue layers developed from embryo; the number of openings in the gut; coelom and blood systems
Photosynthesis – light phase and dark phase
Rate of photosynthesis
ATP as an energy carrier in the cell
Human nutrition
Ingestion, digestion, absorption, assimilation and egestion
Mechanical digestion, Peristalsis and Chemical digestion
Hormonal control of blood sugar levels
Food intake, energy, growth and health
Balanced diet and different diets due to cultural, religious, personal and health choices (vegan, vegetarian, halaal, kosher)
Dietary supplements
Malnutrition
Tooth decay related to diet
Aerobic respiration (glycolysis, Krebs cycle and oxidative phosphorylation) and anaerobic respiration (lactic acid production, fermentation)
Human Gas Exchange
Inspired air and expired air
Homeostatic control of breathing
Respiratory diseases
Smoking legislation in South Africa
Artificial respiration and mouth to mouth resuscitation
Organs of excretion
Urinary system
Ultra-filtration, reabsorption, tubular excretion
Homeostatic control of water and salts: ADH and aldosterone
Dialysis and kidney transplants
Diseases affecting kidney function
Population Size: Immigration, Emigration, mortality, births
Fluctuations
Limiting factors and carrying capacity
Logistic and geometric growth curves
Interactions in the Environment: predation, interspecific competition, intraspecific competition, specialisation: competitive exclusion and resource partitioning, parasitism, mutualism, commensalism
Social Organisation
Primary and secondary succession
Carbon dioxide emissions and ‘carbon footprint’
Deforestation
Greenhouse effect and global warming: desertification, drought and floods; methane emissions; ozone depletion
Water availability
Boreholes
Thermal pollution
Water purification and recycling
Alien plants
Food Security

Droughts and floods (climate change)
Monoculture
Wastage
Loss of Biodiversity (the sixth extinction): • habitat destruction: farming methods, e.g., overgrazing and monoculture, golf estates, mining, urbanisation, deforestation; loss of wetlands and grasslands; poaching; alien plant invasions: control using mechanical, chemical and biological methods; and indigenous knowledge systems and the sustainable use of the environment
Solid Waste Disposal

Facts for grade 11
Microorganisms include: viruses, bacteria, protists and fungi
Microorganisms play a role in maintaining balance in the environment and the web of life
Microorganisms are involved in symbiotic relationships, including: nitrogen fixing bacteria in plants and *E. Coli* in the human intestine
Diseases from each of the four groups include: viruses (rabies, HIV/AIDS, influenza), bacteria (blight, cholera, tuberculosis, anthrax), protists (malaria) and fungi (rusts, thrush, ringworm, athlete's foot)
Microorganisms can be used to produce medicines (e.g., insulin and antibiotics)
Microorganisms can be used in traditional technology to produce, e.g., beer, wine and cheese
Bryophytes, pteridophytes, gymnosperms and angiosperms are grouped according to the presence/absence of: vascular tissue (xylem and phloem), true leaves and roots, seeds or spores, fruit
There is decreasing dependence on water for reproduction from Bryophytes to Angiosperms
Flowers have adaptations for pollination through (different pollinators) wind, insects and birds
Seeds are significant in terms of: seed banks; seeds as a food source and endemic species in South Africa
The six phyla (out of about 30 in the animal kingdom) learned about in grade 11 are: Porifera, Cnidaria, Platyhelminthes, Annelida, Arthropoda and Chordata
Key features in respect to body plans include: symmetry and cephalisation; the number of tissue layers developed from embryo; the number of openings in the gut; coelom and blood systems
Invertebrates play a role in agriculture and ecosystems (e.g., pollination, decomposition, soil aeration etc.)
Photosynthesis involves the intake of raw materials, trapping and storing of energy, the formation of food in chloroplasts, storage of food and the release of oxygen
Photosynthesis is made up of a light phase and a dark phase
Amounts of light, carbon dioxide and temperature have an effect on the rate of photosynthesis
ATP is an important energy carrier in the cell
Human nutrition involves the processes of: ingestion, digestion, absorption, assimilation and egestion
There are two types of digestion: mechanical and physical
Different types of teeth have different structures and functions
Chemical digestion involves enzymes, including: carbohydrases, proteases and lipases
Absorption: small intestine is the region of most absorption of digested food
Assimilation involves the incorporation of glucose and amino acids into cells
The liver plays a role in: glucose metabolism, deamination of excess amino acids, and the breakdown of alcohol, drugs and hormones
Individuals can have different diets due to cultural, religious, personal and health choices, e.g., vegan, vegetarian, halaal, kosher
Dietary supplements can be used for: health, sport, beauty and anti-ageing
Malnutrition can involve: unbalanced diets (e.g., kwashiorkor), starvation (e.g., marasmus and anorexia), bulimia, food allergies, coronary heart disease, diabetes and obesity
Aerobic respiration: takes place in the mitochondria; consists of: glycolysis, Krebs cycle and oxidative phosphorylation
Anaerobic respiration: involves the production of lactic acid in muscles during exercise; is used in the industry, e.g beer brewing and bread making
Requirements of efficient Gas Exchange Organs include: large surface area; thin; moist; well ventilated; protected; transport system
The human ventilation system consists of: trachea; epiglottis; bronchi; bronchioles; lungs; ribs; intercostal muscles; diaphragm; alveoli
Respiratory diseases include: Tuberculosis; asthma; hay fever; bronchitis; emphysema; lung cancer
Organs of excretion include: the lungs; the kidneys and bladder; the liver; the alimentary canal (gut); the skin

