Using ICTs as a pedagogical resource to facilitate epistemological access in science with teacher education students

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Abstract

The study aimed to investigate the kind of knowledge privileged when student teachers use Information Communication Technologies in facilitating learning in science subjects. The assumptions were that future student teachers, through their pedagogic practices, may either reproduce or interrupt educational inequalities. The ability to interrupt inequalities is conditioned by the manner in which these student teachers have been inducted into the field of teacher education and this process includes the ability to manipulate technological resources to facilitate epistemological access. This concept originally coined by Morrow in the 1980s looked at black students seeking entry to university. Since then the concept was used to signify the importance of knowledge in the curriculum. In this study, the exploration of epistemological access goes beyond physical or formal access and includes meaningful access to knowledge.

The semantics dimension of Legitimation Code Theory (LCT) proposed by Maton was used, with a particular focus on semantic density (SD) as a theoretical framework. Maton argues that semantic density can vary across teaching practices and contexts. The study assumes that student teachers, through their pedagogic practices, may either reproduce or interrupt educational inequalities.

Employing a qualitative case study approach, video-based fieldwork was conducted in disadvantaged schools in the Western Cape and these observations were supplemented by a document analysis of lesson plans, subject guides and presentations. This process built a holistic picture of classroom practices. The analysis foregrounded pedagogy, in terms of how student teachers use Information Communication Technologies (ICTs) to weaken semantic density and give learners access to knowledge by taking a dense concept, which has complex and abstract meanings, and making it more accessible.

Six themes emerged from the collected data, namely:

(i) Weakening semantic density, which constrains learners, because they are subjected to context-dependent knowledge.

(ii) Segmented learning which constrains cumulative learning for learners, a practice which could contribute towards the continued marginalisation of students coming from previously disadvantaged backgrounds.
(iii) Poor quality education which perpetuates educational inequalities and assimilates learners into the dominant colonised discourse.
(iv) Semantic flatline which limits learners, because they are being socialised into the field, with a common sense understanding of Science.
(v) Reproduction of traditional pedagogy through ICT and ICTs as a tool to find information which constrains critical thinking in learners and reproduces authoritative and traditional teaching practice.
(vi) Semantic waves which are key to cumulative learning.

Recommendations arising from the findings of this study include the introduction of processes to ensure the development of student teachers who do not perpetuate the colonial education structures. Instead of using ICTs in limited ways, this knowledge of ICTs should be internalised in such a manner that it is used across the curriculum. This practice requires a thorough grounding in ICTs as well as an in-depth knowledge of ICT pedagogy discourse. To improve the quality of teaching and learning in South African schools, educators need to rethink the approaches to teaching and learning, by bringing into the spotlight what is considered to be valid knowledge. Only then will the enabling of epistemological access to learners become a reality. For future studies, it would be important to revisit the knowledge gap that currently exists in schools and teacher education programmes.

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Declaration

I, Dominique Fagan, declare that “Using ICTs as a pedagogical resource to facilitate epistemological access in science with teacher education students” is my own work and that this study has not been submitted previously to any university for examination for the purpose of obtaining a qualification. All cited or quoted sources in this study have been acknowledged by means of references.

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Dominique Fagan

Abbreviations and Acronyms

AT	Activity Theory
BEd	Bachelor of Education
CAPS	Curriculum Assessment Policy Statement
CAT	Computer Application Technology
CK	Content Knowledge
CPUT	Cape Peninsula University of Technology
DBE	Department of Basic Education
DOE	Department of Education
ECPs	Extended Curriculum Programmes
ESRC	Economic and Social Research Council
FET	Further Education and Training
ICT	Information Communication Technology
ICTs	Information Communication Technologies
IT	Information Technology
IWBs	Interactive Whiteboards
LCT	Legitimation Code Theory
LER	Learner-Educator Ratio
LS	Life Sciences
MST	Mathematics, Science and Technology
NEEDU	National Education Evaluation and Development Unit
OBE	Outcomes-Based Education
OECD	Organisation for Economic Cooperation and Development
PANAF	Pan-African Programme
PCK	Pedagogical Content Knowledge
PK	Pedagogical Knowledge
PS	Physical Sciences
SCOPE	Stanford Center for Opportunity Policy in Education
SD	Semantic Density

SG	Semantic Gravity
SG-	Semantic Gravity is weaker
SG+	Semantic Gravity is stronger
SITES	Second International Technology in Education Study
TCK	Technological Content Knowledge
TIMSS	Trends in International Mathematics and Science Study
TK	Technology Knowledge
TPCK	Technological Pedagogical Content Knowledge
TPK	Technological Pedagogical Knowledge
UOT	University of Technology
WCED	Western Cape Education Department
WEF	World Economic Forum
WorLD	World Links for Development Project

Chapter One

Introduction and overview

1.1 Introduction and background

This study considers the potential role presented by Information Communication Technologies (ICTs) as a pedagogical resource used by student teachers to facilitate epistemological access in science subjects in disadvantaged schools in the Western Cape, South Africa. Epistemological access is still under-researched in South Africa, especially with regard to what this particular concept could mean within secondary schooling (Du Plooy and Zilindile, 2014; Boughey, 2010). The term epistemological access was first used by Morrow (2007), a South African scholar, who problematised access to higher education. He used the term to describe two dimensions of access to higher education, being institutional (formal access) and access to knowledge, which he believes institutions distribute (epistemological access). Within this study epistemological access is pinned at meaningful access to knowledge, when learning is structured in a manner which ensures learners develop coherent ways of engaging with and understanding different learning areas (Pendlebury, 2009:24-25). This access, therefore, extends beyond mere physical access to include the ways in which learners are provided with quality teaching and learning.

Owing to the legacy of marginalisation during apartheid, many schools for black South Africans continue to experience lack of adequate resources especially in terms of infrastructure like laboratories and inequality in terms of funding despite various state interventions towards redress, including the provision of Information Communication Technology (ICT) (Ford and Botha, 2010:2). South Africa remains an unequal society in which the physical conditions of schools and the contexts in which these schools are located differ vastly (TIMSS, 2015; South African Government, 2012). There are roughly 7% independent schools and 93% public schools (Reddy *et al*., 2016) in South Africa. The majority of these public institutions are township or rural schools which enrol mostly black children in contrast to the previously advantaged schools in urban areas that enrolled only white children during the apartheid era. All South African public schools are categorised into five groups, called quintiles, largely for purposes of the allocation of financial resources. Quintile one is the 'poorest' quintile and comprises no-fee schools. These poverty rankings are determined nationally according to the poverty of the community in which the school is located, as well as certain infrastructural factors. The South African Government, as part of a strategy to aid disadvantaged schools, implemented a subsidy system for schools ranked as Quintiles 1-3, therefore exempting learners attending these schools from paying fees. Public schools can thus be broadly grouped into two categories, namely fee-paying and non-fee paying schools (Quintile 1 schools). As mentioned previously, the no-fee schools are located within disadvantaged communities and cater predominantly for coloured and black learners from lower income households.

Racial classification was the foundation of all apartheid laws. It placed individuals, firstly into two categories, white and non-white/black. Blacks were further placed in one of three groups: 'native', 'coloured' and 'Asian'. The term ‘coloured’ refers to people of mixed-race parentage and represents a wide range of genetic backgrounds. Coloureds make up 9% of the South African population. The term 'native' was later replaced by the label ‘African’. or 'Black African' and comprise the majority group in the country. During the colonial and apartheid periods, the Black African population of South Africa was divided into major ethnic groups like Zulu, Xhosa, Venda and Pedi.

The no-fee schools were the worst performing schools in the Trends in International Mathematics and Science Study (TIMSS) study undertaken in South Africa with a score of 317. Achievement at a low level was ranked by scores of between 400 and 475 points. Intermediate level includes achievement scores of between 475 and 550 points. High level includes scores of between 550 and 625 and advanced level consists of scores above 625. A fifth category was added, in which the points scored were between 325 and 400. This category was added with the belief that learners could potentially improve their score to above 400 points. The TIMSS International study used a set of benchmarks to provide countries with comparable descriptions of what learners know. Four categories were created together with a fifth category that provided a broader picture of the South African learner performance. The study revealed that only one third of South African Grade 9 learners could achieve the minimal level in science (TIMSS, 2015:23). Performance in science appears to have shifted from a ‘very low level’ in 1995 to a ‘low level’ in 2015 (TIMSS, 2015:23). South African learners could only demonstrate basic knowledge of life sciences (LS).

The World Economic Forum’s (WEF) Global Information Technology Report, ranked South Africa last in the quality of its mathematics and science education (Baller, Dutta and Lanvin, 2016). Despite an improvement in the development of its ICT infrastructure (ranked 44th out of 139 countries in the world) the ICT impact and social impact (ranked 93rd and 112th respectively) remain limited (Baller *et al*., 2016). The ‘social’ impact test focuses on assessing a country’s societal progress brought about or enhanced by the use of ICT. It also includes the extent to which ICTs allow access to education (for example the use of internet at school, as a proxy for the potential benefits that are associated with the use of ICTs in education) together with the impact of ICTs on government efficiency; and the quality and usefulness of information and services provided by a country for the purpose of engaging its citizens in public policymaking, through the use of e-government programmes.

The WEF’s low ranking has prompted the National Department of Basic Education to improve its strategy and focal areas over the next five years in order to ensure the improvement and progression of Mathematics, Science and Technology (MST) (South Africa. Department of Basic Education, 2015:2). According to Minister Motshekga, “the integration of information and communication technology in teaching and learning” will be a core strategy “for developing learners and student teachers who have relevant skills that match the modern needs of our changing world” (South Africa. Department of Basic Education, 2015:3). This strategy has seen an increase in programmes and projects, such as Telkom 1000 Internet Schools project which provided 1000 Internet access points for schools in South Africa, Telkom SuperCentre project, Thintana iLearn project which donated R21,2 million to set-up computer centres in 200 disadvantaged secondary schools, Global Teenager Southern Africa project, Nortel Networks South Africa project, World Links for Development project (WorLD), Sizanani project, Learning Gains project, Adobe Youth Voices, New Futures project and Microsoft maths, all of which are aimed at providing and creating learning communities where educators and learners can use ICTs in the classroom to transform learning.

However, despite this vision and the introduction of programmes to improve the life of the 21st century learner (more than twenty years after the demise of apartheid in 1994), the 2009 National Education Evaluation and Development Unit (NEEDU) concluded that South African rural and township schools are still largely dysfunctional. Factors such as the lack of time management, motivation, interest and teaching strategies, laboratory apparatus, parents' commitment to their children's education and student teachers' content knowledge, are contributing to poor learner performance (Law, *et al*., 2008; Makgato, 2007). Schools that offer science still lack adequate resources and facilities (Booyse, Seroto, le Roux, and Wolhuter, 2011). Singh and Singh (2012) also found evidence of a lack of resources, poor training of science student teachers, incompetent management, overcrowded science classrooms, policy and curriculum issues that negatively affected the culture of teaching and learning for pre-service science teachers at South African schools. As a result, the outcomes indicated in the curriculum for science teaching could not be achieved. These researchers concluded that there is a need for improvisation and innovation in science teaching for pre-service teachers. Underprepared Life Science student teachers are compounding the problem (Booi, 2018). This study moves from a premise that improving the way in which pre-service teachers are trained is a fundamental factor if the country is to redress inequalities in educational outcomes. The reality is that when students qualify as teachers, they are likely to practice in the same type of disadvantaged schools in areas where they were learners.

The assumption driving this study is that these future teachers, through their pedagogic practices, may either reproduce or interrupt educational inequalities. Their ability to interrupt inequalities is conditioned by the manner in which they have been inducted into the field of teacher education and this process includes the ability to manipulate technological resources to facilitate epistemological access. In critical realist terms, the researcher, (afterwards referred to in this study as 'I') therefore, views student teachers' pedagogic practices as 'real' mechanisms with emergent properties, tendencies and effects (Bhaskar, 1978) with the potential to amplify or interrupt inequalities in education. This study will examine what happens in terms of enabling epistemological access when ICTs are integrated into science lessons. The research sample is a group of Bachelor of Education (BEd) science students studying in the Further Education and Training (FET) band.

This study seeks to understand how ICTs are used as a pedagogical resource to facilitate epistemological access in science and the role of student teachers in mediating between technology and the subject matter. It also aims to realise the kind of knowledge that is privileged when the student teachers use ICTs in facilitating learning. It is important to explore how student teachers are 'opening-up' access to powerful knowledge (Muller, 2007 to South African children from previously disadvantaged communities.

The research question which framed the study is:

To what extent are teacher education students using ICTs in teaching science to enable learners' epistemological access?

Despite the demise of apartheid in South Africa in 1994, educational outcomes remain racially skewed (Scott, Yeld and Hendry, 2007). Students coming from disadvantaged backgrounds are the most affected by this bias, and thus remain marginalised, a fact that is seen through the high failure, attrition and dropout rates in the education system (Scott *et al*., 2007). Studies show that in South Africa the majority of the population were deprived of quality education during apartheid (Broekman, Enslin and Pendlebury, 2009). During this period teaching approaches in most disadvantaged schools was mainly 'chalk and talk' through which teachers and student teachers promoted rote learning (Booyse & Chetty, 2016). ICTs currently provide opportunities for redress because proponents see it as a way of challenging conservative pedagogic practices while facilitating the higher level thinking skills essential for participation in the knowledge society (Player-Koro, 2012).

In 2004, the South African government stated its commitment to the use of ICTs in education in the belief that:

> …developments in ICTs create access to learning opportunities, redress inequalities, improve the quality of teaching and learning, and deliver lifelong learning. ICTs can accommodate differences in learning styles and remove barriers to learning by providing expanded opportunities and individualised learning experiences (DOE, 2004: 16).

ICTs in education also afford opportunities for under privileged students and aid in bridging the digital divide (Akinsola, Herselman & Jacobs, 2005). Thus, given the South African context, much of the current literature focuses on ICT access and how ICTs can aid in reducing socio-economic inequalities. ICTs are used as scaffolding for socio-economic development and building of much needed skills in a global society

(Marais, 2009). There is limited attention placed on variables that could be used as predictors of ICT use in order to maximise the limited resources more effectively (Drape, Howie and Blignaut, 2008). While it is vital to raise concerns about the lack of redress and the prevalence of socio-economic inequalities, despite post-apartheid policies focusing on redress and social justice, together with significant increases in funding for previously disadvantaged schools, it is equally important to focus researchers and educators' attention on the integration of ICTs into the curriculum, in order to exploit the full potential presented by this amalgamation. In this study, while acknowledging calls toward redress and the need for skills to contribute toward economic development, I maintain that ICTs in education present an opportunity beyond this economic reductionist view. Through flexibility, ICTs can be used as a tool for enhancement and affirmation in diverse classrooms, while opening opportunities for inclusion and participation in debates around social controversies. In Bernstein's (2000) terms, ICTs in education can be used as a tool to uphold and respect 'pedagogic rights' which are essential in widening students' capabilities by providing opportunities for enhancement through inclusion and participation. Much of the spotlight lies with teacher competence and access to ICTs. However, there is an urgent need to look further than the issue of access, to the ability of learners and student teachers to use these technologies effectively and to integrate ICTs into teaching and learning. Little attention is given to maximising the limited resources found in poorer schools more effectively (Lundall & Howell, 2000). An important focus in all fields of education also should be on the integration of ICTs into teaching in disadvantaged schools to maximise the potential benefits presented by ICTs.

This thinking is in line with the Minister of Education's plea for both the government and private sector to accelerate the pace of integrating ICTs in educational processes in order to equip learners with the skills necessary to participate in the global community and, ultimately, to succeed in the 21st century (Motshekga, 2016). The goal has shifted from skills development to ICT as a tool for teaching and learning, as captured in the government's definition of e-Education:

> In the South African context, the concept of e-Education revolves around the use of ICTs to accelerate the achievement of national education goals. e-Education is about connecting learners and teachers to each other and to professional support services, and providing platforms for learning. e-

> Education will connect learners and teachers to better information, ideas and one another via effective combinations of pedagogy and technology in support of educational reform. It supports larger systematic, pedagogical, curricular and assessment reforms that will facilitate improved education and improved use of educational resources such as ICT. (DoE, 2004)

This study aims to move away from a technicistic or instrumentalist understanding of ICT integration into education and seeks to understand the role of ICTs in teaching. I move from a premise that ICTs can enhance epistemological access (Morrow, 2007) especially for disadvantaged learners. Proper integration of ICTs in teaching can support active construction of knowledge (Maholwana-Sotashe, 2007).

This thesis presents a Critical Realist study and assumptions made are that one's understanding of the world should be guided by relatively objective knowledge (transitive) through judgmental rationalism. I approach this study from a Critical Realism perspective (Bhaskar, 1978). Within this ontology, reality can be stratified into three ontological domains: real, actual and empirical. The real layer (which is the basis of my interest and study), made up of causal mechanisms and structures, produces actual events, which can then be empirically observed. The second domain, actual layer, represents events which actually happen, whether they can be observed or not. Lastly the empirical domain is the layer that can be observed, in other words, human experiences.

Mishra and Koehler's (2006) Technological Pedagogical Content Knowledge (TPCK) model will provide an initial framework to interrogate mechanisms at the layer of the real. This model builds on Shulman's (1987) Pedagogical Content Knowledge (PCK) model, where content and pedagogical knowledge are brought together in teaching practices. This model is premised on the fact that it is essential for teachers to understand technology in relation to their understanding of pedagogy and content. The TPCK model will provide an initial understanding of the kinds of knowledge teachers will need to effectively integrate ICTs into their classrooms.

Howard and Maton (2011) observed that while TPCK does provide us with 'different content or foci of knowledge' in teacher education programmes, it fails to give purchase to means of theorising the forms which that knowledge takes. I, therefore, needed a theory to conceptualise the underlying principles of the practices teachers and student teachers employ when using ICTs in teaching science subjects. This knowledge helps to demonstrate the form taken by technological, pedagogical and content knowledge when enacted together in various combinations and in different contexts (Howard and Maton, 2011). The viewing of these pedagogic practices in this way is in line with the Social Realist view of knowledge (Young and Muller, 2010) and allows educational researchers to see ICTs in teacher education as 'real' with emergent properties, tendencies and effects. This is where Maton's (2010) Legitimation Code Theory (LCT), which builds on Bernstein's theory of educational knowledge codes, becomes critical as a lens to view knowledge practices (pedagogy) as a focal point in educational research.

In this study I wish to draw on the LCT concept of semantic waves, specifically semantic density, (SD) to analyse the pedagogic practices of student teachers who are using ICTs in teaching science subjects. SD refers to the degree in which meanings are reduced within a practice. Weaker semantic density (SD-) meanings are less condensed while when semantic density is stronger (SD+) symbols have a great deal of meaning condensed in them (Maton, 2013). Maton (2014a) notes that classroom discourse can be analysed in terms of how the teacher uses semantic waves to facilitate access to knowledge. This approach allows one to see how pedagogic practices evolve over time with variations between semantic gravity and SD. It also explains how a lesson moves the learner from familiar (everyday) concepts to epistemological (abstract) access**.**

This study sought to understand how the potential benefits presented by ICT tools could be maximised in the South African classroom. It demonstrates that challenges faced by teachers and student teachers when using ICTs in teaching science subjects cannot be divorced from their science knowledge base. The important role that teacher preparation programmes play in preparing future student teachers to integrate ICTs efficiently in their teaching practices are highlighted. The study identified challenges that might exist in the classroom and, if not addressed, may continue to produce unequal educational outcomes.

1.2 Contribution of the study

I hope that this study will have the following benefits:

- Provide information on how student teachers used ICTs as a pedagogical resource to facilitate epistemological access in science subjects in disadvantaged schools;
- Provide useful insights (through the use of semantic waves) into what is key to building knowledge over time;
- Deepen the understanding on Critical Realism within a science teaching context;
- Deepen the understanding on epistemological access in science teaching; and
- Make important and meaningful contributions to teacher training institutions as well as to pre-service teachers by assisting them to evaluate and improve their teaching pedagogy.

1.3 Research design and methodology

This research project was a qualitative study using observation of teacher education students' use of ICTs as a pedagogical resource to facilitate epistemological access in science subjects. Creswell asserts that:

> Qualitative research begins with assumptions, a worldview, the possible use of a theoretical lense, and the study of research problems inquiring into the meaning individuals or groups ascribe to a human or social problem. (2007: 37)

This study employed a case study approach because I could gather insights into the student teachers and learners' classroom experiences. The instrument for data collection was an observation schedule, together with video recordings and document analysis. The focus being on observation of student teachers' pedagogical practices in terms of SD, I (the researcher) used Maton's (2010) LCT concept of SD as an analytical framework to examine the way in which student teachers facilitate epistemological access during their teaching practice session when they teach science subjects using ICTs. In doing so, I created an external language of description to test the strength of SD in the data. To enhance the credibility and trustworthiness of the study, techniques used included triangulation, this entailed using digital video recordings as the primary source of data which was further supported with document analysis.

1.4 Overview of thesis

This thesis consists of eight chapters. Chapter One provided an overview of the study.

Chapter Two consists of the literature review. It describes the landscape and critical issues around ICTs in education both locally in South Africa and internationally. I explore the innovative ways in which student teachers are using ICTs in their teaching, in order to meet the challenge of enabling epistemological access for learners in South African classrooms. I am mindful that scholarly literature has a tendency to view epistemological access as what Morrow (2007) calls 'access to University goods', in this study the exploration goes beyond physical or formal access and focuses rather on meaningful access.

Chapter Three outlines the theoretical debates and frameworks in the field and aims to find a lens to explore 'what' knowledge is taught as well as the form this knowledge takes. This study is embedded in a Critical Realist approach, in other words, the belief that there is a deeper level beyond what is observed on the surface. I explore how Maton's (2010) SD concept which forms part of his LCT builds on Bernstein's concepts of hierarchical and horizontal knowledge structures. The LCT provides a valuable framework to analyse the principles underlying the practices of student teachers.

Chapter Four outlines the research methodology and the analytical framework used in this study. It describes the choice of Critical Realism as a meta-theoretical framework to uncover the underlying structuring principles of pedagogic discourse. Observations, video recordings and document analysis as the data collection method are discussed. A contextual overview of the study is provided, as well as the motivation for a case study approach. I engage with issues around credibility, dependability, transferability and confirmability. A systematic account is given of the techniques used to analyse the data, followed by a discussion on ethical considerations.

Chapter Five presents the findings of the twelve lessons selected as a sample to represent a continuum of teaching science from Grades 8 to 11. Student teacher narratives are presented as case studies, detailing lesson outcomes, the classroom setup and illustrations from each lesson.

Chapter Six presents the use of pedagogic discourse during the observed lessons which is analysed in terms of SD in order to show the degree of condensation within socio-cultural practices such as terms, phrases, symbols, gestures, expressions and so forth. These emerging themes (such as the weakening of semantic density, semantic flatline and the reproduction of traditional pedagogy) are given coding categories and presented in tabular form.

Chapter Seven analyses, interprets and discusses the data using an analytic lens in relation to the research question. The key findings were:

- A continued 'down escalator' when teaching. Learners are mostly exposed to non-specialised, everyday knowledge, which will remain context dependent.
- Learners are exposed to segmented learning which suggests weakly classified and framed educational knowledge.
- Content recitation with little to no time for reflection or to relate the knowledge learned to previous knowledge.
- Student teachers lacked sufficient content knowledge, which could continue the cycle of educational inequalities.
- Learners are socialised into the field with a common-sense understanding of LS and, furthermore are unable to link Indigenous Knowledge Systems to other knowledge.
- Despite the student teachers having access to ICTs, these tools are being used to reproduce traditional pedagogies and the unintended consequence is context dependent knowledge.
- An isolated lesson provided traces of Semantic Waves, because the student teacher was able to navigate the learners between simpler understandings and deeper abstract knowledge. This method empowers learners to navigate between the complex meanings of LS.

Chapter Eight concludes the study with recommendations for teacher education programmes, the integration of ICTs in lessons in order to eliminate the lack of science depth, methods for addressing the simplification of concepts and for moving from disconnected, segmented knowledge to a less unequal and racialised system and epistemological access.

1.5 Summary

This chapter provided an introduction to the study. The problem statement, purpose of the study, and the research question were outlined. I discussed the methodological framework and research design and provided an outline of the focus of each of the chapters. I also discussed the motivation to embark on this study. Chapter Two presents the literature review that engages with the education landscape and critical issues around ICTs in education.

Chapter Two

Literature Review

2.1 Introduction

This literature review provides an overview of critical issues around ICTs in education both locally and internationally and the role of teacher education programmes in equipping pre-service teachers to integrate ICT in their teaching practices. I also highlight existing studies on ICT integration in education and take a realist look at current teaching practices. I engage with the term epistemological access, specifically in terms of how it relates to knowledge within the school context.

A wide range of studies suggest that providing schools with ICT capabilities could have a huge impact on learners and teachers because teachers are given the ability to tap into better educational content, teaching aids and administrative systems (Chigona, Chigona, Kayongo, Kausa, 2010; Condie and Munro, 2007; Balanskat, Blamire and Kefala, 2006; Miller, Naidoo, Belle and Chigona, 2006). Research by Mdlongwa (2012) suggests that teaching with technology changes how content is delivered and requires teachers to be comfortable with using these technologies, as well as adapting traditional content into new pedagogical methods. Teaching and learning using technology is the way of the future and educational institutions across the globe are using different strategies to introduce ICTs into their programmes. Strategies include e-learning, assessment tools and administrative tools. Furthermore, teacher education institutions have also introduced ICTs into their pre-service training through teacher education policy interventions. This process entails increased access to ICTs, the offering of ICT courses, as well as ICT integration in current courses (Granberg, 2011).

2.2 ICTs in education

South Africa is faced with the challenge of transforming an education and training system which has been impacted by more than 45 years of apartheid policy. In dealing with the process of social transformation, the 2011 Curriculum Assessment Policy Statement (CAPS) has undertaken to address principles such as equal educational opportunities for all, as well as tackling past educational imbalances by encouraging active and critical learning rather than mere rote learning of given truths (Department of Basic Education, 2011: 4). Globally ICTs are seen as a means of helping to solve the achievement dilemma because ICTs are believed to enable the innovations which are needed to improve education and training for the 21st century learner (Kampylis *et al*., 2012: 6; Redecker *et al.*, 2011:59). Schools, therefore, are pressured to comply with the government's view that all learners must participate in the information society. This practice means that they should be able to use ICTs confidently and creatively in order to develop knowledge and skills to achieve personal goals.

Adding to these pressures are technology advocates who believe ICTs are critical for educational reform and policy makers who are further pushing for ICTs in education and training (Butcher, 2000: 20). Several themes are revealed in terms of the way education can be transformed through technology. Firstly, a focus on the information society and the necessity to integrate ICTs to improve thinking and problem-solving skills as society shifts from the industrial to the information age. Those teachers, student teachers and learners who align their practices to the information society will reap considerable benefits (Thomas and Stratton, 2006). Links are made between ICTs, globalisation, the information society and fears that countries that do not implement ICTs at all levels might be left behind economically (Player-Koro, 2012b:57). Thomas and Li (2008) share this belief as illustrated below:

> We live in an ever-changing world in which knowledge, power and productive capability will be more dispersed than at any time in our history, a world where value creation will be fast, fluid and presciently disruptive, a world where only the connected will survive. In business, in education, and in our personal lives, those who fail to grasp this truth will find themselves ever more isolated, cut off from the networks that are sharing, adapting, and updating knowledge to create value. (Thomas and Li, 2008:199)

The second theme indicates how agency seems to be ascribed to technology (PlayerKoro, 2012b:57) and shows how the use of new technologies inform educational change and transformation. According to Kim and Baylor (2008) particular reference is made to the use of technology in education:

> In the last 20 years technological advances have resulted in new opportunities to use technology to improve learning and instruction. (Kim and Baylor, 2008:309)

Within the third theme, ICT integration has an enormous impact on educational change, for instance, technological integration influences teaching methods as well as the teachers' social relations with students (Savicka and Cunska, 2012). This theme also often sees the teacher blamed for not integrating technology sufficiently:

> There are promising examples of ICT use in support of new learning arrangements. So why is the use of ICT by these teachers still very limited, despite governmental encouragement, the available infrastructure and the positive attitudes of teachers? (Drent and Meelissen, 2008:188)

The last theme sees technology-based learning introduced as one of the individual student rights needed in the 21st century (Player-Koro, 2012:60). Looi, Chen and Ng (2010) believe students need to be equipped with collaborative learning skills, which are key skills needed by the 21st century workforce. ICTs are believed to bring positive changes to the education system, as well as allowing individuals to contribute to or affect the information society (Deb, 2014).

2.3 ICTs and teaching

ICTs can enable teachers to transform their teaching practices and create higher level thinking (McMahon, 2009; Nivala, 2009). However, studies caution that although ICTs can transform pedagogical practices, this process is not automatic (Polly and Ausband, 2009; Maton, 2016). These researchers believe technology in isolation will not transform anything. Some researchers have also openly questioned whether ICTs have any proven pedagogic benefit (Livingston, 2010; 2012) and call for the production Of stronger evidence to show the creative pedagogic uses of ICTs.

Cox and Marshall (2007:64) share this view:

> To date we have had no large-scale longitudinal studies of ICTs' [educational] impact, such as we have in the form of studies of major curriculum development projects.

It is also argued that the focus of researchers is mainly on the potential of using technology to enhance both learning and cognitive development, with limited concern with the broader aspects of education and society (Selwyn, 2012). Dalvit, Thinyane, Muyingi and Terzoli (2007) recognise the benefits new technologies and e-learning can bring to previously disadvantaged communities and have developed an ecommerce platform in Dwesa, a rural area in Transkei, South Africa. Infrastructure, technical support, teaching of computer literacy and promotion of initiative is taken care of during monthly visits. The results of this project emphasise the importance of contextualising the intervention to local needs and to adjust it to the local context. If Thinyane, Muyingi and Terzoli's model is successful, they wish to export it to similar areas in South Africa as well as the rest of Africa.

An international case study commissioned by the Stanford Center for Opportunity Policy in Education (SCOPE, 2014) in a disadvantaged community in Alabama, where 73 percent of learners qualify for free meals, dropout rates are high and university prospects almost non-existent, found that redesigning the school curriculum achieves success. The focus was on learner engagement through active, project-based learning, integration of ICT tools to support instruction and providing teachers and student teachers with the necessary training to make pedagogical shifts. The result over the course of two years was an increase in graduation rates from 63 percent to 87 percent and university acceptance rates from 33 percent to 78 percent (Darling-Hammond, Zielezinski and Goldman, 2014:13). Suspensions, school changes, dropout rates and routine failures, which had become the norm, decreased significantly.

These positive sentiments are echoed in the E-learning Africa Report, 2012. After surveying the e-learning experiences of various stakeholders across 41 African countries over a period of five years, the study found that ICTs allow learners to:

> learn better, learn faster, learn more, learn differently, learn on their own, learn together, learn inside and outside the classroom, learn in a greater variety of

> ways and learn to be creative … as well as [promoting] an emergence of a new learning culture (E-learning Africa, 2012:32).

This new learning culture using ICTs facilitates:

- more independent learning, provided learners are guided appropriately by teachers;
- learners to produce knowledge themselves;
- access to more content via the Internet;
- learners' motivation to learn;
- easier distance learning;
- connections to experts and access to global resources;
- access to quality learning materials;
- a fun learning environment; and
- a better understanding by learners of topics under study. (E-learning Africa, 2012:32)

An earlier study by Kolderie and McDonald (2009:7) shows that teachers can benefit by using ICTs in ways such as reconstructing and improving their methods of presenting, planning and advising, as well as evaluating and reflecting on their work and teaching practice. ICTs also has a positive impact on learners as they can participate in creating knowledge as well as actively engaging in their own learning (Cassim, 2010:17).

However, data obtained from the eTransform Africa (2012) suggests that the deployment of ICTs is not having the desired impact on classroom practices as research such as the E-learning Africa report, would have us believe. The report revealed that there is a focus on computer literacy for teachers, instead of cultivating an understanding of ICT integration in education from a pedagogic perspective. Integration with the curriculum is imperative as is revealed in a case study undertaken in four Western Cape schools, which were selected based on their well-resourced ICT facilities provided through the Khanya project (Mlitwa and Koranteng, 2013). The Khanya project is a Western Cape Education Department (WCED) initiative aimed to narrow the digital divide by placing ICTs in disadvantaged schools. The schools were located in underprivileged communities in the region. Although they did not lack ICT infrastructure, the study found that very few courses and subjects integrated ICTs into their curriculum – only between 1 to 3 of the total school subjects had a computer facilitated aspect. Mlitwa and Koranteng (2013) found that the issues relating to improved teaching and learning practices extend beyond financial limitations to a lack of common understanding between policy makers, school communities and ICT coordinators and teachers who lack knowledge of some of the basic ICT deployment details for their schools.

Another study looked at three disadvantaged schools equipped with computers through the Khanya project. Their interest was to discover how ICTs were domesticated in schools for curriculum delivery. Haddon (2006) defines domestication, as the process in which people deal with technologies when they encounter them, by either fitting them into their everyday routines or outrightly rejecting these technologies. In Chigona, Chigona, Kayongo and Kausa's study, domestication "describes the process of adopting a technology from acquisition to a point when the product is incorporated into the life of an individual or an institution, that is the integration of the technology" (2010:22). The findings of Chigona *et al*. (2010) revealed that although educators were exposed to training, resources and technical support, they made limited use of ICTs for teaching and learning purposes (Chigona *et al*., 2010). Some factors which could hinder domestication include, the low skill levels of educators, limited resources, socio-economic status of institutions and teachers and insufficient training. Although the schools were equipped with computers, there was a high computer-to-student ratio which could lead to disparities in their learning levels (Pawer *et al*., 2006). The educators were exposed to some training through the Khanya project, but this training seemed insufficient to domesticate ICTs in schools because the educators' skill levels did not improve significantly. Chigona *et al*.'s study showed that the socio-economic status of the school and educators in disadvantaged communities had a negative impact on their computer skills because they could not afford to acquire additional training. Additionally, the study showed that most of these educators were economically challenged and could not afford a home computer or fund their own ICT training arrangements. One of the schools that successfully appropriated ICTs managed to source additional training through a special arrangement with a training company housed on the school premises. However, it was found that the economic situation in most schools in disadvantaged areas means that they cannot afford self-funded training arrangements.

Hardman's (2005) study sought to understand how teachers used computers to teach mathematics in a rural farm school outside Cape Town. The study sought to understand whether technology altered teaching pedagogy and the researcher found that while the learners had sufficient access to computers there was a "contradiction between the computer as a tool for creative student-centred learning and the computer as a tool for lower level drill and practice skills" (Hardman, 2005:12). The introduction of computers into the classrooms of disadvantaged schools did not shift the teacher's pedagogical practice from traditional transmission pedagogy to a more collaborative practice. Teachers did not heed the call from the Minister of Education "…to take full responsibility to deliver ICTs in education [because] the fate of future generations of learners is in our hands [and] we can ill-afford to fail them," (Motshekga, 2016).

Calls such as these are laudable but, unfortunately, the wide, practical implementation of ICTs in education has been lagging (Mdlongwa, 2012). South Africa has a host of dispersed programmes and projects that attempt to integrate ICTs into schools (Isaacs, 2008). Educational practices, as revealed in the case studies cited by Isaacs (2008) may run counter to the optimistic views of the potential of ICTs in education (Selwyn, 2011).

2.4 ICTs in schools

Although teachers claim to have changed their classroom practices, they are merely using computers to do what they have done before, making them a supplement for existing teaching-learning methods (Cuban, 2001). There are no meaningful changes implemented which would transform the teaching and learning from traditional to more advanced digital methods (Cuban, 2001). Player-Koro (2012a) found that traditional subject culture was merely reproduced using digital technologies, for example, "a consistently traditional powerfully classified and framed teaching-learning practice that was built around highly ritualised and structured rules for the transmission of mathematics. This was based on solving exercises related to an examined-textbook based content" (Player-Koro, 2012a:107). Furthermore, results from the PanAf Research Agenda (2008 – 2011) reveal that the focus in classrooms is still on ICT as a tool. Thus ICTs are not used as a way to learn, but rather as a tool to display what is taught. The Economic and Social Research Council (ESRC) funded a two-year project which carried out video case studies in four classrooms in the United Kingdom. They found that the introduction of interactive whiteboards (IWBs) in the classroom involves more than the mere installation of hardware and software. Teachers play a vital role in mediating and integrating software appropriately into the lesson aims, thereby promoting quality interactions and interactivity (Armstrong, *et al*., 2005). New technologies can easily be consumed into existing ways of working instead of transforming teacher pedagogies, thus simply being used as an 'interest enhancer [rather] than as a new approach to learning' (Glover and Miller, 2001:269). Technology may not afford the necessary interaction to transform teaching practices and create higher level thinking skills if simply used as a tool. Armstrong, *et al*., define interaction as:

> the give and take between pupils and teachers, which goes beyond a superficial learning scenario to a stimulating interplay which leads to new formulations and new understanding. (Armstrong, *et al*., 2005:457)

The role of a teacher becomes crucial in integrating ICTs into schools because teachers function as mediating agents between the technological tools (ICTs) and the subject matter which is being taught.

A considerable focus within the literature under review has been on the lack of resources and technical support for the use of technology in the classroom in disadvantaged schools (Mlitwa and Koranteng, 2013; Manduku, Kosgey and Sang, 2012). Sedibe (2011) sought to explore and describe the inequality of access to resources in previously disadvantaged South African high schools. Following an interpretive qualitative research paradigm, three disadvantaged high schools were selected using a purposive sampling method. The study found that although schools were equipped with computer laboratories, the lack of electricity hindered technology use. In their study, Manduku, Kosgey and Sang (2012) used a survey research methodology and collected data from 300 teachers and head teachers in secondary schools in Kenya. The aim of their study was to explore challenges faced by schools in ICT use and adoption. One of their findings was that a lack of technical support hampered the effective use of ICTs in schools.

Claims by technology advocates are that ICTs can make extensive changes to traditional teaching models (Player-Koro, 2012b; Thomas and Li, 2008), especially in South Africa where overcrowded classrooms have become the norm in disadvantaged communities. According to the Department of Basic Education, as of March 2018, the national average LER (Learner-Educator Ratio) for government primary schools was one teacher to every 35.2 learners (BusinessTech, 2018). Ground Up's article (2018) indicates a ratio of 1 to 51. There are classrooms where 205 learners are cramped together with poor ventilation and up to five learners share a double desk. Some of the classrooms have no space for desks and learners are sitting with books on their laps. More than 1630 learners are accommodated in 14 classrooms (Savides, 2016).

Research seems to indicate that ICTs can increase efficiency in overcrowded schools, by implementing dual shift systems (Haddad and Draxler, 2002:32) in which students spend half of their teaching/learning time each day at school and the rest of the time in unconventional settings such as the home, libraries or community centres participating in computer-assisted lessons or watching educational programmes on television, without reducing their actual study time. Furthermore, many South African schools lack sufficient infrastructure and use multi-grade classrooms where different Grades share one classroom (Savides, 2016). There are currently about 5837 multi-grade schools in South Africa (DBE, 2018). ICTs can provide opportunities for a teacher to focus on one group of learners while another group is given ICT educational programmes to keep them occupied in learning activities (Haddad and Draxler, 2002:32).

The belief that ICTs have the potential to enhance the learning environment has led to a rapid increase in government- and donor funded projects aimed at providing disadvantaged schools with resources (Chigona *et. al*., 2010). Duncan (2011) argues that these funded projects often cause harm rather than solve the current educational problems, because disadvantaged schools often lack funding for basics such as electricity, toilets and desks, thus obtaining funding to set up secure classrooms to host computers, and finding tutors and teachers to teach ICT skills, is often daunting and thus frequently lacking. Although some research suggests that the success of ICT projects in disadvantaged schools depends on suitable infrastructure (Disraeli, 2001:4), others suggest that sustainability plays a key role as well:

> A sustainable means of accessing ICT infrastructure is the only way to bridge the gap between the poorest schools in the lower quintiles and those that can afford the necessary IT equipment. What the education sector needs is a long-term solution to IT needs; not corporate dumping of used equipment. (Duncan, 2011:1)

Akinsola, Herselman and Jacobs (2005:15) caution that deployment of ICTs in schools in marginalised communities requires more than ICT equipment donations and the funding of specialised IT related training programmes at these centres; there is a need to pay more attention to the schools' sustainability. In their view, other risk factors exist in relation to the provision of ICTs in disadvantaged communities such as lack of ICT policy, implementation delays (which could result in a loss of interest), technology adaption, lack of maintenance and technical support, rapid technological changes, as well as a lack of donor coordination. Bridging the digital divide in these disadvantaged communities would require suitable telecommunication infrastructure, government policies that encourage ICT usage, a management structure that is committed to maintenance and funds to cater for improvements (Akinsola, Herselman and Jacobs, 2005:33).

2.5 ICTs in Science education

> *"Global competiveness is driven by technological innovations and therefore we have an increased demand for scientific skills to accelerate growth" (Reddy, et al., 2016).*

Two distinct views exist within the field of Science education, one that places emphasis on the need for science education to develop knowledge and understanding of basic scientific principles and another that argues for an emphasis on the processes of science thinking (Osborne and Hennessy, 2003:2). Within the traditional category, teaching science is perceived as the transferring of knowledge from textbook and teacher to students (Howard, McGee, Schwartz and Purcell, 2000) thus “for successful learning (of) science, students, need to memorise relevant scientific formulas and definitions” (Tsai, 2002:775). Laboratory work consists of teachers explaining exercises and learners ritualistically completing these exercises, like a “cookbook” (Hofstein and Lunetta, 2003:40) in contrast to the constructivist category whereby science is perceived as helping students to construct knowledge, through new and exciting ways (Roehrig and Luft, 2004).

Despite these distinct views, Abdullahi (2014) believes that training teachers and student teachers in using ICTs for teaching science appears to have yielded more success than in any other subject. However, Ayogu (2015) found that science teachers training in ICT usage was often limited. Although ICT facilities incorporated the use of projectors, computer systems (with efficient peripherals), PowerPoint facilities, audio-visual equipment, computer-aided instruction packages, email services, games and simulation applications, these teaching tools were not used effectively in the training of science teachers. Barriers identified in using ICT facilities to train science teachers include:

- limited ICT facilities;
- inadequate computers and allied accessories for ICT-based instructions, inadequately skilled personnel for ICT-based instruction;
- insufficient internet facilities;
- limited access to internet connectivity;
- irregular power supply;
- inability to repair faulty ICT facilities; and
- inadequate computer laboratories;

(Ayogu, 2015:7)

When teachers are not sufficiently trained in using ICTs this limitation has implications for quality science education because the teacher manages the learning environment and facilitates learning activities. The knowledge teachers bring to both pedagogical processes and the subject matter determines the quality of the teaching and learning outcomes. Teachers cannot teach skills that they do not personally possess, therefore, effective training in and through the use of ICTs empowers teachers and is fundamental in quality instructional delivery (Ayogu, 2015:8).

With modern technologies, teaching and learning can be strengthened to redress past inequalities, especially in science and mathematics (Ndlovu and Lawrence, 2012). With ICT driven activities such as interactive tutorials, self-assessments, simulations, virtual environments, online tools, educational software, data logging and concept maps, curriculum outcomes can be achieved. Furthermore, ICTs have the potential and capacity to overcome barriers such as fiscal constraints, spatial barriers and other capacity-related limitations to deliver quality education (DoE, 2004:8). Ironically, South African teachers who teach mathematics and science have the lowest ICT usage (Blignaut, Els and Howie, 2010:566). Van Der Walt and Maree (2007:225) and Blignaut, *et al*. (2010) believe that this problem results from the fact that traditional curriculum goals are prioritised over 21st century learning skills. Although ICTs can expand the pedagogical resources available to science teachers (Al-Alwani, 2005), Blignaut, *et al*. (2010) reported that science teachers still reported a lack of ICT competence in rudimentary ICT pedagogical practice and, unfortunately, until such basic competence is achieved, visions such as the 2014 e-Education White Paper which aims to transform learning and teaching through ICTs and to produce ICT capable learners will not be achieved if teachers are not pedagogically equipped.

Although many physical science teachers acknowledge the value of ICTs in teaching and learning, the pedagogical use of ICTs in South African schools remain gloomy (Law, 2009:321; Law and Chow, 2008). Barriers, such as a lack of ICT in laboratory work were highlighted as obstacles to realising pedagogic goals both locally and internationally and basic internet connections were more a local hindrance (Law, *et al*., 2008:87). South Africa ranked as one of the five lowest performing countries in science and mathematics in the 2015 TIMSS research (Reddy *et al*., 2016). Results show that merely 32% (one third) of Grade 9 science learners the minimal level for science, reflecting high educational inequalities, mirroring an unequal society. However, there was a slight improvement in learner performance from 1994 to 2015. Moving from extremely low to low. Patterns reveal that an estimated 80% of these learners achieve the minimal level of competency at independent schools, 60% at public fee-paying schools and an alarming 20% at public no-fee schools (Reddy, *et al*., 2016:15).

An Organisation for Economic Cooperation and Development (OECD) report revealed minimal improvements in student achievement in mathematics or science in countries that have invested heavily in ICT for education. The report, which is an international comparative analysis of the digital skills acquired by students, and of the learning environments designed to improve these skills, also revealed that technology had little to no effect in narrowing the skills divide between advantaged and disadvantaged students (OECD, 2015). This analysis shows that there is still a noticeable lag behind the products and promises of technology.

2.6 The role of teacher training programmes

Teacher preparation programmes are faced with preparing teachers and student teachers with knowledge to integrate ICTs into their classroom practices. Sosibo (2012) noted that ICT taught subjects at a University of Technology (UOT) lacked pedagogical knowledge and were not taught as major subjects. Pedagogical implications were not considered as the focus of these ICT courses is on skills development. Teaching computer skills rather than how to integrate ICTs into education is problematic (Goktas, Gedik and Baydas, 2013). Njenga and Fourie (2010) further support this argument in their ICT integration study:

> Indeed there has been no clear distinction between teaching with and teaching about technology and, therefore, the relevance of such studies has not been brought to the fore. Much of the focus is on the actual educational technology as it advances, rather than its educational functions or the effects it has on the functions of teaching and learning (2010:200).

This fundamental misconception about ICT integration is further highlighted in a study by Maholwana (2007) that looks at challenges faced by secondary school teachers in integrating ICT into the curriculum. According to Maholwana,

> In South Africa ICT has been introduced as Information Technology or Computer Application Technology (CAT) in the Further Education (FET) band. IT is a subject of specialisation which learners who are interested in programming computers and may want to study Computer Science at University take. On the other hand, CAT enables learners to integrate ICT into their curriculum. It provides them with an opportunity to use software such as MS Word and MS Excel. (2007:15)

Skills development is highlighted as CAT involves the study of computer components (hardware and software) and how applications can be used to solve problems. CAT does not teach ICT integration. This concern is further amplified in a study by Chigona and Chetty (2012) who found that teacher educators were not realising the potential benefits that ICTs could offer in enriching learning environments and stimulating high-level thinking and reasoning and recommended that institutions need to focus more on the training of teacher educators to integrate technologies into their pedagogies.

Zhang and Martinovic's (2008) study reveals that pre-service teacher educational programmes are lagging behind in terms of ICT integration training, because they are slow to change. There should be specific training on ICT pedagogical content knowledge and it should be extended over a few semesters. A concern is that teacher educators often use far less sophisticated technologies to train teacher education students than those readily available in schools. Grove concurs:

> As more technology is placed in school classrooms, the need for knowledgeable teachers to use these tools effectively becomes a pressing issue. (2008:1)

The 2015 Cape Peninsula University of Technology (CPUT) enrolment statistics illustrate that 60.5% African and 26.7% Coloured students enrolled for the year in the Educational Faculty and these students would most likely come from previously disadvantaged backgrounds because the provision of education in the post-apartheid South Africa continues to be structured along race and class lines (Chetty, 2014). These student teachers are trained and equipped to go back into their communities with the aim of redressing the problems facing disadvantaged schools. Students from previously disadvantaged backgrounds generally struggle to engage with ICTs (Thinyane, 2010). Hence, teacher education programmes play a vital role in preparing student teachers to facilitate learners' epistemological access through ICTs. A matter of concern is raised in a study surveying 210 student teachers that found that 30% of them felt that they were not expected nor required to integrate technology into their subjects when they teach (Dexter and Riedel, 2003:338).

2.7 Teachers' pedagogic practices

Many predictions are made about how the use of technology will change teachers' pedagogy by facilitating new classroom activities, improving the quality of work and increasing productivity (Hartley, 2007; Ottestad, 2010). This expectation is not surprising, because ICTs in educational practice is supported by theories of learning such as Constructivism. Learning is viewed as a process whereby individuals actively construct knowledge through interaction, rather than merely sitting in traditional lectures (Haddad, 2003; Hartley, 2007). Individual teachers' beliefs around technology usage within teaching and learning play a vital role in classroom use (Lui, 2011).

Teachers with traditional pedagogic beliefs are less likely to use ICTs in their teaching and learning practices (Sang, Valcke, van Braak, Tondeur and Zhu, 2010) and when they do, it is generally to acquire ICT skills or to represent information (Lui, 2011). Disparities often exist between teachers' beliefs and their classroom practices (Chen, 2008). Teachers may have Constructivist beliefs, but still use technology very traditionally. This is because traditional methods prevail (Kane *et al*., 2002). Kaymakamoğlu's (2018) study which explored the fit between teachers' beliefs and their classroom practice in order to acquire an in-depth understanding of the teachers' beliefs, perceived practices and actual classroom practices, confirmed the findings of these earlier studies. The findings of this study again showed that although teachers' perceived practice was Constructivist, traditional teaching methods were more frequently implemented (Kaymakamoğlu, 2018).

There are a variety of reasons for these disparities between theory and practice. Li (2007) found that the fear of being replaced by computers largely contributes to the non-adoption of computer technology, whereas Wallace and Kang (2004) found inconsistent beliefs about science teaching and science learning. In this latter study, a student-centred (Constructivist) approach was used in physics education, while the same teacher conducted a teacher-centred (traditional) class in chemistry lessons (2004:958). This study indicates that teachers' internal belief systems may not be consistent. Although ICTs are believed to transform authoritarian pedagogic modalities, a study using Bernstein's (2000) theoretical framework on how knowledge is produced and reproduced, looked at mathematics teaching using digital technologies and found that although there are claims that technologies can open up new ways of seeing, learning and understanding mathematical concepts, the traditional subject culture was simply reproduced using digital technology (Player-Koro, 2012b:97). Further, studies on the affect ICT has on pedagogy expose the sad reality that traditional pedagogy continues to be mindlessly perpetuated (Granberg, 2011; Player-Koro, 2012a) and not aligned to transformation as some researchers believe.

Researchers call for a radical change within teachers' educational practices to link traditional authoritarian cultures with the needs of the new generation of 'digital natives' (Prensky, 2001). There is an argument that social software can add more meaning to learning, by creating learning cultures that are more in correspondence with student interests (Minocha, 2009:12). One could argue that these Constructivist views (Minocha, 2009) can be deceptive, because, as Bennett and Maton (2010) observed, learning is more privileged than knowledge. This view "de-privileges education, teachers and knowledge while valorising the proclaimed attributes of the tech-savvy students" (Bennett and Maton, 2010:325). Skeptics, such as Jenkins (2004), call for differentiation between formal and informal learning. They believe computer games do not equip students with the essential skills privileged in academia. On the other hand, determinists call for the boundaries to be blurred between formal and informal learning, (Annetta, *et al*., 2006).

Bennett and Maton (2010) are of the opinion that formal and everyday contexts are different because the symbolic 'capital' differs in both the contexts. They caution that educators and researchers should avoid creating dichotomies between education and everyday contexts and rather strive to understand,

> ...what knowledge and assumptions students bring to the academic context from other aspects of their lives, and what that means to teaching and learning. (Bennett and Maton, 2010:326)

Bennett and Maton (2010) highlight the important role teachers play in 'pedagogised' knowledge. Pedagogised knowledge occurs when teachers select knowledge, rearrange it within the curriculum and recontextualise it within specific contexts. Their role, therefore, is to relate students' current learning activities to different contexts. The role of a teacher, thus, is very crucial for integrating ICTs into education, because teachers serve as mediating agents between the technological tools used and the subject matter being taught in any given context (Fagan, 2014:3).

2.8 Integration of ICTs

Khatete, *et al*., (2015) explored the extent to which ICTs are being integrated into the teaching and learning process by teachers and students in Nyeri, in the South District of Kenya. With a target population of 34 public secondary schools, a descriptive survey design was used to obtain a 'ground-view' understanding of what is happening in these schools. The survey's findings revealed that these schools had the capacity to initiate the integration of ICTs into teaching and learning, yet this was not the case in the classroom. Moreover, the teachers' and principals' ICT competence was low in contrast to that of the learners who seemed enthusiastic to learn using ICTs and exhibited a high usage of ICT applications such as Facebook and Twitter.