Urinary system includes: kidneys, ureters, bladder, urethra
Population Size is affected by: Immigration, emigration, mortality, births
Interactions in the Environment include: predation; competition: interspecific: for light, space, water, shelter and food and intraspecific: for food, access to mates, water, space, and shelter; specialisation: competitive exclusion and resource partitioning; parasitism; mutualism; commensalism
Climate change is related to: carbon dioxide emissions; deforestation; the greenhouse effect and global warming; methane emissions; ozone depletion
Water availability is affected by: Construction of dams; Destruction of wetlands; Poor farming practices; Droughts and floods; Exotic plantations and depletion of water table; Boreholes and effects on aquifers; Wastage; Cost of water
Water quality is affected by: agriculture and mining: pollution; diseases; eutrophication and algal bloom
Food Security is affected by: human exponential population growth; droughts and floods (climate change); poor farming practices; pest control; loss of topsoil and the need for fertilisers; alien plants and reduction of agricultural land; the loss of wild varieties: impact on gene pools; genetically engineered foods; wastage
Loss of Biodiversity is related to: habitat destruction: farming methods, e.g., overgrazing and monoculture, golf estates, mining, urbanisation, deforestation; loss of wetlands and grasslands; poaching, e.g., for rhino horn, ivory and 'bush meat'; alien plant invasions; indigenous knowledge systems and the sustainable use of the environment e.g., devils' claw, rooibos, fynbos, the African potato (Hypoxis) and Hoodia
Solid Waste Disposal is related to: managing dumpsites for rehabilitation and prevention of soil and water pollution; using methane from dumpsites for domestic use such as heating and lighting; safe disposal of nuclear waste

Theories for grade 11
Germ theory

Practical investigations and activities for grade 11
Where possible, the prevalence of bacteria/fungi should be demonstrated by growing cultures on agar plates, or bread mould (fungus) on bread (Experiment)
Look for evidence of bacterial/fungal diseases on plants (school and home). Map the distribution of one disease in the study area (Investigation)
Observe and draw relevant macroscopic parts to provide examples of each of the following divisions: • bryophytes: moss plant • pteridophytes: rhizome, frond with sori • gymnosperms: needles, cones and seeds • angiosperms: flower, fruit and seeds (Fieldwork)
Draw a phylogenetic tree showing the evolutionary history of the four plant groups and major structural changes in their history of development (Drawing)
Dissect an example of each of the following types of flowers: • wind pollinated • insect pollinated • bird pollinated Record observations in a comparative table (Dissection)
Observe examples from as many phyla as possible (photographs/DVDs) Select one phylum and design a poster to show diversity in that phylum in South Africa (Fieldwork)
Investigate photosynthesis by showing that • starch is produced during photosynthesis • light is necessary for photosynthesis The following investigations can be done (by learners) as experiments or as demonstrations: • carbon dioxide is necessary for photosynthesis

• chlorophyll is necessary for photosynthesis oxygen is produced during photosynthesis or • data can be provided and interpreted by learners (Investigation)
Obtain intestines of a sheep from a butcher and trace the passage that food will take. Cut open the stomach, portion of the small intestine and a portion of the large intestine to compare the structure of the wall in each (Dissection)
Calculate the nutritional value of a meal/diet. Use dietary information or food packaging (Calculation)
Design an investigation or demonstration to show that: • oxygen is used by living organisms during respiration • carbon dioxide is produced by living organisms during respiration or • provide relevant data that can be interpreted by learners Identify variables, suggest controls for variables and record observations (Investigation)
Use books end on end and one on top of another to illustrate and calculate the differences in respect of surface area to volume ratio which is caused by different shapes: e.g., flatworm (Planaria) and earthworm (Calculation)
Observe and investigate the structure of the lungs, diaphragm, associated pulmonary blood vessels and the heart of a pig or a sheep obtained from a butcher Construct a model of the human breathing system. Explain the limitations of the model (Dissection)
Measure and compare the depth of breathing of two or more learners and the effect of exercise on breathing/pulse rate. Interpret data on depth and rate of breathing
Analyse and interpret data showing the effects of altitude on the number of red blood cells and the consequent effect on athletes at different altitudes (Links to Grade 10)
Dissection of a sheep's or pig's kidney (obtained from butchery). Use a worksheet to identify the following: capsule, cortex, medulla, pyramids, blood vessels, pelvis, ureter and hilum. Draw and label the dissected kidney
Learners must explore the impact of people on their environments (global, international and local). Learners are encouraged to look for and suggest solutions to local environmental problems. The intention is that learners will become more informed and more sensitive to environmental issues and will modify their behaviour to lessen their impact on the environment
Determine the size of a population by quadrant or simple sampling e.g., simulated mark/recapture Collect and record data Interpret data Calculate/estimate the population size
Case study: Rationale for culling, e.g. elephants in the Kruger National Park as an example of an application of estimating population size (link to researched reasons for culling) Draw up a public survey form to test the public opinion about culling. Show results in a pie graph
Draw a life cycle of the bilharzia parasite or tapeworm (simplify larval stages). (Links to animal biodiversity)
Identify an area in or close to the school grounds where succession is taking/has taken place. (e.g., in the goal area on the sports field at the end of a season or a roadside that has been scraped)
Practical observation of ONE example of human influence on the environment in the local area (e.g. the impact of alien species on biodiversity). Written report on the chosen example
Rhino poaching in South Africa: read articles and make suggestions on how it can be prevented
Analyse the solid waste generated in the household in one week, including paper, metals and plastic. Estimate the percentage that could be recycled or reused
Visit a municipal landfill site, or a local refuse dump. Observe rehabilitation (or lack thereof) in practice
Assess the effectiveness of waste management