Chikasha, Ntuli, Sundarjee, and Chikasha (2014) reached similar conclusions in their study that investigated factors that affect ICT integration among secondary school teachers in Johannesburg, South Africa. These researchers believe that the level of ICT infrastructure and support is not a significant predictor of ICT usage by school teachers but found that positive attitudes towards the usage of ICT for teaching and learning purposes, and the perceived ease of use, affected the actual usage of these technologies. These findings suggest that teachers are most likely to integrate ICTs into their curriculum if they believe that ICTs can enhance teaching and learning.

Bingimlas (2009) and Afshari, *et al.* (2009) also highlight barriers, which they believe might further hinder the effective integration of ICTs into education. These barriers include technological anxiety, lack of infrastructure, teachers' attitudes, lack of technical support, teachers' perspectives on ease of use, as well as the usefulness of the ICTs. Studies focusing on presenting a 'holistic account' of the contextual factors that influence how teachers use technology within the classrooms (Scheuermann and Pedro, 2010:7), omit to consider the structuring of educational knowledge as an influence on the integration of ICTs (Howard and Maton, 2011:193). Although the findings of these studies should not be dismissed because they highlight some valuable insights into a variety of factors which might affect integration, they however lack analysis or insights into the underlying principles of what is being taught and learned in science and maths classrooms (Howard and Maton, 2011:193).

Researchers and educators should ensure proper integration of ICTs with pedagogic issues and curriculum (Draper, Howie and Blignaut, 2008). Zhang and Martinovic's (2008) study of a consultative process with pre-service teachers investigated whether an ICT course was expected to equip students with the necessary skills to integrate ICTs into their classroom teachings. The researchers found that pre-service teachers with a science background, were more interested in the skills-oriented part of the course and less interested in the theoretical elements and viewed this aspect as an added burden on their already busy programme. These pre-service teachers preferred options that would satisfy "their current needs in the field, rather than those that would show them the possibilities of innovative pedagogies" (Zhang and Martinovic, 2008:16).

The study by Chigona, *et al.* (2010) investigated factors that affect the integration of ICTs in teaching and learning. Drawing upon the pedagogic practices of teachers from random schools in disadvantaged communities in the Western Cape, they found that several factors impede the integration of ICTs in teaching and learning. These are:

- Lack of technical support;
- Lessons planned without ICT integration because educators were unsure that equipment would be in a working condition; and
- Limited resources, such as a high learner/computer ratio, also discouraged educators from using technology. (2010:28)

A similar study by Mulhim (2014) found that educators teaching in disadvantaged schools make limited use of ICTs for teaching and learning because they lack the necessary skills. As a result, some schools have computer laboratories permanently locked and used only for 'special occasions' (Chigona, *et al.*, 2010). Instead of meaningfully integrating ICTs in education in developing countries as the policy makers, funders and governments intended, there is a mismatch between the values assigned to ICT usage by teachers as a means of improving educational outcomes (Bladergroen, *et al.*, 2012). This study shows that increased investment in ICTs does not translate to greater use nor does it improve educational outcomes.

Studies on educators' perspectives and perceptions in terms of ICT integration in education showed that educators felt that the lack of sufficient training, which they believe is critical, was a barrier to the successful integration of ICTs (Davids, 2009) into their teaching practice. Some educators felt that it was not required of them to use ICTs for curriculum delivery (Bladergroen, 2012) and no policies existed governing their implementation (Anderson *et al.*, 2007). Also due to institutional and personal factors, educators felt disempowered and less capable to manage their use of technology (Bladdergroen, 2012:116).

A qualitative study by Mlitwa and Koranteng (2013) in four disadvantaged schools in the Western Cape, sought to understand the challenges in the integration of ICT into schools and curricula. The study used Activity Theory (AT) to gain a holistic view of the phenomena at hand. The e-Schools system was presented as an activity system. The findings revealed that very few schools had integrated ICTs in their courses and subjects although they were provided with support, resources and infrastructure, as well as the provision of computer-based educational programmes. This study thus highlighted significant gaps in the e-Education policy implementation process.

2.9 Epistemological access and knowledge

The term 'epistemological access' is used in the literature under review with the intent of moving beyond physical or formal access to meaningful access of knowledge (Muller, 2014). According to Rambe and Mawere (2011:6) epistemological access is an acquisition of the discursive, linguistic and textual practices of a discipline which students require to effectively function in a specific academic discipline. Muller, (2014:264) provides different perspectives to the question, 'What is epistemological access affording access to'? Rationalists believe 'epistemological access' gives access to "knowledge of propositions and theoretical systems" (Muller 2014:264). Empiricists on the other hand would argue that 'epistemological access' gives access to "knowledge of things themselves", in other words, the belief that knowledge comprises empirical facts only (Muller, 2014:264). The neutral view (neither Empiricism nor Rationalism) would be that epistemological access gives access to "a practice, [together with] its associated rules, norms and customary moves" (Muller, 2014:264). The danger of the latter view is that knowledge is in danger of being dissolved into practice and, in doing so, one might lose sight of its specificity.

Morrow (2007) argues that teacher education should enable epistemological access to knowledge in the modern world and that teacher education requires new ways of thinking about teaching and learning in South Africa. He problematises what he believes is the dominant Empiricist view as being obscured by the ideologies of learner-centred and outcomes-based education. He argues, that these problems have come to shape curriculum thinking and teaching practice. Teaching practice, therefore, takes place in a muddled epistemological context. Although suggesting that teachers need new ways of teaching if they are to provide learners with epistemological access, he merely alludes to the need for a Realist focus. Morrow (2007) does not make clear what is meant by this Realist focus.

The reviewed literature suggests that to open epistemological access it is necessary to explore curriculum responsiveness (Slonimsky and Shalem, 2006:37). Slonimsky and Shalem draw on the work of Moll (2004:4-7) who claims that curriculum responsiveness embraces cultural, economic, disciplinary and learner responsiveness. Each of these theories is further unpacked below.

Cultural responsiveness to the curriculum refers to drawing from various cultures as well as teaching from different cultural perspectives. Gay (2000) views 'culturally responsive' teaching' as:

- acknowledgement of the cultural heritage of different ethnic groups, as legacies that affect learning and as worthwhile content of the formal curriculum;

- the building of “bridges of meaningfulness” between academic abstractions and lived socio-cultural realities of students (e.g. between home and school);
- a wide variety of instructional strategies related to diverse learning styles;
- teaching learners to understand and value their own and each others' cultural heritages; and
- incorporation of multiple cultural resources and materials in all the subjects and skills routinely taught in schools. (Gap. 2000:29)

Cultural responsiveness acknowledges student diversity by expanding on instructional strategies and learning pathways (Moll, 2004:4).

Economic responsiveness refers to institutions, through their teaching and learning, being able “to meet the changing needs of employers, and hence to provide them with personnel who will be able to increase their economic competitiveness" (Moll, 2004:4).

Disciplinary responsiveness, simply put, is knowing one’s discipline. The curriculum is responsive to the nature of its underlying knowledge discipline by ensuring a close coupling between how knowledge is produced and the way students are educated and trained in the discipline area (Moll, 2004:7). Kelly-Laubscher and Luckett (2016) used an aspect of LCT called Semantics to analyse the type of epistemological access (disciplinary knowledge) students need to gain at school to be successful at universities. The difference in the structuring of knowledge that exists in a high school and university biology curriculum was explored. Analysis was conducted by comparing the same topic in the university and high school textbooks. They found a clear mismatch between the knowledge range students navigate in the high school biology subject and the knowledge range demanded by the university. Most of these discussions still point to what constitutes epistemological access in order to get entry to Higher Education (HE) institutions, as first coined by Morrow (2009) when he grappled with HE policy making and practice. *Learner responsiveness* is ensuring that learners understand the curriculum. In other words, finding the best way to teach learners in a particular course (Moll, 2004:7).

2.10 Epistemological access and schools

The reviewed literature indicates two distinct views on how learners could gain epistemological access through schooling. The first view favours separating everyday knowledge or 'horizontal knowledge' and school knowledge or 'vertical knowledge' (Bernstein, 1999:159). The other view advocates bringing the two forms of knowledge together in the teaching process (Hattam and Ziplin, 2009). Fataar (2012:55) suggests that making a pedagogic connection between these two knowledge codes requires educators and learners to move beyond binary social justice thinking. He describes the complex nature of some schooling in the South African context:

> The children of the black working classes and unemployed poor go to great lengths to access what they perceive as better schools across the city, where they end up receiving a modernist curriculum that strips them of their access to their cultural knowledge and social survival epistemologies, on the assumption that modern middle-class education is what will emancipate them from their parochial cultural identifications. The assumption of cultural assimilation is hard at work in the urban post-apartheid school, albeit with multicultural genuflection to the newer incoming kids' backgrounds. Assimilationist curriculum practices are alive in the city's classrooms, which ostensibly provide the vehicle for their induction into modern life. (Fataar, 2017:7)

Schools are inducting learners into a "one-dimensional, modern racial-colonial canon" (Fataar, 2012:56), which denies learners discursive recognition of both their physical and ontological world. Ndlovu-Gatsheni (2017:51) argues that African people had their own body of knowledge prior to colonisation and when learners are offered cultural assimilationist school experiences (Fataar, 2007) schools maintain an exclusivist culture, where most teachers originate from racial groups other than the learners in their classes, aid in "retaining their school's hegemonic orientations" (Fataar, 2012:56). Educators must establish a pedagogical relationship between the two knowledge discourses. A relationship that respects the importance of 'vertical' school knowledge and the life experiences of disadvantaged students (Fataar, 2012:55). This affiliation can only happen when schools recognise and affirm the diverse heritages, cultures and languages of all its learners (Luckett, 2015).

Lotz-Sisitka (2009) explores the teaching practices observed in rural public schools in the Eastern Cape. In one such case, a Grade 11 student drops out of school, despite being intellectually capable and eager to learn, after struggling for years having to ask for help with assignments and terminology, he did not understand in all learning areas. According to Lotz-Sisitka,

> the child's experience of schooling was littered with 'foreign words' that apparently held little meaning; concepts that were not accessible to him through the cultural resources in his life world (except through the innovative strategy he used in asking for help with his homework through which he could access other cultural resources and a mediation process, (2009:61).

The second case follows a lesson during which learners are asked to answer questions. The teacher writes the instructions on the board and learners are asked to go outside into the garden to finish the practical component of the lesson. The teacher, however, is unable to follow through on the intended lesson outcomes which involves listing the names of the vegetables on the board, because she lacks an understanding of the plants that grow in the area in which the school is located. The learners are thus left to "work in the garden" until the end of the lesson (Lotz-Sisitka, 2009:63).

The third case follows a teacher who refuses to teach learners a specific topic because he feels the learners would possess more knowledge of the subject than himself as they are originally from the locality in which he is teaching (Lotz-Sisitka, 2009:63-64).

Errors made in teaching and assessment of learners' work is also prevalent in other cases. As found in similar studies (Mazingiza, 2009) when Learning Outcome and Assessment Standards were reduced, recontextualisation took place at a superficial level, which both missed learning opportunities and lacked a deeper understanding of curriculum discourse.

The first case highlights instances in which the curriculum is not responsive to the needs of the learners, the second case highlights a lack of disciplinary knowledge on the part of the teacher and the third case portrays teachers who do not understand how to include cultural aspects into their lessons. These challenges are limiting epistemological access and conflict with social justice calls. Henning (2012) warns that:

> A country cannot claim social justice in education if teachers do not know their subjects, and if they do not know how the children and youth whom they teach learn these subjects. (2012:185)

This lack of knowledge on the part of teachers is problematic, especially in South Africa, where teachers are frequently accused of lacking sufficient content knowledge (Du Plooy and Zilindile, 2014:198). This deficiency has unintentional implications for social justice approaches to education. Further challenges to providing learners with epistemological access are illiteracy rates and a lack of understanding of the potential of computers. Rambe and Mawere (2011) found that epistemological access in Mozambique's schools has been delayed by low literacy rates, a minimalist understanding of literacy, and teachers' failure to use computers to develop critical literacy, and ask for a conception of literacy "that transcends the acquisition of decontextualised skills to embrace literacy as a practice that is deeply implicated in the exercise of social power, self and relational positioning and the application of agency", (Rambe and Mawere, 2011:21).

2.11 Summary

This chapter outlined the educational landscape in South Africa in terms of ICTs. It surveyed issues related to ICT integration and usage in schools, specifically disadvantaged schools. The role teacher training programmes play in preparing future teachers to integrate ICTs in their teaching practice was explored and the findings revealed that the focus is still primarily on skills development. There has not been sufficient shifts in realising the knowledge accessing potential when ICTs are fully integrated into teaching practices. This chapter uncovers shifts in teachers' pedagogic practices when ICTs are integrated into their teaching. Teachers are a crucial factor for the integration of ICTs into education because they are essentially the mediating agents between the subject being taught and the technological tools used. There was also an engagement with the complex issue of epistemological access. I first established what is meant by epistemological access and then discussed insights into how learners could gain epistemological access. The following chapter engages with conceptual and theoretical debates which could provide a lens to answer my research questions.

Chapter Three

Theoretical Framework

3.1 Introduction

Bernstein (1999) distinguishes between two forms (discourses) which knowledge can take. These are horizontal discourse which takes the form of (i) 'local, segmentally organised, context specific and dependent' knowledge (1999:159), meaning everyday or common-sense knowledge, and (ii) vertical discourse which can either be 'coherent, explicit, and systematically principled structure, hierarchically organised' knowledge or 'a series of specialised languages with specialised modes of interrogation and specialised criteria for the production and circulation of texts' (1999:159). Bernstein regards the latter form as being school or academic knowledge. Bernstein also distinguishes between the two knowledge structures found in vertical discourse. These are hierarchical knowledge structures more often found in the natural sciences and horizontal knowledge structures found in the humanities and social sciences.

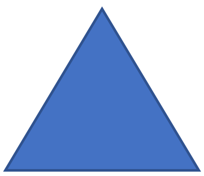


Figure 1: Hierarchical knowledge structure – Bernstein (1999:162)

In this form of hierarchical knowledge theories are integrated and previous knowledge subsumed at the lower levels to operate at more abstract levels.

L1 L 2L 3L 4L 5L 6L 7 … Ln

Figure 2: Horizontal knowledge structures - Bernstein (1999:162)

Horizontal knowledge structures depicted, however, as Ls in a horizontal line, represent a 'series of specialised languages with specialised modes of interrogation and criteria for the construction and circulation of texts' (Bernstein, 1999:162). These modes of interrogation develop through the accumulation of a series of specialised languages with different methodologies to theoretical construction.

Maton (2009) argues that Bernstein's focus is on the 'production of new knowledge in intellectual fields' but fails to address how knowledge develops within a curriculum or students' learning experiences. Maton contends that this exploration can be completed by:

> …distinguish[ing] the ways in which students' understanding develops over time (as evidenced by, for example, their work products), according to whether they build on their previously learned knowledge, and take that understanding forward into future contexts, or learn knowledge that is strongly bounded from other knowledges and contexts. (Maton, 2009:45)

Maton (2009) calls this type of development, cumulative learning, in other words, it involves students being able to transfer knowledge across contexts and through time. This method is different to segmented learning, in which knowledge transference is inhibited. Supporting Maton, Shalem and Slonimsky (2010) argue that in the field of knowledge production the emphasis is on building vertical knowledge structures, whereas the field of knowledge reproduction requires movements between abstract and concrete knowledge.

Bernstein (1975) describes a language of description for pedagogic discourse in terms of 'classification' and 'framing'. Classification is used to show the way in which knowledge is organised, as well as the relationship between every day and educational knowledge, whereas "framing refers to the degree of control a teacher and learner possess over the selection, sequencing, pacing and evaluation of the knowledge transmitted and received in the pedagogical relationship" (Bernstein, 1975:88). Classification is stronger when there are clear distinctions between boundaries and categories and weaker when integration occurs or boundaries are blurred. Strong framing would signal more control for the teacher in terms of how knowledge is transmitted, while weaker framing would suggest more control being given to the learners in terms of sequencing, pacing, selection and evaluation of the knowledge transmitted.

Hoadley (2005) drawing on Bernstein's concept of classification and framing, reveals how social class differences can be reproduced through pedagogy, and the role of the teacher in this process. Her findings showed that there was a prevalence of localising strategies within the working-class context where learners engage with familiar and non-specialised knowledge every day, in a contrast to the middle-class context where students are exposed to specialised knowledge. Within the middle-class context, pedagogy was driven by esoteric domain principles foregrounding the abstract aspects of learning, while the working-class context pedagogy was built upon a public domain logic, and tasks were connected by themes rather than particular concepts. Hoadley (2005) argues that these differences in the reproduction of knowledge serve merely to reproduce social class differences, because teachers operating within the middleclass context made available elaborated orientation, while teachers within the working class context usually restricted the learners' orientation.

Chetty notes that schools and universities are important agents in reinforcing these social injustices, "what counts as official knowledge are all tied to the production of unequal class outcomes" (2014:92). He further argues that students from working class backgrounds are victims of poor quality public education which impedes their opportunities to gain entrance to tertiary education and asks the pertinent question "So where can a bright, intellectually ambitious poor student turn?" (2014: 96). Fagan (2014) shows that the recontextualising agent has a huge responsibility. The way the student teacher is inducted into the field has major implications for learners. Student teachers are exposed to 'trained gazes' and are thus unable to move beyond their current context. "There is no evidence of rich theoretical educational knowledge to supplement what they already know" (Fagan, 2014:78) a fact which shows that, while middle-class students' everyday skills might be polished, they are excluded from being taught powerful pedagogic ICT discourses which can be implemented in future classrooms. Fagan further argues that this situation occurs because the focus of their training is more on everyday technological knowledge, which benefits only those students who already possess the right social capital or resources (2014:78).

3.2 Technological pedagogical content knowledge model

The Technological Pedagogical Content Knowledge (TPCK) model allows us to understand the knowledge needed within the field of educational technology (Koehler, Mishra and Yahya, 2007). The TPCK model extends Shulman's (1987) Pedagogical Content Knowledge (PCK) model, in which content and pedagogical knowledge are brought together in teaching practices. The TPCK model serves as a way of thinking, understanding and explaining teachers' use of technology in their classrooms. This model argues that using technology in the classroom requires 'teachers to possess knowledge that connects the affordances (and constraints) of these new technologies to the transformation of content and pedagogy' (Koehler *et al*., 2014:102). TPCK is an interplay of the three primary forms of knowledge, being Content Knowledge (CK), Pedagogy Knowledge (PK) and Technology Knowledge (TK). Furthermore the TPACK framework emphasis the kinds of knowledge that lie at the intersections between the three primary forms: Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge

(TPK), and Technological Pedagogical Content Knowledge (TPACK) (Mishra and Koehler, 2006). To effectively integrate technology into pedagogy in different subject areas educators require sensitisation to the complexity of the transactional relationship between components of knowledge in different contexts. For instance:

- Content Knowledge (CK) – This is the teachers' knowledge on the subject matter being learned or taught. For example, the content covered in a high school science class is different from the content being taught in an undergraduate university science course.
- Pedagogical Knowledge (PK) – This is the deep knowledge teachers possess in terms of the processes and practices or methods of teaching and learning.
- Technology Knowledge (TK) – This is how teachers think about using technology, this awareness includes identifying whether a particular technology would assist or impede the achievement of a goal.
- Pedagogical Content Knowledge (PCK) – Here the teacher interprets the subject matter, finds ways to represent it, and adapts the material to students' prior knowledge (Shulman, 1986).

- Technological Content Knowledge (TCK) – Here the teacher requires an understanding of how the lesson taught (content) can be changed by the application of a particular technology.
- Technological Pedagogical Knowledge (TPK) – This is the teacher's understanding of how teaching and learning changes when particular technologies are used in different ways.
- Technological Pedagogical Content Knowledge (TPACK) – This is the teacher's:

> "understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn, and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones". (Koehler and Mishra, 2009:66)

Mishra and Koehler (2006) assert that teachers need to interact with PK, CK, PK and PCK to form new types of knowledge. This knowledge would be TCK, TPK and/or TPACK (see figure 3

below).

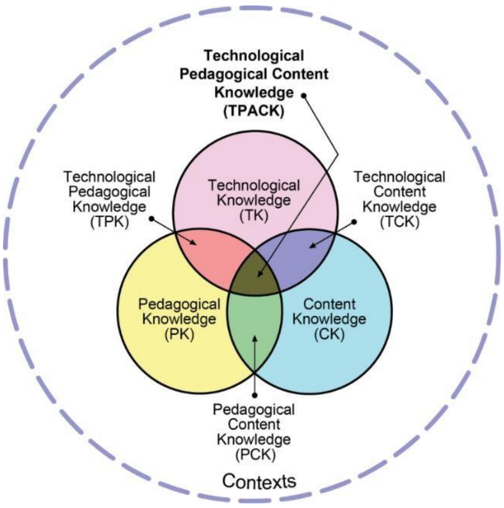


Figure 3: The TPACK model - Mishra and Koehler (2006)

However, Howard and Maton (2011) argue that educators need to move from mere empirical descriptions of knowledge practices to analysing the principles underlying those practices. For instance, TPACK provides useful insights, but needs further development. In this case, the knowledge forms are under-theorised, and this is problematic and referred to as ‘knowledge short-sightedness’ by Howard and Maton (2011). They argue that “studies using these models remain at the level of empirical differences and locked into their context of study” (2011:194). Studies which focus on the integration of ICTs in education are attempting to develop a holistic account of contextual factors affecting ICT usage in the classroom, without taking into account ‘what’ knowledge is to be learnt and the form which that knowledge takes (Howard and Maton, 2011). Many studies point to the development of higher order thinking skills and providing learners with epistemological access (Mishra and Kereluik, 2011), TPACK does not speak to the content that needs to be covered in a lesson and how it is to be taught.

3.3 Legitimation Code Theory

Maton’s (2010) LCT builds on Bernstein’s theory of educational knowledge codes to theorise the underlying principles generating discourses, knowledge structures, curriculum structures and forms of learning. This theory attempts to explore below the practices characterising fields of social practice to uncover their underlying structuring principles. Maton “views the practices and beliefs of actors as embodying competing claims to legitimacy, or messages as to what should be considered the dominant basis of achievement within a social field of practice” (2009:45). Maton and Moore (2010) argue that LCT allows both teachers and their learners, to view knowledge as the focal point of enquiry.

3.3.1 Specialisation

Specialisation was the first and most widely used dimension of LCT to emerge. Maton (2013) identifies four codes which emphasise the legitimation of the knowledge form, namely *knowledge codes,* which emphasises the possession of explicit principles, skills and procedures, *knower codes,* which emphasises attitudes, aptitudes and dispositions of actors, *elite codes,* which emphasises both knowledge and dispositions and lastly *relativist codes,* where neither knowledge nor dispositions are emphasised, the key being which code is dominant. These codes bring to light the underlying principles which generate forms of knowledge. Maton (2007), Moore (2007) and

Muller (2007) argue that hierarchical knowledge structures are based on knowledge codes and horizontal knowledge structures produced by knower codes.

Using these concepts, I have examined which relations are emphasised in teaching science. Knowledge claims are made based on the possession of specialised knowledge, procedures and skills, thus knowledge codes dominate.

3.3.2 Semantics

Semantics, the main analytical framework, is a dimension of LCT that emerged in the late 2000s from empirical studies of classroom practices and intellectual fields. This framework allows educators to view 'semantic gravity' and SD in the analysis of discourses.

3.3.2.1 Semantic gravity

Semantic gravity (SG) ‘refers to the degree to which meaning relates to its context’. (Maton 2014:2). Semantic gravity is stronger (SG+) when meanings relate stronger to a context and semantic gravity (SG-) is weaker when meanings are less dependent on the context.

Maton argues:

> … cumulative learning depends on weaker semantic gravity and segmented learning is characterised by stronger semantic gravity constraining the transfer of meaning between contexts. Thus, one condition for building knowledge or understanding over time may be weaker semantic gravity. (2009:46)

This study draws on semantic density to analyse pedagogic practices of student teachers who are using ICTs in teaching science subjects.

3.3.2.2 Semantic density

Semantic density (SD) ‘refers to the degree of condensation of meaning within practices’ (Maton, 2014b:129). Semantic density is stronger (SD+) when meanings are condensed and semantic density is weaker (SD-) when meanings are less condensed.

Maton and Doran (2017) use the example of a previously meaningless word 'Gwiffly' to explain the relationality of meanings. The more meanings are related, the stronger the SD. According to Maton, if researchers/educators state 'there is a Gwiffly' there is an establishment of a solitary node of meaning (number 1 in Figure 4). They can go further and define two kinds of Gwiffly as 'A' and 'B' (number 2). There is now a relation between the Gwiffly and two other terms. This concept can be taken further by describing their characteristics, such as 'Gwiffly A is red and Gwiffly B is blue, thus augmenting the terms by relating them to more meanings (number 3). This action creates a 'constellation' of meanings (Maton 2013:12). More meanings can be added (number 4) and the SD strengthens as more relationships with other meanings are established.

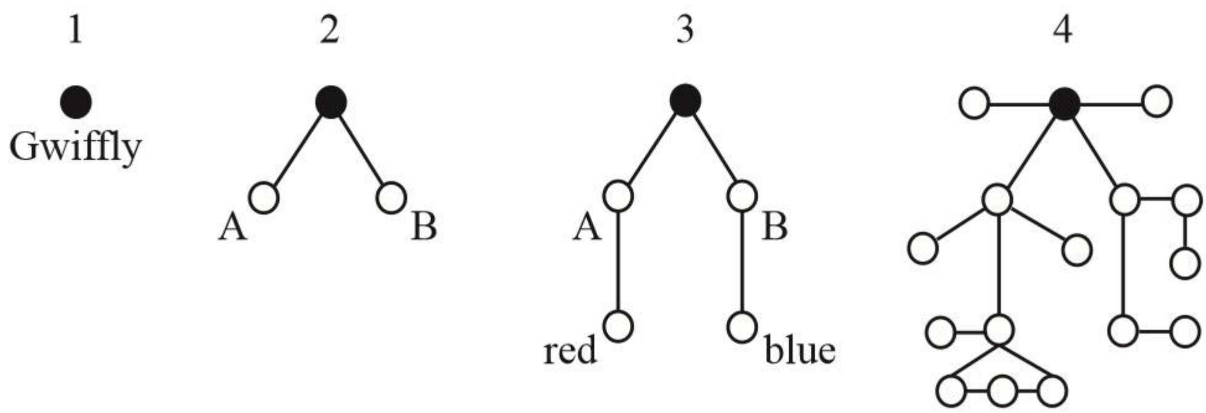


Figure 4: Constellating a gwiffly (Maton and Doran, 2017)

3.3.3 Semantic profiles

Maton has developed a method whereby shifts in SG and SD can be analysed over time. This analyses is conducted by tracing the strengths of SG and SD (referred to as semantic profiles) of practices as they unfold over time. Maton (2013) defines a semantic scale as the range between the highest and lowest strengths of SD and SG. Figure 5 illustrates an example of a semantic scale against time. The semantic scale (range of SD and SG) is displayed on the y-axis and time on the x-axis. This scale illustrates a high semantic flatline (A), a low semantic flatline (B) and a semantic wave (C). Semantic profiles can reveal different semantic ranges between the highest and lowest points in a variety of different scenarios, for example, a classroom discourse, student assignments and the curriculum. In the diagram below A and B have lower semantic ranges than C.

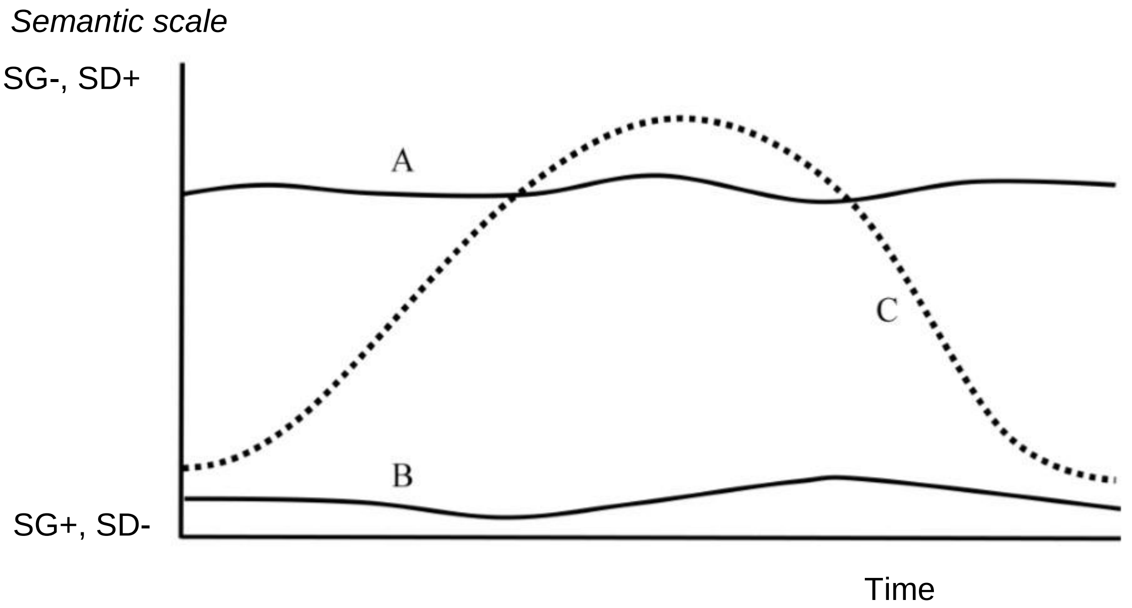


Figure 5: Semantic profile – Maton (2013)

Maton (2013:18) states that semantic waves represent the pulse of knowledge building that involve the shifts in context-dependent, simplified meanings and decontextualised, condensed meanings. He argues that the movement in SD and SG (semantic waves) is crucial for knowledge building and especially in teaching for cumulative knowledge building (Maton, 2011:66; Macnaught *et al*., 2013) and further highlights dominant patterns in classroom teaching such as recurrent downward shifts such as frequent movements from abstract highly condensed meanings towards simpler, every day context dependent meanings. Maton (2011) calls this downward movement ‘unpacking’ and involves moving learners towards the use of more familiar common-sense language. He, however, argues that while the downward shift is important to connect with students’ lived experiences, teaching and learning also requires an ‘upward shift’. Shay and Steyn (2016) refer to this action as ‘upshifting’. Maton (2014c:12) argues that both ‘downshifting’ to plain, contextualised meanings and ‘upshifting’ towards more condensed meanings are key for cumulative learning.

3.4 Summary

This chapter provided the theoretical framework for this study and the key theorists whose ideas have been discussed are Bernstein (1999) and Maton (2011; 2014b).
The chapter has given an overview of some of the key arguments, assumptions and frameworks that inform this study. This overview provides a lens to answer my research question posed in Chapter One. In Chapter Four, I will introduce the research methodology and delineate my choice of research design.

Chapter Four

Research Design and Methodology

4.1 Introduction

This chapter outlines the choice of research design and explains the techniques used to collect and analyse the data. The study draws on the concept 'Semantics', a dimension of Maton's (2010) Legitimation Code Theory (LCT). In particular, the concept semantic density. This chapter explores the methodology, which includes the research site, research design, the stages in data collection and how the concepts and theoretical framework helped guide the study.

4.2 Research strategy

The research strategy employed is a case study approach. It provided in-depth insights into the behaviour and experiences of student teachers. Creswell defines a case study as a project where the "researcher explores in depth a program, an event, an activity, a process, or one or more individuals" (2005:15).

Richer data was revealed because participants were in their natural environment, in other words, their daily teaching setting and, as such, was not a forced environment. The aim of the single case study, therefore, was "not to prove but to improve" their teaching practice (Stufflebeam, Madaus and Kellagham, 2000:283). This case study observed teacher education students during their teaching practice sessions in disadvantaged schools in Cape Town. The study focused on analysing and uncovering the principles underpinning pedagogic practices. Instead of merely examining local practices at the level of experience (Bhasker, 1978), it looked deeper at the level of the "real" and created knowledge about pedagogic practice in teaching that can be applied beyond the current context.

A common concern of case studies is that they lack generalisability and rigour, might be influenced by research bias and are open to a range of different interpretations (Yin, 2003:10). Yin (2012) counters this view by arguing that case studies can be used to generalise theories, which means the researcher can generalise particular results to broader theoretical propositions. To counter these conflicting perspectives in this particular study, multiple research methods were used and concerns around generalisability, rigour and research bias are addressed under the validity section.

The case study took place at 12 disadvantaged schools in the Western Cape. These schools differed in size and were in a range of geographical locations and included high schools (Grades 8 to 12) and combination schools that cater for learners from Grades R to 12. The study observed teacher education students' use of ICTs as a pedagogical resource to facilitate epistemological access in science subjects. Life sciences is a subject taught within the FET (Further Education and Training) band for Grades 10 to 12. The subject continues from Natural Sciences, taught in the GET (General Education and Training) band and focuses on four knowledge areas, namely tissue cells and molecular studies, structures and control of processes in basic life systems, environmental studies and diversity, change and continuity of life.

4.3 Research philosophy

The research philosophy can be understood as a belief or assumption about the development of knowledge. In other words, the way data should be gathered, analysed and used. This study employs a Critical Realism philosophical perspective. A key distinction between Critical Realism and other philosophical views is the distinction between ontology and epistemology (Maxwell, 2012). Ontology refers to the nature of knowledge and epistemology refers to how we gain knowledge. Critical Realism combines a realist ontology with a constructivist epistemology (Maxwell, 2012). Maxwell believes that applying a realist ontology to methodological issues in qualitative research, provides a "stronger justification for what qualitative researchers do, and significantly contributes to and reshapes some of our theories and practices" (Maxwell, 2012:viii). This Critical Realist perspective allows a new and productive way of thinking about the phenomena studied and the methods used, because it helped to "defend [the] qualitative research against the criticisms that are often levelled against it by proponents of science-based research" (Maxwell, 2012:ix)

Causality has been a contested issue within qualitative and quantitative research. Positivists believe that knowledge of causality does not extend beyond directly observable factors (Hume, 1739). While others deny the validity of causality. The latter view was later grounded in a Constructivist stance, declaring "there exists multiple, socially constructed realities ungoverned by natural laws causal or otherwise" (Guba and Lincoln, 1989:86). Both approaches ignore the notion of causality being the actual causal mechanisms and processes involved in various events and situations. In this study, the researcher uses Bhaskar's (1979) depth ontology to address causality. This ontology accounts for the underlying structuring principles of the pedagogic discourse in which reality is stratified into three ontological domains, *viz*. empirical, actual and real.

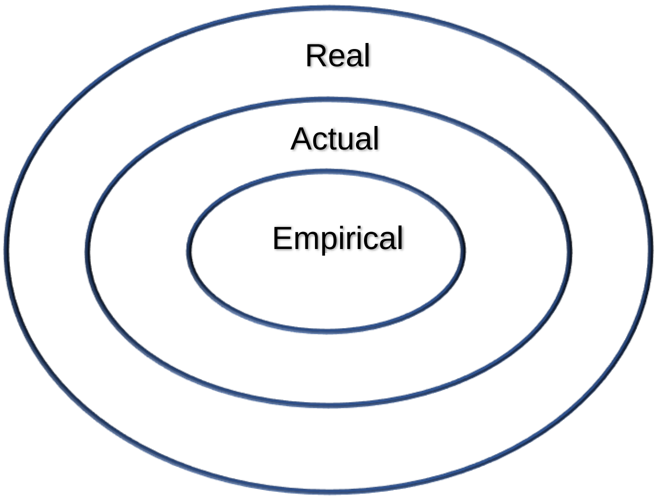


Figure 6: Bhaskars' three ontological domains (1979)

The empirical layer refers to that which is observable, in other words, the layer of human experiences, the actual layer refers to the actual occurrence of events, which may or may not be observed. Lastly, the real layer points to the casual mechanisms and structures which produce actual occurrences or empirical events. It is generally understood that causality operates transfactually, meaning the ongoing operation of mechanisms apart from that which is observed and identified in experimentally closed systems. These mechanisms can be understood as the reason people do things in a certain way, that is the structures, powers and mechanisms that frame an entity's predispositions as they operate and interact. Maxwell (2012) argues that processes can often be mental rather than physical and, therefore, may not allow direct observations in social settings. In such instances, inferences can be made from behaviour, such as speech. By making clear the realist understanding of causality, I provide a philosophical justification for how explanations are later given.

4.4 Methods

Two data collection methods were used, namely, observation together with video recordings and document analysis.

4.4.1 Observations using video clips (digital recordings)

Videos (previously film) have been used by many researchers in workplace studies (Heath, Hindmarsh and Luff, 2010). In this study, I used video-based fieldwork. These digital video recordings of the classroom sessions formed the basis for the data collection. I started my data collection by observing the teaching and learning activities when the students taught science during their teaching practice session. I focused on observing the pedagogical practices of student teachers in terms of semantic density. The advantage of using video recordings is that they could be 're-opened' later to observe aspects which I might have not noticed during the earlier viewing sessions. Videos enable the researcher to revisit a moment 'not as past but formerly present' (Jewitt, 2012:8). I recorded two classroom sessions for each of the 12 research participants. The timing of the video-recording was negotiated with the student teachers based upon their teaching schedules. The focus was on observing their pedagogical practices while teaching.

The topics taught during the different classroom sessions were not identical.

Table 4.4.1: Summary of classroom observations

Focus of the observation	**Lesson number**	**Student Teacher (pseudonym)**	**Classroom topic**	**Grade**
Observed pedagogical practices in terms of SD	1	Monica	Biomes	10
	2	Craig	Deforestation	11
	3	Shafiek	Naming organisms	10
	4	Jennifer	History of life on earth	10
	5	Elvin	Genetic modification	11
	6	Victor	Evolution	10
	7	Sipho	Feeding relationships	8
	8	Cecelia	Biosphere	10
	9	Beauty	Debate – 'Science must fall'	10
	10	Freda	The chambers of the heart	11
	11	Hester	Revision	10
	12	Alex	Deforestation	11

During the classroom observations, I was able to develop an 'intimate and informal relationship' with the student teachers (Cohen and Manion, 1980:104) (these individuals are further discussed under research participants) and through discussions, I gained insight into student teachers' pedagogical practices.

4.4.2 Document analysis

The documents used in the analysis were:

Doc A – lesson plans (Appendix A)

Doc B – course/subject outline

Doc C - PowerPoint presentations etc. (Appendix B)

The lesson plans gave insight into the learning outcomes, the teaching methods as well as the measures used to make sure that the goal was achieved. In addition, the course/subject outline documents obtained from the class teacher and subject head of department gave insight into the teaching and learning approaches. Furthermore, the PowerPoint presentations used during the lessons assisted with reading the transcripts of the video recordings and field notes of the 'salient features' (Cohen and Manion, 1980:103) of the pedagogical practices.

4.5 Research participants

The main participants of this study were 4th year teacher education students with a Life Science (LS) or Physical Science (PS) major conducting their teaching practice at disadvantaged high schools in the Western Cape. As mentioned in Chapter One, disadvantaged schools are ones in the lower quintiles (1 to 3) (explained in Chapter One) and chosen from the high poverty areas in the Cape Flats. The Cape Flats comprise densely populated areas in Cape Town, where 'non-white' households were forced to move during the apartheid era by race-based legislation called the 'Group Areas Act'. In contrast to central urban areas which were designated for whites, the Cape Flats consists mostly of townships, flats and informal settlements. Purposive sampling was used for this study, this is a technique used to sample from a particular population, while being guided by the purpose of the study (Babbie, 2010). Student teachers were selected from a teaching practice schedule obtained from the Teaching Practice Administrator (TPA) at the University of Technology (UOT). The schools were listed alphabetically, with details of the student teachers who would be teaching classes at the school.

The total number of schools listed was 121. To create a sample for this study, the schools were further sampled according to the major subjects of the student teachers assigned to the school being either LS or PS, which limited the number of potential schools to 65. Of these 65 schools, at only 13 were there student teachers who were teaching PS. The remaining 52 schools all had student teachers teaching LS. The student teachers teaching at the 65 schools were contacted telephonically to establish whether (i) the school possessed ICT equipment, (2) the student teachers taught using ICTs and (3) if they were interested in participating in the study. The same approach was applied in the schools in which the student teachers taught a LS major subject. If a positive response to the three criteria was received, these student teachers were added to the selection list. Finally, the last criteria for inclusion in the research sample was applied – is it a previously disadvantaged school? Finally, it was established that twelve schools at which the student teachers taught LS met all the criteria necessary for inclusion in the research sample, while only two schools at which the student teachers taught PS met all the requisite criteria. It was decided not to include the two schools where PS were taught because the sample size was limited. I proceeded with the sample of twelve schools where LS were taught. The student teachers at these 12 schools were keen to participate in the study and its purpose and rationale were explained to them at an introductory meeting before the commencement of the study. The study participants provided their written consent before I proceeded with the observation and video recordings of lessons. The study participants are known only by pseudonyms to protect their identities. Further information on the schools is provided in Chapter Five in which the study's findings are presented.

4.5.1 Biographical details of participants

Monica (pseudonym) a coloured female student teacher, came from a small town in the central Karoo which lies to the north of the Western Cape Province in South Africa. After completing Grade 12 in 1999, she took a 'gap year' to earn money to fund her registration fees. The next year she began her formal teaching qualification studies. For teaching practice, she chose a school within walking distance of her temporary residence, which serves children residing in 'townships' despite its being located in a middle-class area in the Southern Suburbs of Cape Town. Monica's love for computers started in primary school when she was introduced to computers and technology. Although her mother tongue is Afrikaans, she now teaches in English. Her two majors are LS and Mathematical Literacy.

Craig (pseudonym) a mature black male student teacher who is conducting his teaching practice at a school in a coloured community in the Northern Suburbs of Cape

Town. After matriculating he studied Marketing at a tertiary college for two years. After five years of working part-time and failing to find permanent employment, Craig decided to pursue an alternative profession. He then enrolled for an Education Degree. His majors are LS and Entrepreneurship.

Shafiek (pseudonym) is a coloured male student who enrolled for his teaching qualification after completing his Grade 12 year. For his teaching practice he chose a school located close to his home in a township in the Southern Suburbs of the Western Cape. Despite the area being renowned for gangsterism, crime and drug addiction amongst the youth, the school was the first school in the area to receive a 100% matric pass rate in 2014. Shafiek's majors are LS and Mathematical Literacy.

Jennifer (pseudonym) has always wanted to become a teacher. As a coloured, female student this is her 'small' way of giving back to the community she grew up in. After a 'gap year' completing religious studies, Jennifer enrolled for a teaching qualification. Her love for computers started at a young age when her parents bought her a personal computer. She explored projects such as collage making and picture editing. For her teaching practice she choose an urban school, located in the Southern Suburbs of Cape Town which is close to her home. This is a 'developing' school, in need of improvements in academics, infrastructure, security and social environment, thus Jennifer became involved with programmes that enable her to make a positive contribution towards improving these conditions. Her majors are LS and Mathematics.

Elvin (pseudonym) is a mature black male student. His love for computers started when his parents bought a computer which had a complementary 'Maths for Children' programme which he played every day. He conducted his teaching practice at a school in a disadvantaged community in Bellville, which is close to his home. His majors are LS and Entrepreneurship.

Victor (pseudonym) is a black male student who grew up in the Eastern Cape and moved to the Western Cape to complete Grades 10 to 12. The following year, due to his failure to apply timeously at university, he enrolled for a one-year college computer course. The following year he started studying towards a teaching qualification when he was put on a waiting list for his first choice, a Law degree. His decision to complete his teaching practice at a school in the Southern Suburbs of Cape Town was based on the view that the school embraces multi-culturalism and the teaching medium is English. He felt that a township school would have more "codeswitching[1]". His majors are LS, isiXhosa and Mathematical Literacy.

Sipho (pseudonym) is a black male student who pursued a BSc in Medical Bioscience qualification following his matriculation but 'dropped out' after his second year. A 'gap year' followed after which he enrolled for his teaching degree. Sipho chose an urban school in the Southern Suburbs of Cape Town for his teaching practice because it is close to home. His majors are LS and Mathematics.

Cecelia (pseudonym) took a 'gap year' after completing Grade 12. She then enrolled for a teaching degree. She chose to complete her teaching practice at her previous high school in Cape Town's Northern Suburbs because it is close to her home. This area is known for high crime rate, drugs, sexual offences and murder. Her majors are LS and Afrikaans (an official South African language).

Beauty (pseudonym) is a coloured female student who grew up in Saldanha on the south-western coast of Western Cape. After matric, she took three 'gap years', when she worked in her family business and completed a year of Islamic studies before her father moved their family to Cape Town. She then formally enrolled for a teaching degree. She started her teaching practice at a combined school in the Northern Suburbs of Cape Town. The area is known for poverty, unemployment, substance abuse, crime, gangsterism, as well as the physical abuse of women and children, with many parents addicted to drugs and alcohol. Her motivation for choosing the school at which she conducted her teaching practice was because she believes the Mathematics teacher is a good mentor. Her majors are LS and Mathematics.

Freda (pseudonym) a black female who lives in the Northern Suburbs of Cape Town. After completing matric, she enrolled for her teaching degree. For her teaching

[1] Codeswitching is the use of two or more languages, varieties, or even dialects within a single language turn (King and Chetty, 2014:40). In this case the two languages are isiXhosa and English.

practice she chose a combined school in the Southern Suburbs of Cape Town which, although situated in a high crime and drug related area, has a high standard of learner discipline and educator enthusiasm. It has a high ratio of foreign learners compared to local students at the school. Freda's majors are LS and Mathematical Literacy.

Hester (pseudonym) is a coloured female who enrolled for a teaching degree immediately following completion of Grade 12. The school is located in the eastern part of the Cape Flats, in a community where Hester was raised and serves children who live in the surrounding areas. Various funding benefactors provided the school with equipment such as smartboards, digital dissecting microscopes, Bluetooth soundbars, computer microscopes (which use optics, digital imaging, and the latest computer technology) and tablets for teachers. The school is keen on exploring ways of using ICTs in teaching to enhance learning. Hester's majors are LS and Business Studies.

Alex (pseudonym) a mature female, 45 years old, who decided to pursue a teaching degree after struggling to find employment for many years. Her teaching practice was conducted in a school located in the northern part of the Cape Flats. Her majors were LS and Afrikaans.

4.6 Validity

To ensure the trustworthiness of a qualitative research study, Lincoln and Guba (1985) and Creswell (1998) explain that there is a need to establish credibility, dependability, transferability, and confirmability.

In terms of credibility, realists have identified a variety of methodological strategies for producing more credible and rigorous qualitative research. These strategies allow the researcher to develop a richer and more complete understanding of the phenomena being investigated. These phenomena include careful purposive or theoretical sampling, "different outcomes can provide case-based comparisons that can illuminate factors in the real domain of prime importance" (Clarke, 2008:169). Other strategies include prolonged engagement, standardisation of field notes, recordings and transcribing, peer review or debriefing, triangulation and persistent observation (Lincoln and Guba, 1985). Maxwell (2012:134) argues that validity relates to the kinds of understanding that accounts can embody. He distinguishes between three broad categories of validity, namely descriptive validity, interpretive validity and theoretical validity.

Descriptive validity is concerned with the factual accuracy of the account. In this study, the video recordings were transcribed verbatim. This is in line with Wolcott's (1994) view that description is the foundation of qualitative research:

> Whenever I engage in fieldwork, I try to record as accurately as possible, and in precisely their words, what I judge to be important of what people do and say. (Wolcott,1994:349)

Maxwell's (2012:137) second category, interpretive validity, refers to "what these objects, events and behaviours mean to the people engaged in and with them". Realists recognise that knowledge of the world exists and that social structures influence human behaviour in the recognition of hermeneutical dimensions. Clark argues that the beliefs, understandings, and meanings of humans do matter— not because they determine what objective reality is but rather because they are likely to influence behaviour (2008:169). To ensure interpretive validity in this study, I did not draw inferences from my perspective. When uncertain, I compared the transcripts to the video recordings to make an accurate evaluation.

The third concept proposed by Maxwell (2012:140) is theoretical validity, "an account's validity as a theory of some phenomenon". In line with Bhaskar's (2002) theory of transcendental rationalism, to distance the researcher from the data, the LCT was used, to move beyond perceptions of the world to account for underlying mechanisms of events. Using these concepts, I was able to distance myself from the data. This approach allowed me to overcome research bias and reactivity, two broad threats to qualitative research (Maxwell, 2013). Reactivity is the effect that a researcher has on a particular setting and research bias can often result in the impartiality of the researcher when collecting data.

Triangulation was also used to overcome any bias in the research in addition to improving the dependability (Lincoln and Guba, 1985) of the study. Triangulation is defined as giving "a more detailed and balanced picture of the situation" (Altrichter, Feldman, Posch and Somekh, 2008:147). Dependability can be defined as the stability of data over time and conditions. In this study, I used digital video recordings of the classroom sessions as the main source of data but supported this evidence with document analysis to triangulate the data, and to strengthen the reliability of the research (Hussein, 2009). Furthermore, I make clear the detailed process of how data was analysed.

In terms of transferability, the process which allows connections in this study to be applied to other studies, thick descriptions of the phenomenon are provided (Trochim and Donnelly, 2007:149) which allow other researchers a proper understanding of it, thus enabling them to compare the instances of the phenomenon and how it might be applied to other studies.

Lincoln and Guba's (1985) last strategy, confirmability, is the extent to which the findings in a study are shaped by respondents and not the researcher's bias. It is through this strategy that the researcher admits his or her predispositions (Miles and Huberman, 1994). To establish the confirmability of this study, an audit trail was kept detailing the process of data collection, data analysis and the interpretation of the data. This record includes an explanation of the thought process involved when coding the themes and the meaning of themes. In this study, I have thoroughly discussed the beliefs underpinning decisions made, the methods adopted as well as the reasons for the research approach. The findings are shaped by the participants and not the researcher's bias.

4.7 Data analysis

This study focused on student teachers' pedagogic practices and aimed to develop a framework that can extend, as well as critique, current approaches to enact pedagogic practice.

4.7.1 Transcribing the data

Henning, van Rensburg and Smith (2004) recommend that researchers should complete their own transcriptions because this process allows researchers to become familiar with their data. Henning *et al*. (2004) claim that, in doing so, researchers would be in a better position to make sense of the data during the analysis. Based on this recommendation, I transcribed the video recordings verbatim.

4.7.2 Organising the data

After transcribing the video recordings, the data amounted to approximately 88 pages. To manage the transcribed data, as well as the observation notes, I used the NVivo 10 software package to organise the data into different categories and to view the data simultaneously, it was, however, a time-consuming process. I decided, therefore, to discontinue the use of NVivo and rather to manually code the data.

I highlighted recurring patterns, for example ‘simplifying concepts’, ‘teaching concepts in isolation’, ‘power words’, ‘recapping concepts’, ‘memorisation’, ‘poor content knowledge’, ‘strong teacher monologue’, ‘ICTs as display’, ‘semantic flatline’ and ‘creating semantic waves’ by reading through the transcripts and summarising the important points (Maxwell, 2013). The data relating to a theme was grouped under broad categories such as ‘knowledge’, ‘concepts’, ‘pedagogy’ and ‘ICTs’.

Maxwell (2012:112-113) contends that categories can be derived or deduced from theory (grounded theory “etic” categories) or drawn from the concepts of people studied (“emic”). Being mindful of this statement, I tried not to force the theory onto

the data. This practice made working with and understanding the data easier, as I was then:

> “prepared to live in the muddle which is unordered data, and enjoy the pleasure of its potential, to be able to generate the theoretical apparatus which is specific to it”. (Moss, 2001:18)

Chen and Maton (2014) agree that with this method of data organising the researcher can obtain rich stories from the data, instead of ‘smothering it’ (the data) with theory too soon. After the data organisation, I developed a language of description that allowed the researcher to look at the data through an analytic lens.

4.7.3 Analytical framework

In this study, I drew on LCT's concept of semantic codes to examine how student teachers facilitate epistemological access during their teaching practice session when they teach science subjects with ICTs. The semantic codes were explained as theoretical concepts in the theoretical framework and here it is translated into analytical tools. To recap, this is the concept of semantic density (SD). In line with the Social Realist approach, theoretically generated empirical referents such as developing an external language of description from the internal language of description (theory). Therefore, I will draw from theory (internal language of description) to create an external language of description using LCT concepts. Thus, using theory to explain real world concepts or what Bernstein (2000) calls empirical referents. This analytical framework will help me understand how student teachers teach using ICTs and question whether it transcends boundaries.

4.7.3.1 Translation device

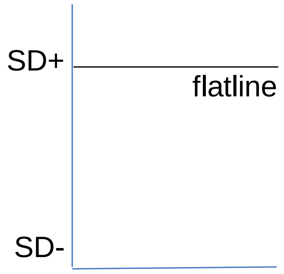
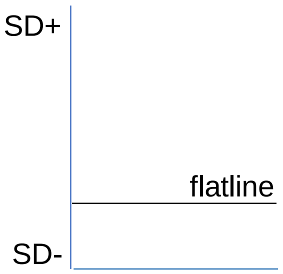
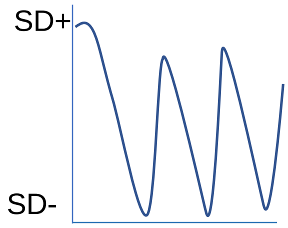
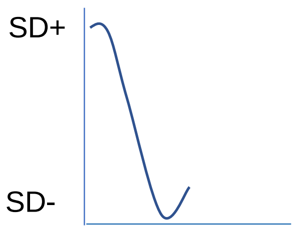
Bernstein (2000: 209) emphasises a 'discursive gap' as an omitted link between theory and data. The theory might be very powerful but there is difficulty in applying it to the external phenomena concerned. This limits the ability to build epistemologically powerful knowledge (Chen and Maton, 2014:29). With Bernstein's concept of 'external languages of description', the discursive gap can be acknowledged through a translation device. The theory, therefore, is not forced onto the data nor miraculously derived from data (Chen and Maton, 2014:29).

Drawing on previous studies in LS contexts (Kelly-Laubscher and Luckett, 2016; Maton, 2013) suggest that when ways of coding the relative strengths of SG and SD is presented, a language of description was developed. Tables 4.7.3.1 and 4.7.3.2 illustrates how a language of description was developed in terms of the strengths of SD within the data.

Table 4.7.3.1: External language of description for the strengths of SD

SD *Relates to the condensation of knowledge*		
Symbol	**Meaning**	**Examples**
+	Introduces Life Science concepts	Biomes, precipitation, altitude, latitude
-	Simplifies concepts making them accessible to students	"[the] biome you are dealing with are the rainfall, you also know its precipitation" "bituminous is another name for a different form fossil" "anthracite is also known as Charcoal right"

Table 4.7.3.2: External language of description for the strengths of SD continues

Semantic Profile		
semantic flatline	***Abstract*** 	Talking about science in abstract terms and remain at that level SD+
	Simplified 	Talking about science in everyday terms, weakening SD and I keep on doing that.
semantic wave		Simplification, weakening of density by using examples to enable connections to concepts where after building up to the concept again and relating it with other related concepts within the field thus strengthening the density once more.
downward escalation		Uses every day, common sense meanings or examples to connect with concepts and does not follow with upward escalation to connect back to the concept.

Semantic waves could be used to graphically represent how epistemological access is facilitated cumulatively or segmented through pedagogy during each lesson.

4.8 Ethical considerations

A letter of consent, containing detailed information on the study was drafted and given to participants as well as the school principals. Participants were informed that participation was voluntary and they could withdraw from the project at any time. Confidentiality was also explained and pseudonyms were used to ensure anonymity. Participating pre-service teachers were required to provide written consent (see Appendix C) which detailed the study objects and procedures. During the discussion with the pre-service teachers, I highlighted that the research focus was not to critique their teaching, but rather to explore the affordances ICTs has on the different curriculum structures. Ethical clearance, in line with the University Ethical Protocol, was obtained from the Research Ethics Board at the University of the Western Cape, and the project received clearance from the Western Cape Education Department.

4.9 Summary

This chapter provided an overview of the research design and methodology employed in this study. The research for this study falls within the philosophy of Critical Realism and uses a qualitative approach with a case study research strategy. The research methods involved a combination of observations and document analysis. Bhaskar's depth ontology was used as an ontological lens to move beyond observable factors. The data analysis process was described from transcribing to organising the data in terms of themes as well as the analytical framework used as analytical tools. A translation device was developed in line with Bernstein's (1996:136) concept of 'external language of description'. The chapter further discussed issues around sampling, validity and ethical considerations. Chapter Five presents the findings that emanated from the classroom observations.

Chapter Five

Findings

5.1 Introduction

Findings of the data collected are presented in this chapter. The main objective of the study was to explore how ICT were used as a pedagogic tool to enable learners epistemological access. I move away from a technicist or instrumentalist understanding of ICT integration into education to a belief that this process is a structured human activity. I assume that when ICTs are properly integrated into lessons to support and enhance learning outcomes, they could provide learners with epistemological access. Moss and Chamorro (2008) argue that to avoid fragmenting the pedagogic discourse, teachers should become aware of the movement of discourse between everyday and scientific knowledge. Maton proposes that in pedagogical practices teachers build semantic waves during their lessons, to scaffold the abstract meanings often found in science because learners from different social backgrounds often bring with them different dispositions (Maton, 2014:204-205). For instance, Hassan (2009) found that learners from middle-class families are more likely to have the ability to navigate between simpler meanings and abstract concepts than those from working class families due to their socialisation practices. It is important, therefore, to explore how teachers are opening up 'powerful knowledge' (Muller, 2005) to learners from previously disadvantaged backgrounds.

For the purpose of this study, twelve lessons were selected to represent the continuum of teaching science from Grade 8 to Grade 11. These lessons, described below, look at how pre-service teachers are using ICTs to give learners access to knowledge, or 'epistemological access', using the words of Morrow (2007). They are presented in the form of case studies, together with brief background information about the student teachers (referred to as 'teacher' in the examples provided in this chapter) and the schools involved. Lesson outcomes as indicated in the lesson plan and illustrations taken from each lesson are also included in each case study.

5.2 Observation of science lessons

5.2.1 School 1 – Grade 10 (Monica)

Topic: Biomes

Lesson outcomes

The learning outcomes required learners to distinguish between different biomes along with the ability to name characteristics of these biomes. The purpose of the lesson was for learners to understand key concepts and terminology and to use new information in real life contexts.

Classroom setup

The desks were arranged in a computer laboratory style. The first row of computer stations faced the left wall, a walkway separated the first row from the middle two rows which had workstations arranged back-to-back; another walkway separated these workstations from the last row which faced the right wall. Some workstations were aligned with the back row of the classroom (see Figure 5.2.1). The learners slowly made their way into the classroom. Each learner took a seat behind a workstation, while still talking to each other and trying to switch on the computers.

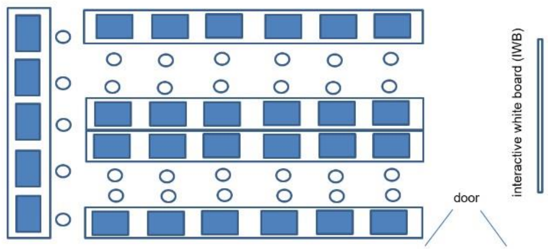


Figure 5.2.1 Monica's classroom setup

Lesson summary

The lesson started immediately when the teacher entered the classroom. She was engaged in a telephone conversation with a 'friend' attempting to plan a holiday to Paris. Some of the learners who at that point had their backs or sides facing the teacher moved to the front and gathered in both the walkways, now facing the teacher. After the brief introduction, the teacher drew the learners' attention to a presentation on the interactive whiteboard (IWB), which was used as a teaching aid. The teacher seemed enthusiastic and positive and, as part of the holiday theme, was dressed in a hat, scarf and sunglasses.

Teacher introduced the topic 'Biomes' and it was clear that she expected the learners to have some background on the topic. The class appeared relaxed, occasionally laughing when the teacher made an amusing comment. The teacher, however, seemed rushed, moving swiftly through the slides and did not elaborate on the content in great detail. For example, in response to one slide (Figure 5.2.2) she read *"Biomes are regions of the world, it's similar physical environments"*, and promptly continued to discuss factors that influence Biomes and read out the words, *"rainfall (precipitation), temperature, altitude and latitude"* after which she explained *"that is how high you are above sea level and how low"*. She continued *"boundaries of the biomes normally are distinct, meaning they is, it's unlimited"*. This explanation was different from the bullet on the slide which read, 'boundaries are indistinct'.

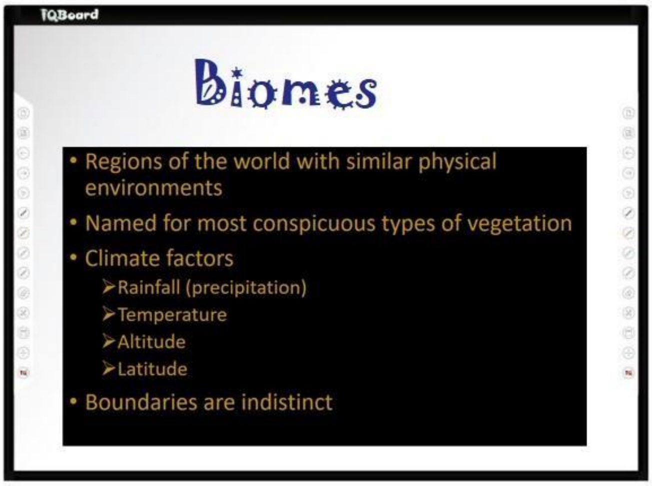


Figure 5.2.2 Biomes slide

The teacher read *"succulent karoo"*, stopping to question the learners' familiarity with this phrase. The learners unenthusiastically responded in the positive. The remaining phrases "*fynbos*", "*forest*", "*thicket*", "*savannah*", "*grassland*" and "*desert*" were read out with the teacher requesting familiarity after each one.

The teacher placed great emphasis on visual presentation and map work (Figure 5.2.3). Pointing to a map on one of the slides (Figure 5.2.4) she profusely apologised for a mistake made with one of the colours indicated, as well as the brightness, "*it's not as vibrant or bright*" and assured the learners that she would illustrate the colours later on the computer (after the lesson). She identified the different areas on the map as well as the location of the biomes. Her tone throughout the lesson was conversational, touching on the holiday theme and her heritage. She comically remarked that she feels as if she is predicting the weather.

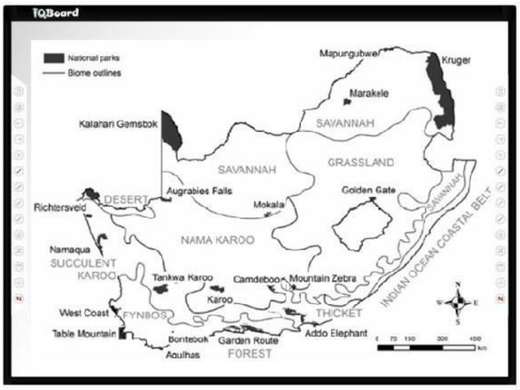


Figure 5.2.3 Location of Biomes

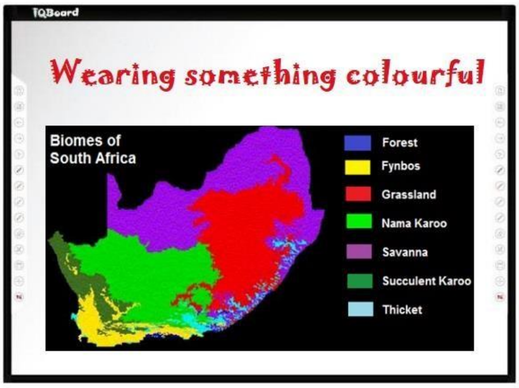


Figure 5.2.4 Biomes of South Africa

The teacher then involved the learners in classroom activities. In the first activity, the learners were asked to look at a picture and to identify the Biome, while the second task (Figure 5.2.5) required learners to form groups of six and to provide three holiday destinations, with two motivations for choosing each destination. The learners were allowed to use the Internet. During the first activity, the learners orderly raised their hands waiting for acknowledgement from the teacher before answering the question. When learners provided incorrect answers, the teacher did not correct them but merely continued to the next learner until, finally, in frustration she asked learners to consult the Internet for the correct answer to the question.

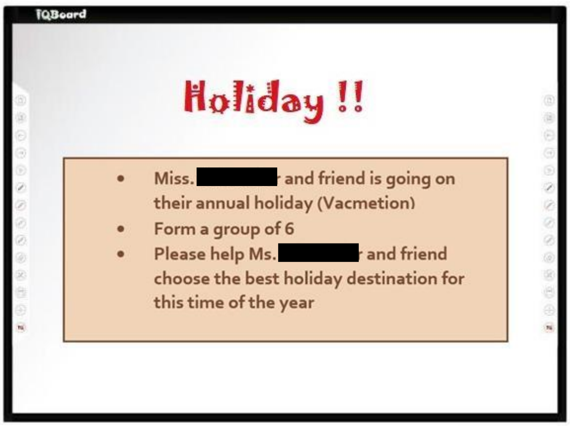


Figure 5.2.5 Class task

When learners took too long to complete the task, the teacher provided examples explaining why some areas would not be a good choice during certain weather conditions, for example, the Nama Karoo:

> "… *because we have extremes in temperature. I won't be able to enjoy myself and with our drought on hands, we won't be able to go to a swimming pool and you know, waste water, or we won't even be able to you know like play in front or on the grass*".

In order to fast track the latter task, she then asked the learners to name only one destination. She further explained "*name the plant, animal, the weather pattern [and] where it's situated*".

The learners formed different groups and used the Internet as a resource to search for solutions (Figure 5.2.6). Leaners seemed to forget the rules of the classroom because they were very noisy during this activity and some were occupied with matters other than the lesson task. The bell rang signalling the end of the lesson. None of the groups completed the task. Learners were asked if the lesson could be continued the following day. An exercise was handed out and the lesson ended with the teacher commenting "*.. we going to visit Clifton, picking strawberries, we tasting wine in Stellenbosch and uhm we will be having a ball of a time. Is that okay*?"... The learners then left the classroom.

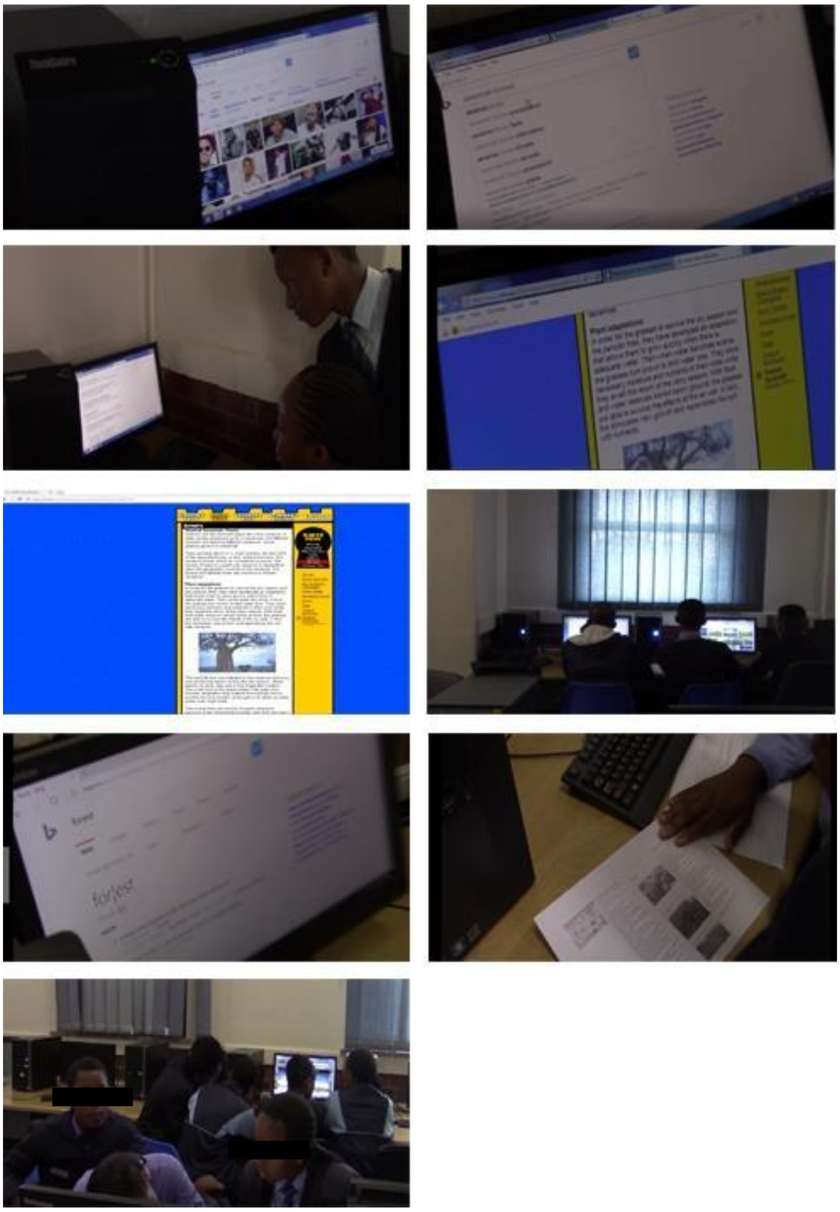


Figure 5.2.6 Classwork illustration

5.2.2 School 2 – Grade 11 (Craig)

Topic: Deforestation

Lesson outcomes

The learning outcomes required the learners to define the term deforestation, as well as to explain the cause and effects of deforestation. Learners should be able to apply the information about deforestation in a relevant case study, graph or table.

Classroom setup

Desks were arranged in a laboratory style setup with a fixed projector connected to a laptop on the teacher's desk. The classroom was noticeably dark with green painted walls and science posters on the walls. Learners seemed noisy, energetic and distracted throughout the lesson.

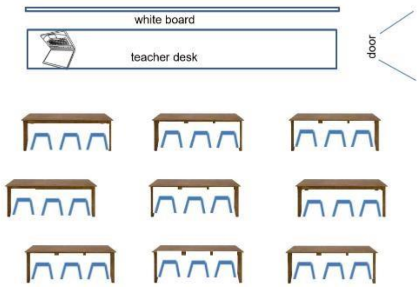


Figure 5.2.2.1 Craig's classroom setup

Lesson summary

Written notes were handed to the learners as they entered the classroom. The lesson started with the teacher attempting to link learners' existing knowledge to an image displayed on the whiteboard. The teacher then moved the lesson on by trying to connect charcoal to a forest in a specific area and, then, rapidly proceeded to discuss deforestation which was the topic of the day. Throughout the lesson learners responded to questions in an unorderly manner, only raising their hands when they were reminded to do so. The lesson then focused on the definition and causes of deforestation, as well as the impact thereof on the environment. The teacher paused to remind learners about the importance of knowing the definition of deforestation (Figure 5.2.2.2).

> *You need to know this definition. You need to know deforestation. If I were to ask you to define deforestation, I want it to be in line with this... I don't expect*

you guys to have the exact same words as I give you, but then you just have to have a similar definition OK. It is the permanent destruction of natural, indigenous trees and bushes by felling or burning. Felling is [when] it is being destroyed by either animals that pass through or by human interactions OK, in order to clear that specific area for specific reasons and we are going to go through that right now.

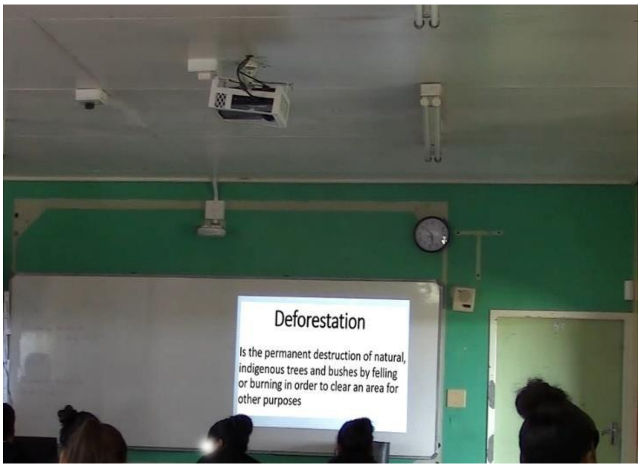


Figure 5.2.2.2 Definition of deforestation

The teacher informed the learners that he would be displaying a video clip[2] on deforestation, after which they would be required to answer specific questions listed in the worksheet he had handed out earlier. During the presentation of the video clip, the teacher paused at a section during which the narrator explained the significance of trees and their connection to everyday products such as desks, pencils, paper and furniture and commented as follows:

Can you remember I explained these to you earlier about the trees and the furniture, okay, um, I think most of the money from these trees okay some of these companies, what they do is they try to fund certain things maybe to grow trees in order for them to get um the license … to approve their license to cut more trees down okay but basically what they need to do is basically is to destroy that industry and try to let the trees grow more okay at the moment they cutting off a lot of trees because of these stuff okay (lifts up a book) we all need books but we come in the era of technology that we don't really need this we have all the pdf documents that you can download, okay.

A learner responds, "*it's data and what, what...*". Agreeing with him, the teacher continued:

that is also the back log of the problem because of data, so eventually the government will come to their senses and allow most of everything, and then

[2] https://www.youtube.com/watch?v=Nc7f5563azs

> *because maybe one day I can even send the documents to your phones and it will be much easier.*

In support, a learner responds, "*email it to us*". The teacher countered that he has a problem with emailing documents to learners because they do not use their phones for courses. Disagreeing the student stated, "*yes we do!*". The teacher scolded the learners, "*You play games and watch clips!*" – a practice which he does not like.

The teacher continued to show the video clip and paused at certain points to either explain in more detail what the terminology meant, stress important information, for example, selective and partial harvesting, or to highlight aspects discussed during the lesson, for example, the cooling effect of the water cycle. He also used a questioning strategy to test the learners' listening skills, he said (referring to the video clip) *"so now they spoke about these 3 points. You guys know about it. You know recycle, reuse, and what was the other one?"* Learners responded "reduce". The teacher highlighted their common practice of wasting paper and pleaded with the learners to use both sides of the pages. The lesson concluded with the teacher stating:

> "*Let's just end it off today. That work I gave you I want you to try question number 6, not question number 7 anymore. Only question number 6, okay*".

Question 6 read:

> 'The industrial and technological revolutions, use of fossil fuels and deforestation, released much of Earth's "stored" carbon from its natural locked-up form in the soil and forests. How can this carbon be returned to the natural carbon cycle by:
>
> a farmers?
>
> b home owners?
>
> c industry?
>
> d schools?'

5.2.3 School 3 - Grade 10 (Shafiek)

Topic: Naming organisms

Lesson outcomes

Learners should be able to provide the scientific sequence of naming organisms according to taxa (taxonomy table). They should also be able to use the scientific sequence to rearrange the order of a specific organism. Furthermore, learners should be able to define each term of taxa.

Classroom setup

Desks were arranged in straight rows facing the front of the classroom where the teacher stood. The walls were painted bright pink with contrasting green cupboards.

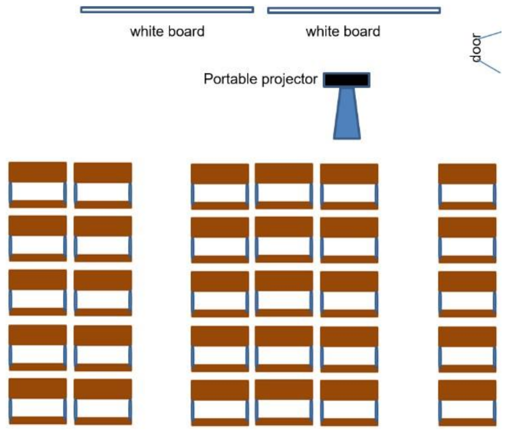


Figure 5.2.3 Shafiek's classroom setup

Lesson summary

The teacher posed the following questions to the learners, in an attempt to build on previous knowledge:

- Describe biodiversity?
- In what three ways can we describe biodiversity?
- What is indigenous?"

The questions progressed to the following: *"Where do you find fynbos?"* and *"Where do you find Maputo?".* Learners randomly provided answers. The teacher moved to the whiteboard and drew a map, pointing to certain areas as he continued the questioning strategy. *"The Northern Cape that is where you will find the….?".*

Learners answer in unison, "*succulents*". This teaching style continued, with the teacher pointing to areas on the board while questioning, *"and this is where you will find the?"* The learners answer "*floral*". The teacher next asked in a quizzical tone "*okay let me see what I can still give you. Describe species diversity? Species diversity, anybody? The different variety of …?".* The learners responded "*species*". The questions continued for about seven minutes before the teacher introduced the topic of the day - the history of classification. The teacher attempted to explain the first two slides (Figures 5.2.3.2 and Figures 5.2.3.3) as follows:

He read the first bullet of the slide (Figures 5.2.3.2) *"Carl Linneous, a Swedish scientist, classified all living things based on shared features …"* and explained:

> *"… so he first started off with 2 kingdoms but then they realised that was too broad for so many different species and stuff so they changed it to, what did they change it to? What was the 5 kingdoms?"*

He does not provide the answer to the last questions, he continues:

> "*Right they started off with two… animals and?" while pointing to the word 'plants' which is highlighted in pink in the first bullet in 5.2.3.2.*

The learners echo what they see which is the word *'plants'.* The teacher continues with his explanation, "Plants right and then they went further and they changed it to 5, what is the 5?". The learners again answer in a singing manner, *"Monera, Protista, Fungi, Plantae, Animalia".* The teacher briefly touches on the binomial system, explaining the difference between a generic and specific name and then moves along to the seven taxa in roughly five minutes, before moving to a classroom activity aimed at explaining the process of taxa. Six specific learners were called to the front of the classroom and given an exercise. The first learner was given a cardboard box with smaller boxes tucked inside and was instructed to read the message on the lid, as well as the message underneath the lid, to the rest of the class before passing the remaining boxes along to another learner.

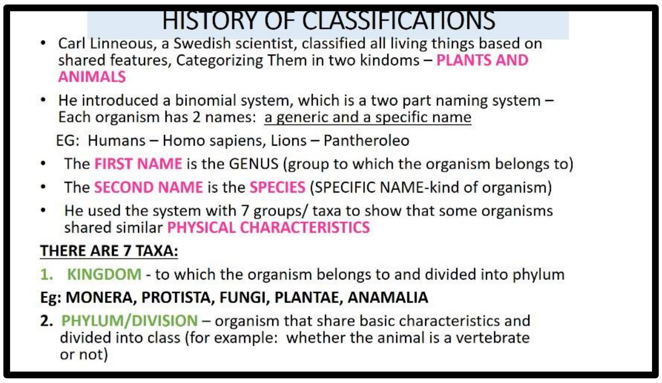


Figure 5.2.3.2: slide one

Figure 5.2.3.3: slide two

The teacher then presented the last slide (Figure 5.2.3.4) and read the examples to the learners. The learners were told to use keywords to remember the order. The teacher wrote the following sentences on the board:

"King Phillip crossed over for gold & silver" and

"King Phuma came over for ***G****ogo's* ***s****tew",*

He underlined the first letter of each word, to emphasise for example the "k" in kingdom, "p" in phylum, and "c" in class, (Figure 5.2.3.5 and Figure 5.2.3.6).

Many of the slides displayed a great deal of information and, hence, their quality was not clear. The teacher's writing on the board was also difficult to read (Figure 5.2.3.6).

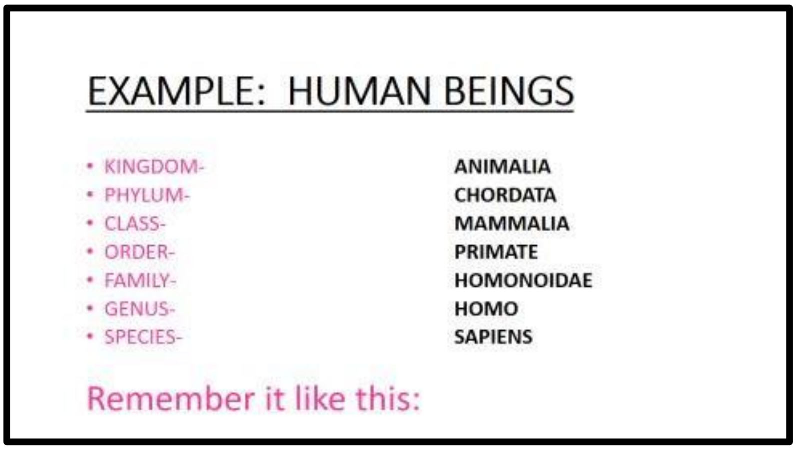


Figure 5.2.3.4: slide three

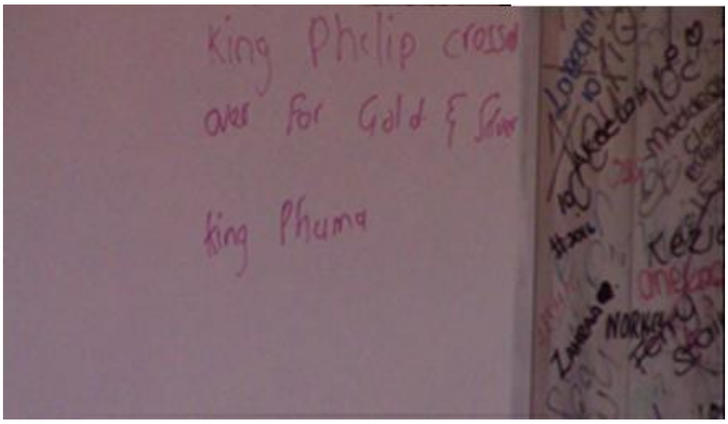


Figure 5.2.3.5 Shafiek additional writing

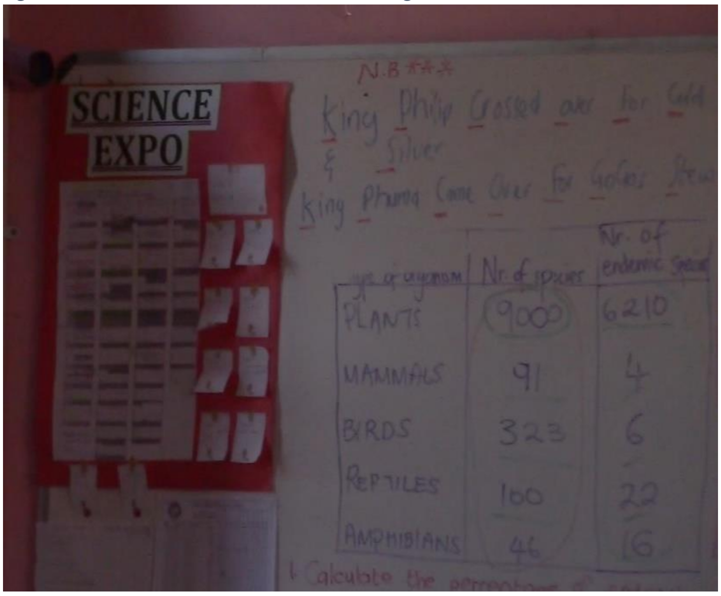


Figure 5.2.3.6 Shafiek additional writing 2

The remainder of the period (30 minutes) was used by the learners to copy the information from the PowerPoint presentation into their workbooks as well as for completing an activity (Classify a domestic cat, lion and an African baobab according their seven levels of classification.). However, due to time constraints, this exercise became a homework activity.

5.2.4 School 4 – Grade 10 (Jennifer)

Topic: History of life on earth

Lesson outcomes

The lesson outcome required the learners to name important events that contributed to the history of life on earth. Learners should also be able to identify how changes in oxygen levels caused life on earth to flourish. In addition, learners should be able to discuss climate change, and also define continental drift and bio-geography.

Classroom setup

Long tables were arranged in rows facing the teacher who stood in front. The sound of students talking and shouting outside the classroom was a disturbance throughout the lesson.

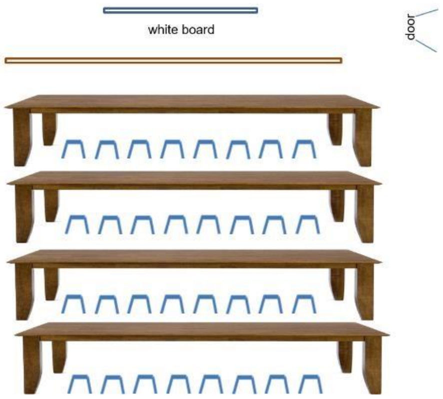


Figure 5.2.4 Jennifer's classroom setup

c) Lesson summary

The lesson started with an introductory story on how life on earth started, this story was linked to learners' previous knowledge as well as life forms and bacteria (which had been discussed in previous lessons according to the lesson plans in 'Jennifer's' Teaching Practice file). The teacher then began to question learners' knowledge of the age of life and the existence of life on earth. This revision exercise involved asking questions and receiving answers from the learners, for example, *"What do you think is the estimated age of earth?"* Some answers from the learners were '*85 million, 25 billion, 8.5 billion'* and '*3 billion*'. The teacher also probed learners' knowledge of the elements which are essential to sustain life on earth. The learners answered '*carbon dioxide', 'oxygen'* and '*water*'. She then informed the learners that she would focus on one of these important factors – oxygen – and specifically, the increase of oxygen levels in the atmosphere and the resultant climate change.

The teacher gave learners three handouts: a geological timescale, notes and an activity. The teacher worked through two of these handouts (see Figures 5.2.4.1 and 5.2.4.2) and highlighted various definitions, such as ice ages and glaciation and, thereafter, each section was summarized verbally. For instance, after each section during which the teacher explained concepts, she would summarise as follows:

> "*ok to summarise this one. What is an ice age? It is a long period of drastic decrease in earth's atmosphere temperature. What is glaciation? It is the formation of large ice sheets due to the cooling temperatures and I just have an image illustrating glaciation".*

She then went on to explain continental drift, illustrating what a 'super continent' is and how continents can drift apart.

UNIT 2:
HISTORY OF LIFE ON EARTH

HISTORY OF LIFE

Scientists estimate that the earth came into existence approximately 4,6 billion years ago.

1 billion = 1 000 million
∴ 4,6 billion = 4 600 million

According to scientists, life on earth started 3,8 billion years ago with a unicellular, prokaryotic cell similar to a bacterial cell. Multicellular organisms only developed a few billion years later.

Scientists try to make sense of the history of life on earth by relating it to other important events, such as:

INCREASE IN OXYGEN LEVELS

- When the earth formed, oxygen levels in the earth's atmosphere were very low.
- Modern theories suggest that the first life forms, i.e. the prokaryotes, which appeared 3,8 billion years ago, did not need oxygen. They respired **anaerobically** and therefore obtained energy from their food, without using oxygen.
- Between 3,5 and 2,5 billion years ago different types of bacteria arose, which could produce their own food through photosynthesis. Carbon dioxide, which occurred in large quantities in the atmosphere, was used and oxygen was released.
- Oxygen levels in the atmosphere started to increase and oxygen-dependent organisms (**aerobic** organisms) developed.
- The increase in oxygen levels in the atmosphere resulted in an increased variety of living organisms on earth.

CLIMATE CHANGE, e.g. ICE AGES

- Ice ages are long geological periods of drastic decrease in the temperature of the earth's surface and atmosphere.
- Glaciation takes place because large ice sheets form due to cooling temperatures.
- There is evidence of at least four ice ages since the origin of the earth.
- During the ice ages, many species that could not adapt to the low temperatures died out.
- Some species were forced to migrate towards the equator where temperatures were higher.
- The climate was drier because most of the water was trapped in snow and ice. Many terrestrial species became extinct due to the dry climate.
- Due to ice formation, the sea level dropped. This resulted in decreased habitats and the extinction of many aquatic species.
- Ice ages therefore affected life on earth due to the extinction and redistribution of species.

GEOLOGICAL EVENTS e.g. CONTINENTAL DRIFT

- Up until 200 million years ago all the continents were fused to form one giant continent, Pangaea. Pangaea broke up into two super continents: Laurasia in the north and Gondwanaland in the south.
- Approximately 120 million years ago these two super continents broke up even further into the continents we know at present.

mya = millions of years ago

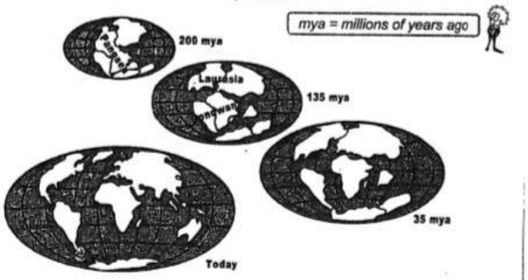
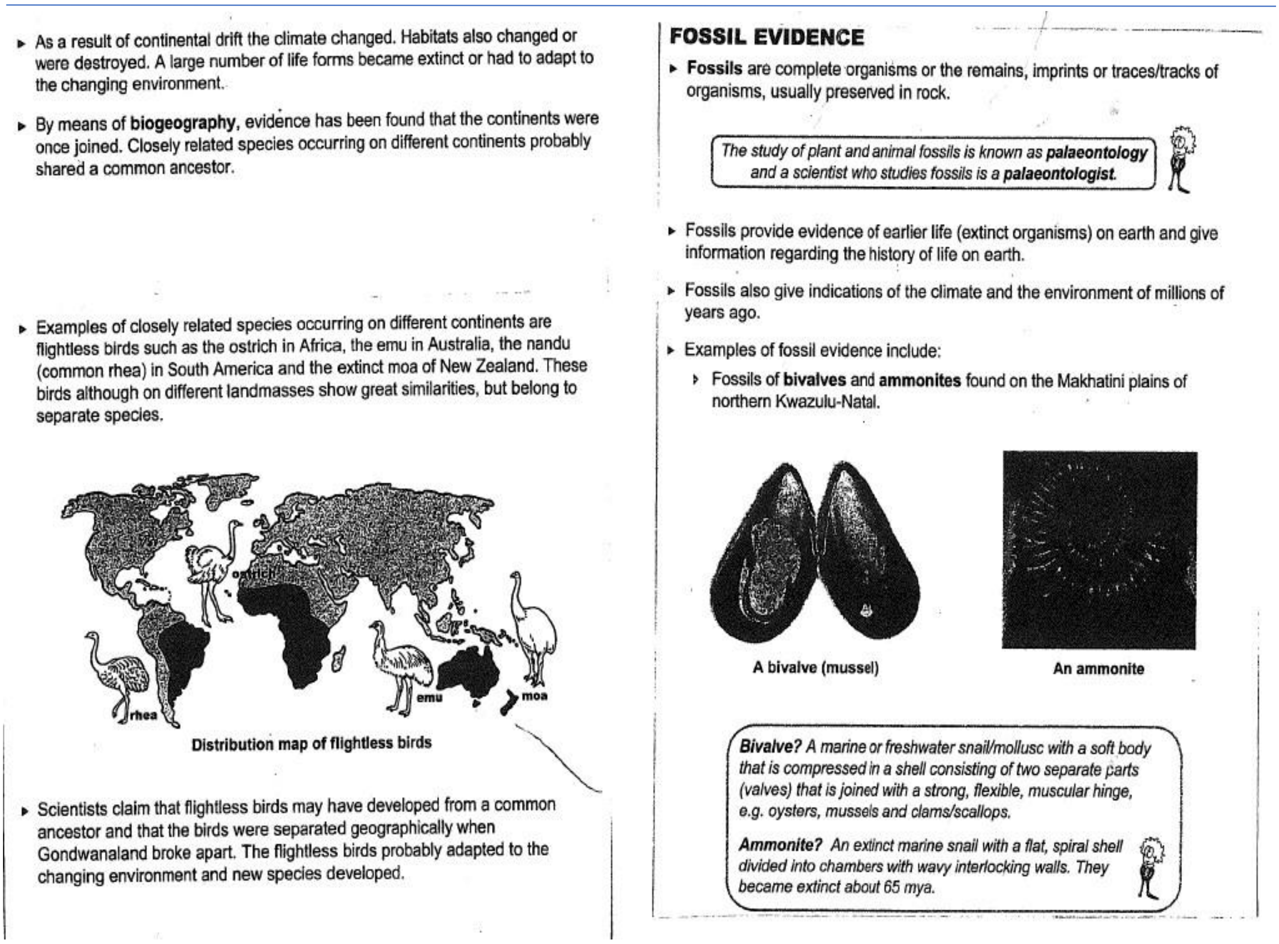


Figure 5.2.4.1 Classroom handout



- As a result of continental drift the climate changed. Habitats also changed or were destroyed. A large number of life forms became extinct or had to adapt to the changing environment.
- By means of **biogeography**, evidence has been found that the continents were once joined. Closely related species occurring on different continents probably shared a common ancestor.
- Examples of closely related species occurring on different continents are flightless birds such as the ostrich in Africa, the emu in Australia, the nandu (common rhea) in South America and the extinct moa of New Zealand. These birds although on different landmasses show great similarities, but belong to separate species.

Distribution map of flightless birds

- Scientists claim that flightless birds may have developed from a common ancestor and that the birds were separated geographically when Gondwanaland broke apart. The flightless birds probably adapted to the changing environment and new species developed.

FOSSIL EVIDENCE

- **Fossils** are complete organisms or the remains, imprints or traces/tracks of organisms, usually preserved in rock.

*The study of plant and animal fossils is known as **palaeontology** and a scientist who studies fossils is a **palaeontologist**.*

- Fossils provide evidence of earlier life (extinct organisms) on earth and give information regarding the history of life on earth.
- Fossils also give indications of the climate and the environment of millions of years ago.
- Examples of fossil evidence include:
  - Fossils of **bivalves** and **ammonites** found on the Makhatini plains of northern Kwazulu-Natal.

A bivalve (mussel) **An ammonite**

Bivalve? *A marine or freshwater snail/mollusc with a soft body that is compressed in a shell consisting of two separate parts (valves) that is joined with a strong, flexible, muscular hinge, e.g. oysters, mussels and clams/scallops.*

Ammonite? *An extinct marine snail with a flat, spiral shell divided into chambers with wavy interlocking walls. They became extinct about 65 mya.*

Figure 5.2.4.2 Classroom handout continues

The teacher followed the presentation and explanation of the slides with a video clip illustrating continental drift. The purpose of the video was to visualise how continental drift occurred and its effect on organisms, especially those that are now extinct, for example the saber-tooth squirrel. The focus of the lesson then progressed to bio-geography and its effects. The teacher began with a definition of bio-geography being *"…the study of the distribution of existing and extinct plant and animal species in specific geographical region on earth".* She used an example of flightless birds to illustrate how species could have adapted to changing environments. She then moved to fossil evidence and pointed to the two pictures on the handout (Figure 5.2.4.2), *"the drawing didn't print so nicely but you can also look at the size of this. This was an ammonite snail, that once roamed earth."* She asked the learners to underline the words 'bivalve' and 'ammonite' on the handout as well as the definitions printed on the handout. The teacher proceeded to explain how her father preserved a shell and how she views it as her example of a fossil:

> *"I wanted to show you this very pretty shell that my father preserved. What he basically did was opened up the shell, removed all the contents in it, sealed it*

closed and polished it and I think this would kind a serve as my own at home fossil. So you can pass it around and have a look at it".

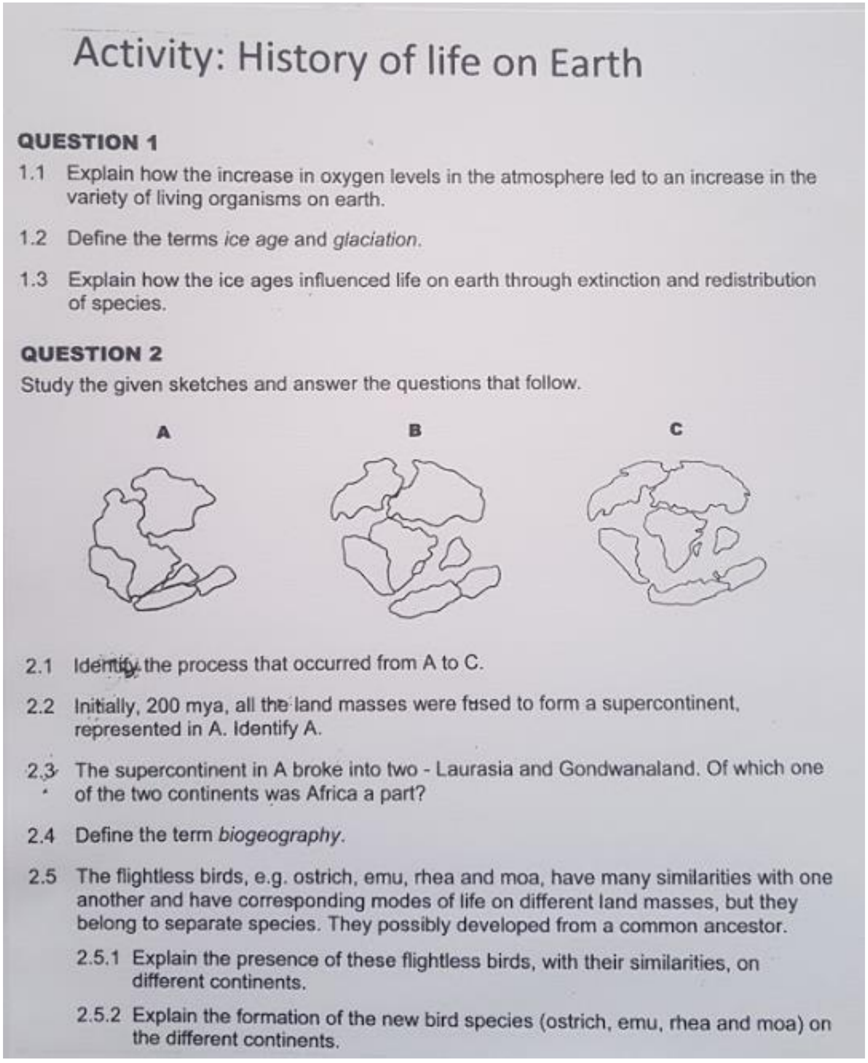
Thereafter, she proceeded to the class activity (see Figure 5.2.4.3). The questions were read aloud by the teacher and repeated by the learners. The same activity was digitally projected simultaneously on the whiteboard. Learners were asked to answer these questions individually, and they received an instruction to paste all the handouts (including their responses to the activity) into their workbooks. The teacher asked one of the learners to read the first question out loud. He read:

"Explain how the increase in oxygen levels in the atmosphere led to an increase in the variety of living organisms on earth. 1.2 Define the terms ice age and glaciation. 1.3 Explain how the ice ages influenced life on earth through extinction and redistribution of species".

At this point she stopped the learner and commented:

"You can stop there. Okay so that is basically the first half of the work where we look at oxygen levels, defining ice ages and glaciation and how the ice ages influenced extinction and distribution".

The teacher then made the same request for the remaining questions. The first questions were answered in class, by the teacher posing the questions again to individual learners and learners providing answers verbally. Most of the learners read the answers from the handout. The remaining questions which could not be completed in the class were given as homework.



Activity: History of life on Earth

QUESTION 1

1.1 Explain how the increase in oxygen levels in the atmosphere led to an increase in the variety of living organisms on earth.

1.2 Define the terms *ice age* and *glaciation*.

1.3 Explain how the ice ages influenced life on earth through extinction and redistribution of species.

QUESTION 2

Study the given sketches and answer the questions that follow.

A B C

2.1 Identify the process that occurred from A to C.

2.2 Initially, 200 mya, all the land masses were fused to form a supercontinent, represented in A. Identify A.

2.3 The supercontinent in A broke into two - Laurasia and Gondwanaland. Of which one of the two continents was Africa a part?

2.4 Define the term *biogeography*.

2.5 The flightless birds, e.g. ostrich, emu, rhea and moa, have many similarities with one another and have corresponding modes of life on different land masses, but they belong to separate species. They possibly developed from a common ancestor.

2.5.1 Explain the presence of these flightless birds, with their similarities, on different continents.

2.5.2 Explain the formation of the new bird species (ostrich, emu, rhea and moa) on the different continents.

Figure 5.2.4.3 classroom activity

5.2.5 School 5 – Grade 11 (Elvin)

Topic: Genetic modification

Lesson outcomes

The lesson outcome required the learners to define genetic modification and, in addition, to relate this concept to previous lessons on photosynthesis.

- Learners should be able to predict the outcome when genetic modification is used by plants and animals.
- Learners should also be able to discuss ethical and religious views on genetic engineering.

Classroom setup

The classroom setup was similar to that in school 2 described above where the desks were arranged in a laboratory style setup with a fixed projector connected to a laptop on the teacher's desk.

Lesson summary

The lesson started with an introduction by the teacher on the topic 'genetic modification'. He circulated an empty 'chips' packet and asked one of the learners to recite the ingredients displayed on the back of the packet. The learner responded "*msg*", the teacher interrupted the learner and questioned him further: "*What is wrong with msg?*" A brief discussion followed around 'msg' and the learners' attention is drawn to a statement on the packaging. The lesson is disrupted when a cluster of late learners entered the classroom. After allowing these learners to settle down, the teacher restarted the lesson and read the statement on the back of the chips packet "…p*roduced using genetic modification, product made in a factory using peanuts*…" He summarised by explaining that the chips are 'genetically modified'.

The focus of the lesson moved to the reasons why the chips are genetically modified. The prepared PowerPoint presentation was displayed on the whiteboard and the learners' attention was drawn to a new concept "Polysaccharides" on the first slide. The teacher sketched a sun and plant on the whiteboard (Figure 5.2.5.1) depicting photosynthesis, to encourage learners to reflect on the process of photosynthesis. The emphasis then moved to ATP (Adinosine Tri Phosphate) and what this concept means.

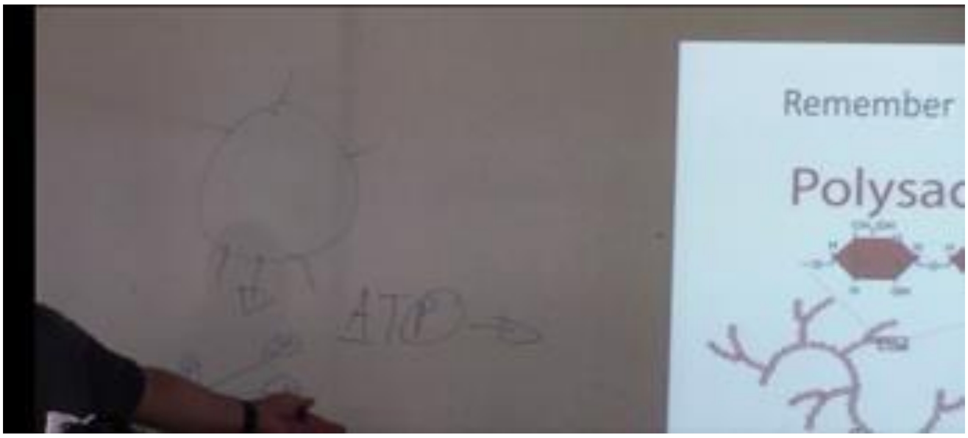


Figure 5.2.5.1 Teacher explains photosynthesis with a drawing on the whiteboard

The teacher proceeded to link the phrase "*you are what you eat*" to genetically modified foods. He continued by explaining the impact on the gene pool, genetic engineering and the advantages and disadvantages of genetically modified foods (Figures 5.2.5.2 and 5.2.5.3). Towards the end of the lesson the teacher presented a short video clip on genetically engineered foods. He paused at different times throughout the video to highlight points already discussed. Before the end of the clip, the bell rang indicating the end of the lesson period. In an attempt to finish the lesson, the teacher continued, while a message from the principal could be heard simultaneously over the intercom explaining the afternoons' detention session. The learners started to pack their bags. The lesson ended abruptly. No homework was given.

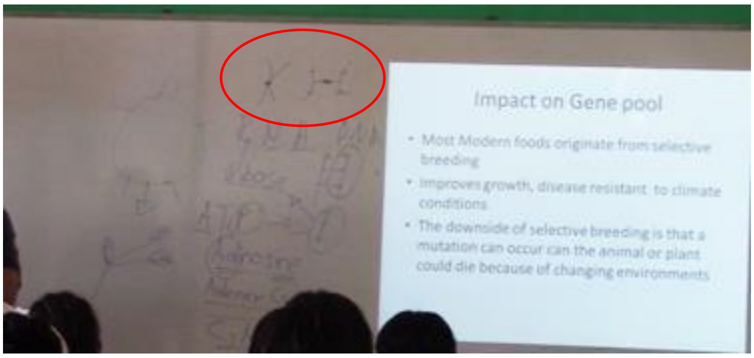


Figure 5.2.5.2 A figure drawn on the board (red circle) to explain genetic mutation

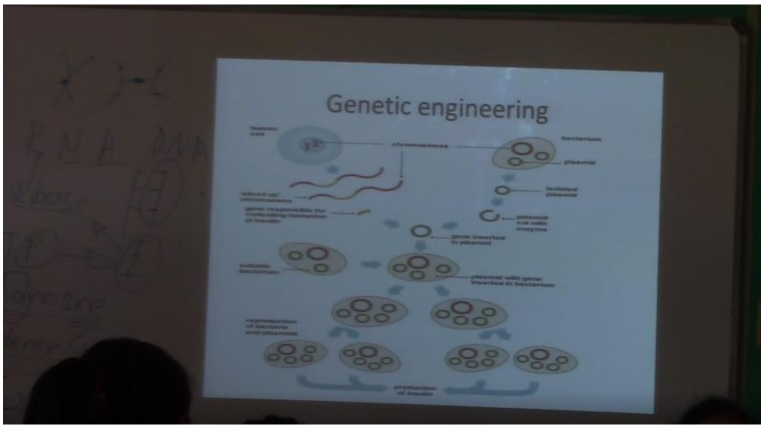


Figure 5.2.5.3 Explaining genetic engineering

5.2.6 School 6 – Grade 10 (Victor)

Topic: Evolution

Lesson outcomes

At the end of the lesson, learners will be able to:

- Differentiate between theory, hypothesis and evolution;
- State the differences between two theorists (Darwin and Lamarck); and
- Debate for or against one of these two theorists.

The purpose of the lesson was to enable learners to be informed of the concept of evolution as well as to equip learners with knowledge of key biological concepts of evolution. In addition, to enable learners to acquire knowledge on the purpose of theory in general and, in particular, Darwin and Lamarck's theories of Natural Selection, Use & Disuse and Inheritance.

Classroom setup

The classroom setup was similar to that in school 3 (indicated above) with desks arranged in straight rows facing the front of the classroom where the teacher stood. In this case, the only difference was the presence of a fixed data projector.

Lesson summary

The lesson started with questions on three terms, 'hypothesis', 'theory' and 'evolution' (Figure 5.2.6.1).

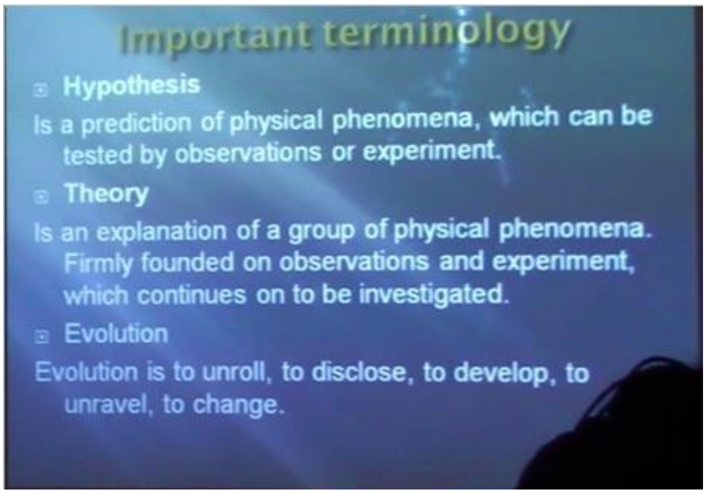


Figure 5.2.6.1 Important terminology

The teacher asked the learners *"What do you know about hypothesis"* and after receiving no response he continued *"[It] is a prediction of physical phenomena, which can be tested by observations or experiment"*. He then asked learners for an example, but because none of the learners responded, the teacher then volunteered to provide an answer:

> *"Okay let me come first. I live in Khayelitsha, If I live in Khayelitsha, I say, Ok if I leave Khayelitsha by 6:30am I will reach Walmer at 7:30am. Did you hear what I said. If I leave Khayelitsha, if I leave Khayelitsha, which means I am not sure, right, I leave Khayelitsha by 6:30am I will reach Walmer at 7:30. What will I have to do in order for my hypothesis to be successful? What do I need to do? I need to do a practical. Firstly, I need to setup my time, I leave Khayelitsha by 6:30, if I get here by 8:30, it means, it means that my hypothesis is wrong. Then what do I need to do? I need to redo it again. To check whether if again I will reach at 8:30 or more or below the time I have set. Therefore, we will know what is hypothesis now. It is when you guess. You guess something will be like this. Then you test it. Don't forget it because if someone says if, which means that person is not sure".*

After this explanation there is no further discussion of the term 'hypothesis'. The teacher moves on to the term 'theory'. He tells the class that the term is used by most scientists, for example Lamarck and Darwin, and gives the following explanation: *"theory is an explanation of a group of physical phenomena firmly founded on observations and experiment … which continue to be investigated".* However, before he completed the sentence, he probed the learners for the meaning of *'firmly'.* When he received no response the teacher stated, *"this word firmly, which means concrete"*.

The teacher then provides another practical example of the term 'theory' when he explained:

> *"for example, if I say If I say the world is U-shaped whereas the scientists say the world is round. The world is round! If I come and say the world is U-shaped the scientists will ask me to bring what? Evidence! The evidence that is needed so that we can show and believe that the world is U-shaped. Like I said if I say the world is U-shaped, the scientists know that the world is round so I have to bring evidence. So that they can believe that the world is U-shaped. It is firmly founded because now I brought what, evidence. Firmly founded on observations and experiment".*

The teacher asked the learners whether they were taking notes and reminded them that he expected them to take notes. He moved to the next topic definition 'evolution' and again introduced the definition with an example, *"You know in my days we are not use to these phones [raises cellular phone]. We were using telephones, we were writing letters and we use to fax them. If you wanted to communicate with someone it was difficult…it was very expensive that time, very expensive and it takes what, a lot of time, it consumes time so now as generations are moving along as time goes on we have these phones today [raises cellular phone again] which is very easy if I want to communicate straight I just phone them straight".*

He affirmed the definition of evolution as merely being a 'change', apparently, it was confirmed by the dictionary as well as scientists. He moved along to the 'theory of evolution', he started by reading the definition projected on the whiteboard (see Figure 5.2.6.2), "*The theory of evolution states that all species of living things*.." but abruptly stopped and probed the learners again, "*What is this term 'species'?"* "*Like the same type of organisms*", a learner answered. The teacher agreed with the learner, "*species are part of organisms*" and moved back to the definition projected on the whiteboard (Figure 5.2.6.2). He read out:

> *"now they say here, theory or the theory of evolution states that all species of living things that existed today or exists today and many more that are now extinct".*

The learners were now asked what the word 'extinct' meant. He did not wait for an answer before saying "*does not exist anymore. It is all dead. They are no longer there*".

The teacher then read further, "*The word it has evolved from simple life form, what is that simple life form?*" and explained it as being "*a cell*". He then asked the learners "*What is a cell*?" A learner responded that it was a basic unit of life. The teacher summarised the point with "*So all those species start from a basic unit of life or a cell*", before he moved along to highlight the connection he was trying to make with all these questions, being that although Darwin and Lamarck's theories were different, they shared one common belief, that is *"all species evolve from older species"*. While key terminology was underlined and probed for definitions, the questions asked seemed very basic and the concepts were simplistic. This trend continued when the term 'evolve' was underlined and learners were requested to provide meanings for this term.

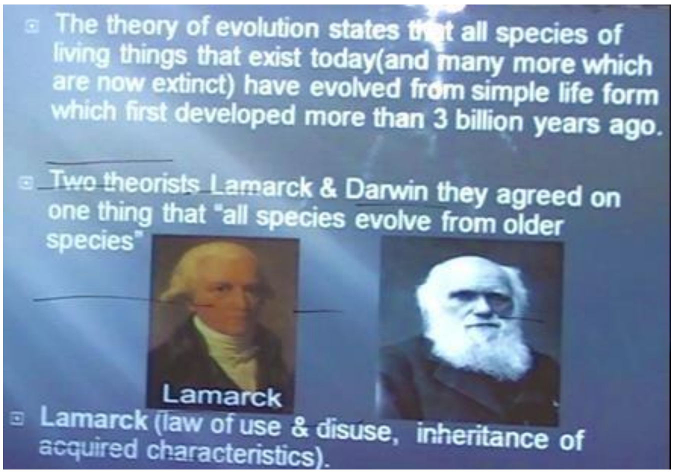


Figure 5.2.6.2 Lamarck and Darwin's theories introduced

The teacher continued the discussion on Lamarck's two theories (Figure 5.2.6.3). He told the class that Lamarck's theories were rejected, and promptly asked learners "*What does it mean to 'reject' something?*".

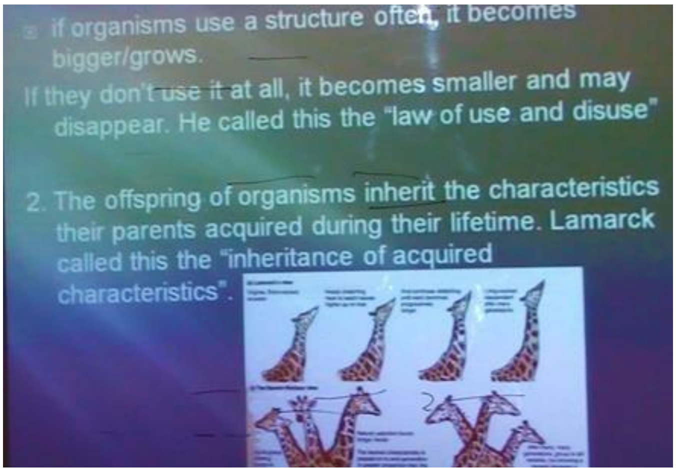


Figure 5.2.6.3 Lamarck's two theories

Thereafter, the teacher named the two theories, 'law of use and disuse' and the 'inheritance of acquired characteristics'. He explained Lamarck's 'law of use and disuse' theory using an example of a giraffe. He told the learners that Lamarck believed that all giraffes originally had short necks, but because of their environment, their necks grew longer. The teacher explained,

> *"Lamarck says in the end organisms change because they want to change. It means if you also want to change you can change. Do you agree with that? Do you agree with that? If you want to change you can change. If you want to become short you can become short. No you cannot. If you want to be tall, for*

> *example, can you change yourself? No you can't. Lamarck is saying that. They had short necks so they wanted to change so they changed. That is*
>
> *Lamarck saying that. Because giraffe's had short necks they didn't want competition so they stretched their neck so that they can be tall. Because they don't want to eat with bugs, goats and sheep".*

He then touched on Lamarck's second theory 'inheritance of acquired characteristics' and explained this as follows:

> *"Offsprings of organisms inherit their characteristics their parents acquired in their lifetime. What does that mean? It means that when I have children, my children will look like me, they will have my exact identity. A copy of myself. Do you agree with me? That is what Lanmarck says. Let us move along because the time is against us".*

The teacher next discussed Darwin's theory of natural selection. A learner was asked to read the first bullet on the slide (Figure 5.2.6.4). The teacher repeated this sentence. He then stated Darwin's claim that "*genes determine our environment*" and quoted the example of humans living in a cold place − "*if people survive and have offspring, these offspring would inherit the gene of 'survival in cold weather'*. He followed this with his own locally contextualised example:

> *"Around June/July it is very cold, some of you don't come to school right, and those that come to school in winter, if they had their offspring if they do produce their children, their children will have a gene of survival in the winter."*

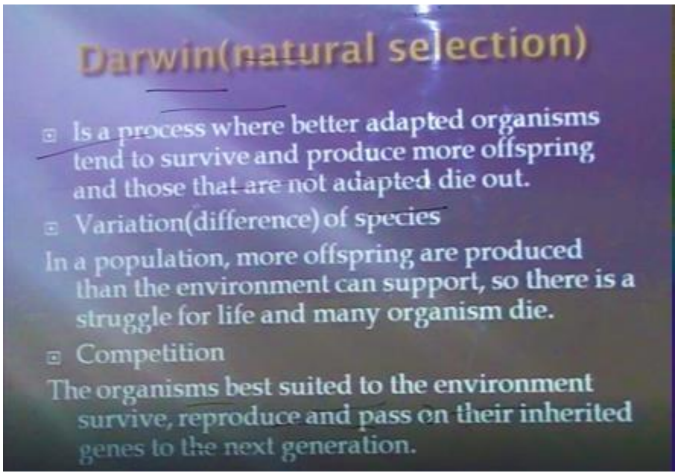


Figure 5.2.6.4 Darwin's theory

The teacher explained that "*In a population, more species are produced than the environment can support"* (second bullet Figure 5.2.6.4) with another basic example "M*aybe say in this class we are, the class can take fifty and if there is a hundred students in the class are we all going to fit in here?*" At this stage the bell rang and the teacher moved swiftly to the term 'competition' on the same slide. He reiterates what he previously said:

> "*those who survive will pass their genes to the next generation, in this way the composition of the population changes, which means the population evolves now … because the best-suited individuals survive, the population remains suitable to its environment*".

He proceeded to the next slide (Figure 5.2.6.5) entitled Why Lamarck's theory was rejected and the teacher supported the rejection because he maintained that organisms cannot change because they simply have a desire to change.

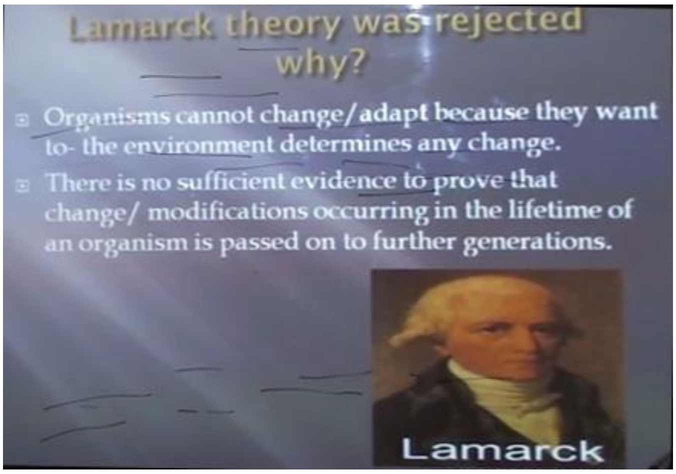


Figure 5.2.6.5 Rejection of Lamarck's theory

The learners were then instructed to write down the information displayed on the slide. For homework they were instructed to choose one of the theorists discussed in the lesson and to either argue for or against their theories.

5.2.7 School 7 – Grade 8 (Sipho)

Topic: Feeding relationships

Lesson outcomes

At the end of the lesson, the learners should be able to describe different feeding relationships as well as draw food chains to show energy flow.

Classroom setup

The classroom setup was similar to that of school 3 (described above) with desks arranged in straight rows facing an old rusted whiteboard attached to the wall at the front of the classroom. A portable projector stood on a small wooden chair in front of the teacher's desk which allowed the provision of a small digital display (Figure 5.2.7). On the right-hand side of the classroom (from the teacher's perspective) stood an unused cathode ray tube (CRT) computer monitor, and on the left-hand side was an old bookcase containing some books.

Figure 5.2.7 Sipho class presentation

Lesson summary

The teacher introduced the lesson by exploring how living organisms acquired and used energy. Sunlight was given as the main source of energy through the use of real life examples which showed how living organisms used sunlight for energy:

> "*so plants, green plants like the grass that my feet kicks gets energy from the sun and then takes that energy, takes the light energy and converts to kinetic energy for food and that process is called photosynthesis*"..

A PowerPoint presentation was used as a teaching tool to work through the classification of living organisms. Definitions of key terms were given, such as 'energy', 'producers', 'consumers' and 'decomposers'. The learners were extremely noisy and chatty and, consequently, were constantly reprimanded by the teacher. However, they continued to interrupt the teacher by asking whether they needed to write down the notes, *"Sir are we supposed to be writing this down?", "Sir, must we write those?".* Lack of discipline was obviously a problem resulting in the teacher having to frequently reprimand learners, *"Don't shout, or you will get a cricket bat"*.

The teacher's frustration with the learners' lack of attention is seen in a short dialogue between the teacher and learners.

Teacher:	*What is .. What do you understand by feeding relationships?*
Laeeqa:	*It is similar too* (pauses)…
Teacher:	*Nothing, obviously nothing!*
Laeeqa:	(makes gasping sound).

The teacher used names of learners to illustrate the behaviour of carnivores, herbivores and omnivores, which the rest of the class found hilarious.

Teacher:	*Omnivore, that is called an omnivore. Right, so Washier eats the grass and then Ashiek kills Washier .. and then he eats Washier for lunch. There are three types of Omnivores*.
Learners:	(noise) *and after that Rashiek comes along* … (laughing)
Teacher:	*Thank you*
Learner:	*Scavengers* (teachers and learners laugh at comment)

Teacher:	*There is three types of Carnivores ok. The first one predators, like that boy at the back, called Washier. So predators are animals that kill.*
Learner:	*So are sir telling me that Washier, killed himself* (laughing).
Teacher:	*Yes, that is what I am telling you. Ok predators kill. Washier thank you.*
Learner:	*Shhhhhh.*

The same pattern is seen when the teacher explains scavengers:

> *"Scavengers feed on dead animals. So Washier eats the grass, Ashiek kills Washier. Who eats Ashiek a hyena, Taliek and then Taliek eat the leftovers. If Ashiek is full he leaves Washier there"*.

The teacher continued to use the names of learners as examples, a practice that added to the chaos because learners found it hilarious, for example:

Teacher:	… *Insectivores eat only on insects*
Learner:	*Like birds*…?
Teacher:	*Like 'Mujied'* [Mujied is the name of a learner]

The teacher jokingly referred to Amy (a learner in the classroom) as an insectivore, as she apparently ate cockroaches. He did the same with Paul, whom he pointed to and called a baboon, "*as you can see humans and 'Pauls'*". He used the same approach when he described decomposers:

> "*So once the scavengers are done then Xola and all her other friends come along and they recycle whatever is left of all the nutrients that is in the soil" and*

> *"When Washier eats the grass, then Ashiek kills Washier. Then when Ashiek is done, he 'skuurs' … runs away and then Taliek and Anieta come and eat the left overs and when they are done, they fight over leftovers, yes when they are done then Sam, Nicole, Simba, Sipho, Tom, they all come*".

Although the teacher used examples to illustrate points, he made it clear that he did not want learners to use examples when answering questions unless specifically asked to do so:

> Teacher: …*Does anyone know what a decomposer is?*
> Learner: *Maggots.*
> Teacher: *I didn't ask you to answer with an example*!

The teacher expanded on the important role of decomposers. He explained that decomposers recycle minerals and nutrients, found in dead organisms, back into the environment. The teacher was constantly mocked by learners with such comments as "*I love the way you explain that, sir*!" and "*We love you*." after which the rest of the learners would laugh. For the remainder of the lesson, the learners' demeanour remained chaotic and unruly. Towards the end of the lesson, the teacher threatened to evict a particular learner from the classroom for refusing to stop talking, however, after warning the learner, he continued with the lesson. The lesson concluded with in class exercises. The first exercise required learners to provide answers to questions on the content learnt in the lesson (see Figure 5.2.7.2).

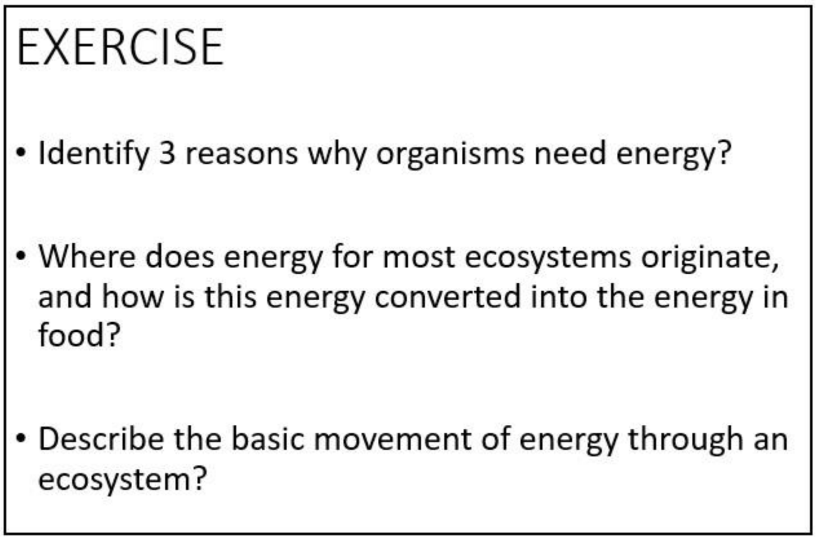


Figure 5.2.7.2 Classroom

There was also a matching exercise in which learners had to match the contents in column A to the contents in column B, see Figure 5.2.7.3 below.

Exercise continued

COLUMN A	COLUMN B
1. GOAT	a. Producer
2. GRASS	b. Scavenger
3. LEOPARD	c. Herbivore
4. VULTURE	d. Predator

Figure 5.2.7.3 Classroom exercise continued

Lastly, learners had to name the 'producer', 'consumers' and 'decomposers' in a picture provided, see Figure 5.2.7.4 below.

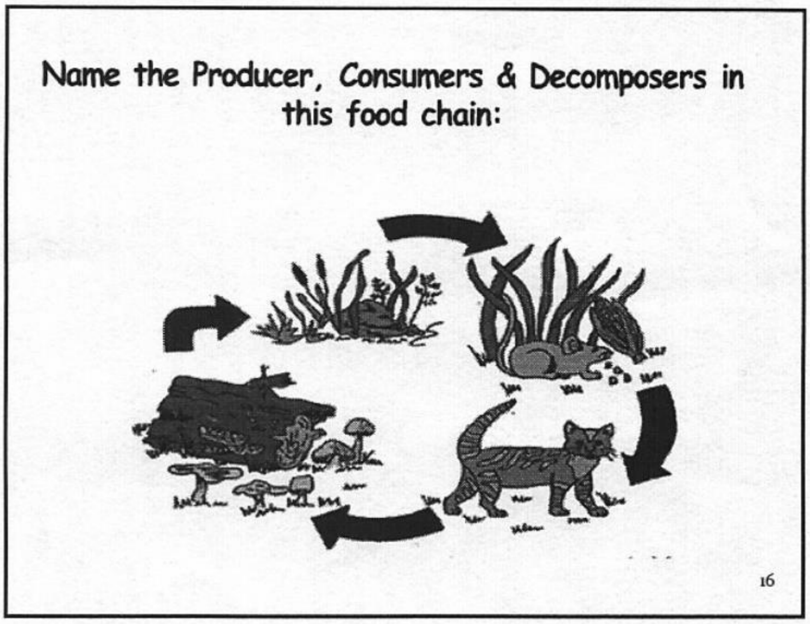


Figure 5.2.7.4 Food Chain exercise

These three exercises were verbally completed by learners as a group.

5.2.8 School 8 – Grade 10 (Cecelia)

Topic: Biosphere

Lesson outcomes

At the end of the lesson learners should be able to acquire the following knowledge:

- Ability to access information from a variety of sources;
- Select key ideas obtained from sources;
- Recall and describe knowledge related to LS; and
- Analyse, discuss and debate ethical and legal issues surrounding biotechnology.

Classroom setup

The classroom setup was similar to that in school 3 (described above). In this case the only difference was a fixed data projector in the classroom's ceiling.

Lesson summary

The lesson started with the teacher displaying an image of earth (Figure 5.2.8.1).

Figure 5.2.8.1 Image of earth

The lesson was taught in a mixture of English and Afrikaans. The questioning method was used to recap on previous work completed on the Biosphere topic. First, the teacher asked the learners to identify a concept she referred to as a 'total' [circle with her hands] where there is life. This concept was identified by the learners as the biosphere. Then she questioned the learners on how many 'groups' the biosphere is divided into. They answered three. Thereafter, she asked individual learners to name and explain what happens in these three 'groups'. A learner identified the 'hydrosphere' and pointed to the middle line on the picture. The teacher wrote the label 'hydrosphere' next to the middle line (Figure 5.2.8.2).

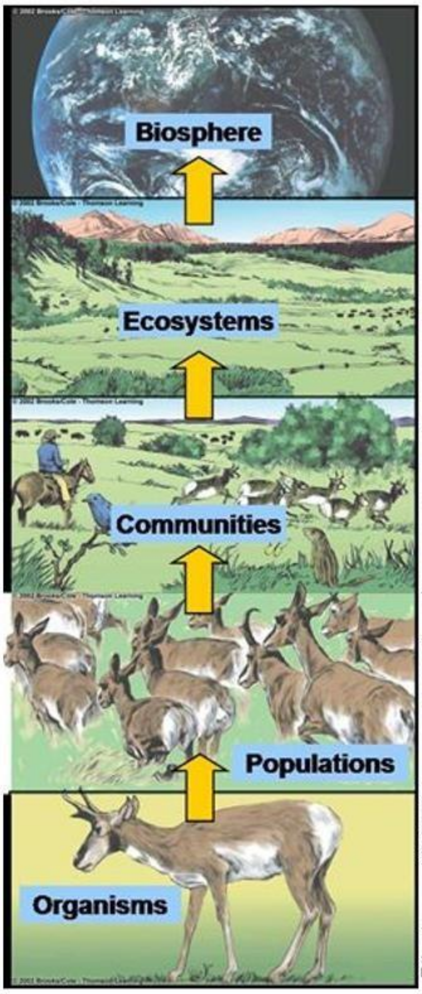
Figure 5.2.8.2 Teacher writing labels

She then asked this learner to explain what happens in the hydrosphere. He answered, '*This is how the vissies [fish] live*. The teacher accepted the answer and further elaborated:

> "*All the vissies [fish] live here. So this is 'hydro', tells us it is water, so all the vissies [fish] lives in the hydrosphere … so it is your rivers, it's your oceans, it's your lakes ne".*

She probed further to identify the other layers in the image (Figure 5.2.8.1). A learner answered the '*atmosphere*' and '*lithosphere*'. The teacher was not happy with the answer given and responded with a "*no, no, no*". She explained to the learner, "*okay yes you get the atmosphere and lithosphere, but okay we are going to start with the atmosphere which is the dots around*" while making imaginary dots around the picture. She also wrote in the label 'atmosphere' next to the picture. She asked the learners to tell her more about the atmosphere. She told them that "'*atmos' says it is about air and gasses"*. There was also a brief discussion on the English pronunciation of the Afrikaans word 'gas'.

The teacher then proceeded to question what the air in the atmosphere consists of. Learners gave answers such as '*oxygen', 'nitrog*en' and '*carbon dioxide'*. She then wanted to know what oxygen is used for in daily life. A learner answered, "*Ons gee uit* *carbon dioxide, dan kry ons die oxygen van die bome en plante* [We give out carbon dioxide, and we get oxygen from the trees and plants]". She probed further by asking what plants use carbon dioxide for. A simple response '*photosynthesis*' came from a learner. She moved along questioning what the layer of gas around the earth protects the people from. There was a response, '*the sun*' from a learner. The teacher took this opportunity to quickly warn the girls about the pending summer and the need to use sunscreen and face cream to protect against old age marks and skin cancer before questioning whether learners understood all three concepts (atmosphere', 'hydrosphere', and 'lithosphere'). The learners nodded in agreement, but the teacher realised that she had not yet covered the last topic 'lithosphere'. She quickly apologised and wrote the label lithosphere on the board, referring to it as '*the ground wherein we live*'. She wanted to know what the lithosphere consists of and the learners responded '*rocks'*. She agreed and said '*rocks' and 'soil'*. The lesson turned conversational involving an off topic discussion on whether a house could be built in the ocean. The teacher then returned to the lesson topic and asked the learners to take out their workbooks, which contained notes on the topic. She also explained that this lesson would assist them with a test they would be writing the following Monday and that she wanted to return to the basic ideas relating to the biosphere. She asked individual learners to read the various sections out loud from the sequence taken from the bottom section headed 'Organism, habitat, niche, species' to the 'Biosphere' section at the top of their notes (Figure 5.2.8.3).



Biosphere
Where life is found on earth; made up of atmosphere (air), hydrosphere (water), and lithosphere (land).

Biome
Large area with a certain climate and species of plants and animals; made up of smaller ecosystems.

Biological community
All the populations of different species in a place. E.g. populations of lion, impala, thorn trees and other plants interacting in an area.

Ecosystem
Communities of plants and animals interacting with each other and with their non-living environment. E.g. all the plants, animals, soil, water and other non-living things.

Population
A group of organisms of the same species, living in a specific area at the same time. e.g. all lions living in one pride.

Organism, habitat, niche, species
An organism is a single form of life (e.g. one impala);
The habitat is where it lives;
The niche is the role it plays where it lives;
And a species is a group of organisms of the same kind, which can breed with one another (all impala are one specie)

Figure 5.2.8.3 Extract from the learners' notes

The organism was referred to as a single form of life and she used a springbok and herself as an example of an organism. Then she moved to explain what a 'population' is. She used her household as an example and explained this concept as being her mother, father, brothers and sisters all living in the same house and interacting with each other. She moved on to an 'ecosystem', and again used her household as an example of this concept and how the members now proceeded to move outside of their house and came into contact with other objects (living and non-living) outside their 'home' space. The same example was used for 'biological communication'. When explaining the Biome, the teacher asked learners to provide a definition without looking at their notes. However, before the learners could give her a definition, she started probing the Biome they thought they lived in, as well as the number of Biomes in South Africa, together with the characteristics of Biomes. The learners answered all these questions using examples such as:

"In Cape, here by us we have wines and stuff and in Durban there is sugar and corn and maize. So it is the type of land and soil".

A few learners were called to the front of the classroom and given similar printed images to those in their notes. They were instructed to arrange the pictures from the simplest to the most complex form with the help of input from the rest of the class but without consulting their notes (Figures 5.2.8.4, 5.2.8.5 and 5.2.8.6).

Figure 5.2.8.4 Learners with printed images

Figure 5.2.8.5 Learners completing an activity

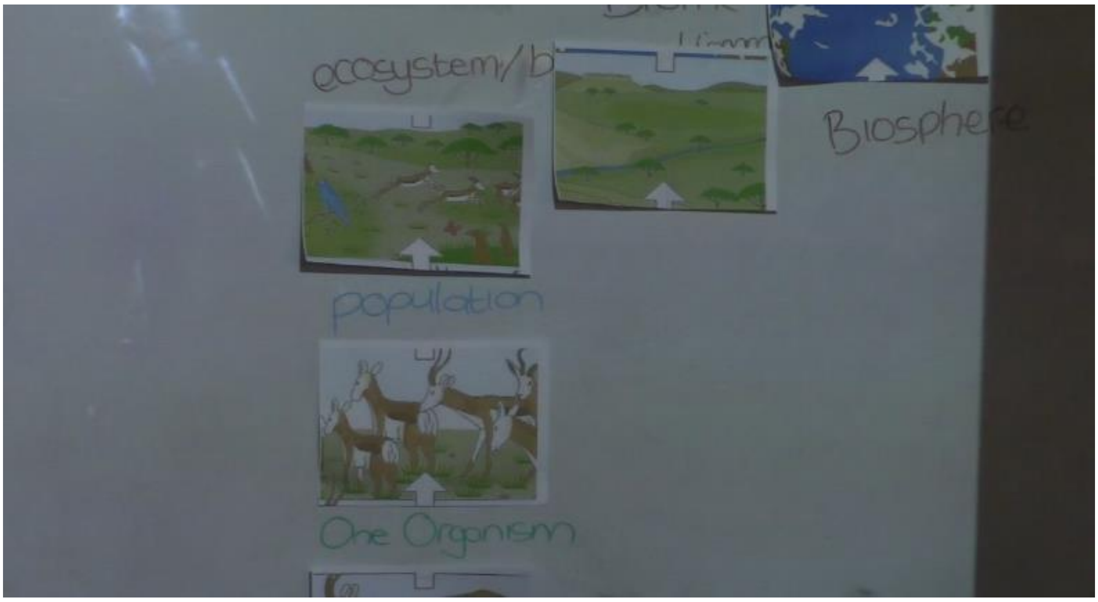


Figure 5.2.8.6 Part illustration of the completed activity

The epistemological level of this exercise was basic considering all of the information provided in the learners' notes (see Figure 5.2.8.3).

The next section of the lesson focused on working through a revision activity (Figure 5.2.8.7). The teacher read out the questions which were based on a picture, '*Identify the living things*', followed by '*Identify the non-living things*'. Next, the teacher read '*Identify any relationships between the living things*'. The last revision question was '*In* *what ways do living things need non-living things'* and the learners worked through the answers as a group. For the first question, the learners identified 'fish' and 'plants' as living things. Next, they identified 'water', 'sunlight' and 'soil' as non-living things with the help of the teacher. The teacher had to remind them that their answers had to be based on information provided in the picture (Figure 5.2.8.7). '*Fish eat plants'* was given as the relationship between living things. The teacher questioned whether there could be a relationship between the large and small objects (although this link was not depicted in the picture portrayed in Figure 5.2.8.7). She reminded them that "*bigger fish could eat smaller fish*". Eventually, the learners identified "*fish need water"* and "*plants need sunlight for growth and photosynthesis*". The teacher then reminded them that "*fish also need air for respiration*".

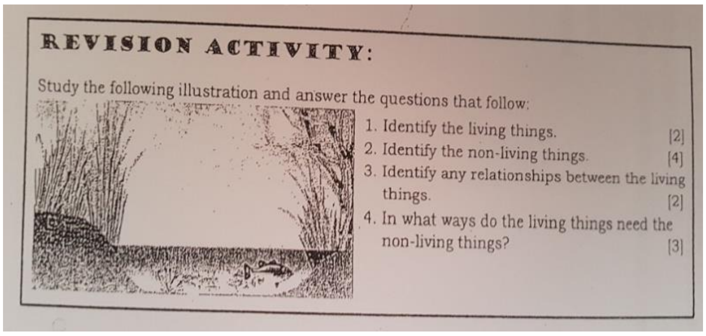


Figure 5.2.8.7 Revision activity

A classroom activity from the learners' LS textbook followed. The instruction was to identify the three labels on the picture provided in the exercise. The image was also displayed on the whiteboard for clarity (Figure 5.2.8.8). For the remainder of the lesson (about 15 minutes), the learners were occupied with the activity before the bell rang. No answers were given to the learners.

Figure 5.2.8.8 Activity displayed

5.2.9 School 9 – Grade 10 (Beauty)

Topic: A debate on 'Science must fall'

Lesson outcomes

No lesson outcome was provided as none were prepared.

Classroom setup

The desks were arranged in straight rows facing a green chalk board filled with previous lesson notes and there was an interactive whiteboard mounted in the middle of the chalk board. A portable projector stood on a blue plastic chair on top of a desk with portable speakers on either side of the desk.

Lesson summary

The learners were shown a video clip entitled "Science must fall." depicting of a panel discussion about 'decolonised' education[3] that was being distributed via social media. In the video clip, a speaker claims that science is a "product of Western modernity" and science should be 'scrapped', "especially in Africa". After watching the video, the

[3] March 2015 a group of students campaigned for the removal of the Cecil Rhodes statue found on the University of Cape Town, the #RhodesMustFall hashtag trended and raised the issue of white iconic historical figures and their significance in a multicultural democracy. Soon (late 2015) #FeesMustFall a student led protest movement began in response to an increase in fees at South African universities especially for poor students and called for free, decolonised education. This sparked various debates around what #DecolonisedEducation meant for Africans and whose interests the current curriculum serves.

learners were provided with a brief overview of the contents and context thereof, and asked for individual opinions on the subject and contents. The teacher explained that Africa was colonised by the British:

> *"they came and erected their missionary schools in order to teach the African people what they themselves thought was right because they thought African culture and religion and values and beliefs were barbaric"*.

She further probed, *"Do you know what that* [barbaric] *means?"*

A learner enthusiastically responded, "*Yes Miss, wild*". The teacher affirmed the learner's response and continued, that they (the British) replaced all or most of the African things (presumably she was referring to African customs and knowledge sources). She explained, throwing out science completely as suggested in the video clip might not be right and asked for the learners' opinions. What followed was a chaotic and noisy discussion on the topic over which the teacher had little control.

A learner shouted "*That's racist*", followed by another saying "*very racist*". The teacher reprimanded the learners and advised them as follows: *"Please no one is [*being*] insulting or racist or rude and if you are going to have an opinion it is going to be a logical[ly] thought out one"*. Another learner shouts, "*that's racism… that's racism right there. Why would you bring in an African perspective*?". The teacher asks the learners what is wrong with 'an African perspective'? A learner sarcastically responds, "*What is wrong with an African perspective*?". Another learner shouts "*Exactly*!!". The teacher is frustrated when another learner responds: "*Miss must ask the question, and give the answer also*." and she continues, *"I asked you what you think about it".* A learner mumbles "E*verything is already in order and now they want to*..".

The teacher desperately tried to explain the point of view expressed in the video, namely that in South Africa learners are taught mainly from a Western point of view and they should also be learning about what happens in Africa. "*No miss but Africa discovered nothing*" a learner comments. The teacher questions, *"How do you know that?",* while pleading with the rest of the learners to be quiet. "*Miss what can we give to society? African languages*?". The rest of the learners laughed loudly. After many failed attempts to persuade the learners to behave and listen, the teacher responded: *"Grade 10s you do realise this will affect you because you are going to University?".* Some learners reacted in a positive manner and others negatively. The teacher again questioned why the learners felt that nothing comes from Africa? A learner hesitantly answered:

> *"Excuse me miss, seeing that the video was Science must fall, does it mean all types of science, including life science, physical … everything miss? So if science must fall, I am not trying to be racist or anything… South Africa is seen… if we look we have water conservationist… We are kind of … (developing country?* Girl next to her answers*) no not that… you cannot attack South Africa. If you attack from the top you have to go through all the countries on top, if you attack from the bottom. What can I say … (navy?* The girl sitting next to her trying to help*) Navy. We have one of the best navies. . So if there is no science we will be an unprotected country. So there will be no guns, no ships, no planes … no nothing… so … so … we will have…"*

The teacher hushed the class again, while the learner continued,

> "… *so we will have a weak spot. Where we look at Russia, America, Japan, their development in technology uses science. So yes as the girl said we should look at science from an African perspective".*

The teacher again attempts to reduce the noise level in the class. Next, a discussion on Sangomas[4] and witchdoctors followed as a result of a comment in the video clip which suggested that Sangomas practise science when they 'send' lighting to strike someone. A learner cautions that not all Sangomas are wicked or dangerous and compares Sangomas to herbalists in Islam who provide medication. Another learner pleads with the teacher to ask another question. The teacher summarised her argument by stating,

> "*you can learn more about Africa and whatever was discovered whether scientific or geographical or sociological, by adding to what you are already learning. Therefore, learners are not simply learning about Western scientists but also what was discovered in Africa as a continent and not necessarily South Africa".*

A confused learner answered: "*but it is the main continent, South Africa*". Ignoring this comment, the teacher continued: "*should the subject of African cultures and what was discovered in Africa be a separate subject?* In a last attempt to make learners think about decolonised education, she probed whether it would broaden their horizons to know more about their country. She used an example of a microscope and pointed out that any discussion of it is always preceded by some history on how it was

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[4] *Sangoma* is a Zulu term commonly used to describe different types of Southern African traditional healers.

discovered. She suggests that in order to achieve a South African perspective on any topic, educators merely need add a little history around how this topic applies to the learners in their current context. The last comment heard was *"There were other things discovered that we don't learn*".

Learners were now talking and walking freely around the classroom. At this point, the bell rang, signalling the end of the period so no homework was given to the learners.

5.2.10 School 10 – Grade 11 (Freda)

Topic: The chambers of the heart

Lesson outcomes

At the end of the lesson, learners will be able to:

- Label the external structure of the heart and list the functions of those structures; and
- Name the main components of the circulatory system

Classroom setup

The classroom setup was similar to that described for school 3 (see above). In this case, the only difference was a fixed data projector attached to the ceiling and pictures decorating the walls (Figure 5.2.10.1).

Figure 5.2.10.1 Picture of the classroom

Lesson summary

From the onset, the teacher had technical problems with the displaying of her PowerPoint presentation. One of the learners was tasked to call the technician. In the meantime, she focused on sketching a scenario through which the learners could think about the functions of the heart. She told them to imagine a boy in love with a girl. Every time he sees her; his heart goes *“boom boom boom boom”*. He finally acquires the courage to approach her and her negative response ‘breaks’ his heart. After the sketched scenario, she asked a learner to draw a picture of the structure or shape of his heart on the whiteboard, followed by a picture of the heart being broken (Figures 5.2.10.2 and 5.2.10.3). She did not specify whether she meant the breaking to be figurative or literal.

Figure 5.2.10.2 Learner drawing a heart

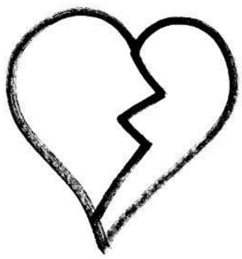

Figure 5.2.10.3 Picture of heart drawn on the whiteboard

She questioned the class, “*Do you agree with what he drew? Is this how you draw a heart?”*. The learners responded in the negative. *“So we already know that Jacob doesn’t really know how the heart looks inside his body. So who can help Jacob by telling us where the heart is situated in our body?”* A question session followed on where the heart is situated and what body parts protect the heart. It took roughly ten minutes for the technical problem to be fixed, after which time she could continue with her planned lesson. She started a PowerPoint presentation and paused on the first slide to read the topic, ‘External structure of the heart’. She moved to the second slide which depicted a picture of the location of the human heart, and this was immediately followed by a six-minute *YouTube* animation video clip on the anatomy of the heart[5]. The narrator traced a drop of blood as it moved through the heart.

The learners were instructed to write down and answer questions in their books to test how much knowledge they had acquired during the lesson. The operation of the audio-visual equipment again proved problematic. the teacher, therefore, narrated the following questions to the learners.

1. *What are the arteries that carries deoxygenated blood?*
2. *Through what vein does oxygenated blood return to?*
3. *How does the blood flow from your left atrium to your left ventricle?*

Just before her narration of the last question, the learners were alerted to the fact that the technical error had been resolved. The teacher then displayed the same questions on the whiteboard and the learners were able to copy the remaining questions from the displayed presentation (Figures 5.2.10.4). After providing a lengthy period for the questions to be written down by the learners, she repeated the same video clip.

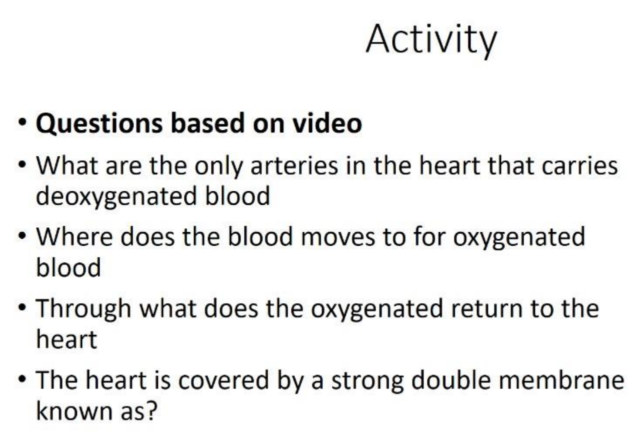

Figure 5.2.10.4 Questions displayed on the whiteboard

The lesson moved to learners writing the answers on the chalkboard (Figure 5.2.10.5).

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[5] https://www.youtube.com/watch?v=ESFPSHCDDZU

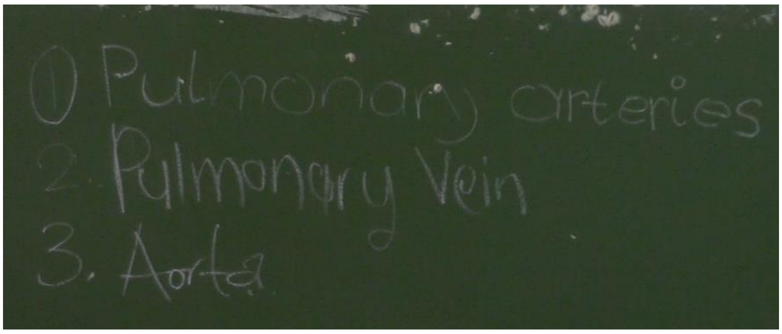


Figure 5.2.10.5 Answer on chalkboard 1

One of the learners alerted the teacher to a mistake made in one of the answers written on the board. She told the learners:

> *"You know I am a teacher and I am human and we have seen that somehow someone has made a mistake and I asked the class do you agree and you said yes! … and when miss looked at the answer number 2 is wrong, and then they swapped it. So what is the answer of number two? Where does the blood moves too? Oxygenated blood. It moves to the …".*

A learner responded "*lungs*". The teacher then asked the boy to correct the answer on the board. She questioned the third answer as well, and casually remarked "*People are just realising now that they did not listen*". The boy corrected the answer (Figure 5.2.10.6).

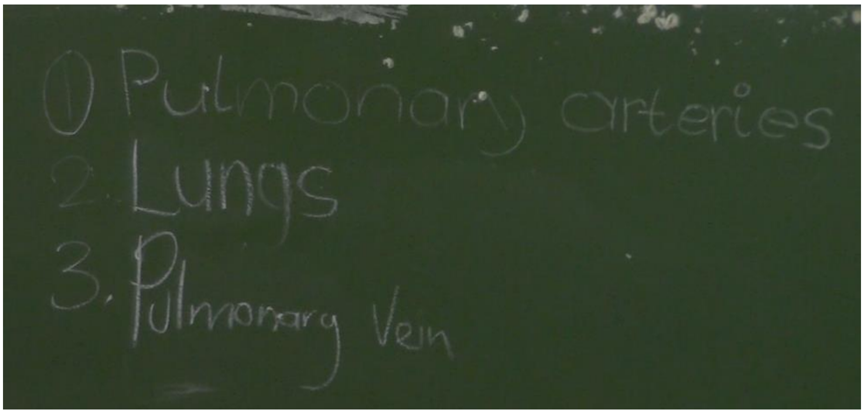


Figure 5.2.10.6 Answer on chalkboard 2

To the last question projected, 'The heart is covered by a strong double membrane known as …………?', a learner wrote the answer 'Pericardium'. Thereafter, the lesson was concluded with the learners being asked to complete an exercise from their textbook. A picture showing the external structure of the heart including labels, was projected onto the whiteboard. This was the same picture as one in the learners' textbook (Figure 5.2.10.7). Learners were instructed to familiarise themselves with the labels for five minutes before completing the set exercise.

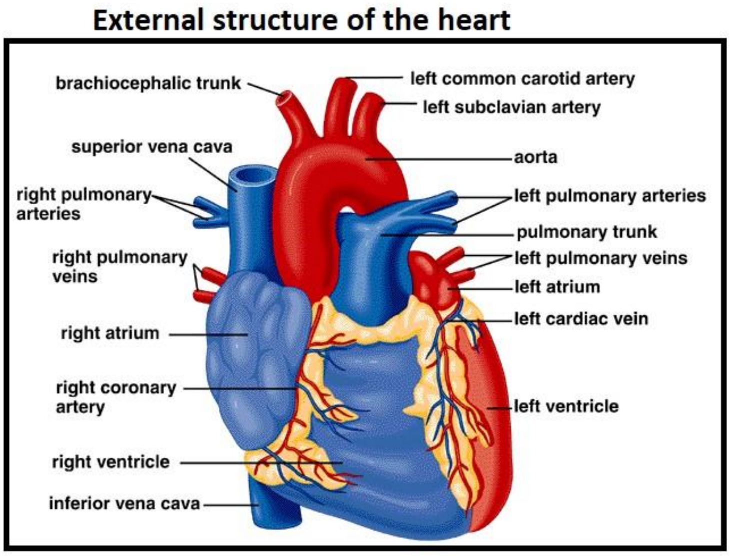


Figure 5.2.10.7 External structure of the heart

The exercise included questions such as 'Which blood vessel carry blood away from the heart and towards the heart?', 'Why is blood in arteries a brighter red than blood in the veins?'. Learners were required also to complete a table by filling in three structural differences between an artery and a vein. The learners were given the remainder of the lesson to complete the exercise. Learners seemed occupied with chatting rather than fulfilling the set task. The teacher did not check their answers.

5.2.11 School 11 – Grade 10 (Hester)

Topic: Revision

Lesson outcomes

This was a revision lesson aimed at preparing learners for the end of term examinations.

Classroom setup

Figure 5.2.11.1 Classroom setup

Lesson summary

The lesson was conducted in Afrikaans. Every second learner was given a card with an image of a heart as well as two pieces of wool (Figure 5.2.11.2).

Figure 5.2.11.2 Classroom activity wool and 'heart card'

At the start of the lesson, the teacher displayed the 'heart card' on the whiteboard (figure 5.2.11.3) and asked general questions around the heart and its functions.

Figure 5.2.11.3 – The 'heart card' given to learners digitally displayed on the board during lesson

One of the questions asked by the teacher was: '*What is the importance of the heart?*'. A learner answered: '*It pumps blood*'. The teacher probed further, '*What is the function of that blood, what does it transport*?'. A learner answered '*oxygen*'. The teacher also asked what type of pump the heart is and laughed when a learner answered a '*muscle pump*'. This was not the answer she expected but she continued: '*What does it do?*'. When the learner answered '*blood pump*'. '*Pumps blood to where?*' the teacher continued and the learners answered in unison 'T*o the rest of the body'*. This question and answer session continued for about 15 minutes. Thereafter, the teacher played a video showing a rap artist[6] who rapped the functions of the heart. She asked learners to listen intently because the classroom speakers were not working and she had to play the sound directly from the laptop.

[6] Rhythm Rhymes. The circulatory system, https://www.youtube.com/watch?v=LqhvmUEdOYY

Rap

Taking blood from the heart to the cells and back
Dealing with all things vascular and cardiac
Capillaries, Arteries & Veins
All I'm saying is circulation is the name of the game

Repeat (blue)
Repeat (green)

Now let's start from the heart 'cause that seems smart
It's not hard to see that it is most important part
The first step is to gather up oxygen
Sends blood to the lungs, back to the heart again
Next up, we'll talk about the arteries
They take blood from the heart to where it's gotta be
The biggest artery, the main transporter
Right next to the heart, it's called the AORTA

Repeat (blue section)
Repeat (green section)
Repeat (blue section)
Repeat (green section)

From the arteries into the capillaries
All your organs and muscles become the
Of all the oxygen and nutrients they bring through
Very tiny vessels inside the body tissue
And now the oxygen's gone
But first we have some carbon dioxide waste to take on
Then it's into the veins and back to the heart again

Repeat (blue section)
Repeat (green section)

Repeat (blue section)
Repeat (green section)

Repeat (blue section)

Figure 5.2.11.3 Rap words

At the end of the video, the teacher drew the learners' attention to specific sections of the visual presentation, for example the veins, and required learners to identify certain parts of the image (Figure 5.2.11.4) while elaborating further on other parts of the heart and its functions or asking learners to elaborate on these (Figure 5.2.11.5).

> Juffrou: Onthou julle hierdie sketsie? Wie kan vir my sê wat is alles in hierdie sketsie? Daar is nou alklaar een, so te sê een byskrif vir jou, veins is jou wat? Is jou aare, is jou vene, so die rooi gedeelte, as mens sê jou vene. Blou het ons gesê stel wat voor? [English translation below]
>
> Teacher: *Do you remember this sketch? Who can tell me what's in this sketch? There is already one caption, so to speak, veins [referring to the English word) is your what? It's your veins, it's your vein, so the red part, if you say your vein. Blue we said represents what?*

Another example of this would be where she asked the class to look at a picture (figure 5.2.11.5) and to tell her what it looks like. In this case, the learners responded, "like an eight". The teacher asked the learners to recall that she drew an 'eight' earlier during the lesson and told them that the heart is known as a double circulatory system. She continued, *"why do we say a double circulatory system? The blood moves around how many times?"* Learners responded, "*two times*".

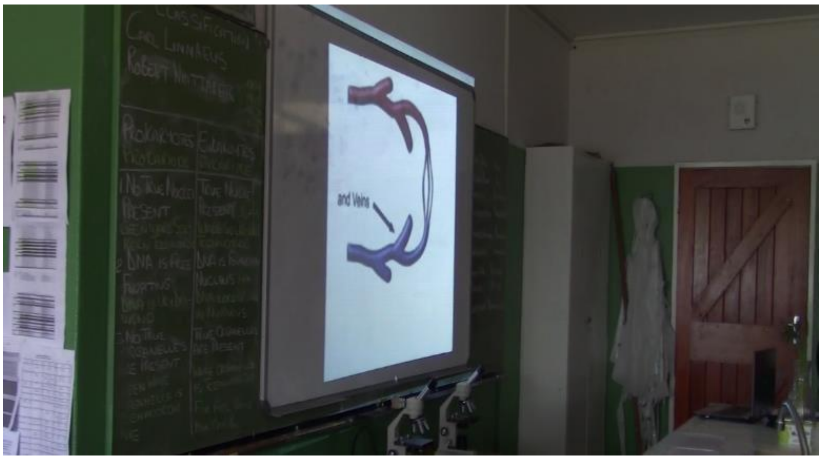


Figure 5.2.11.4 Name the parts

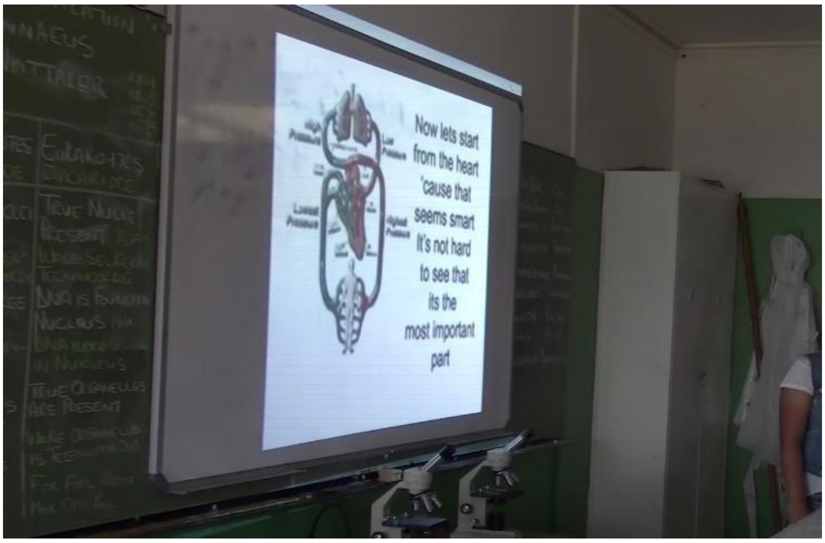
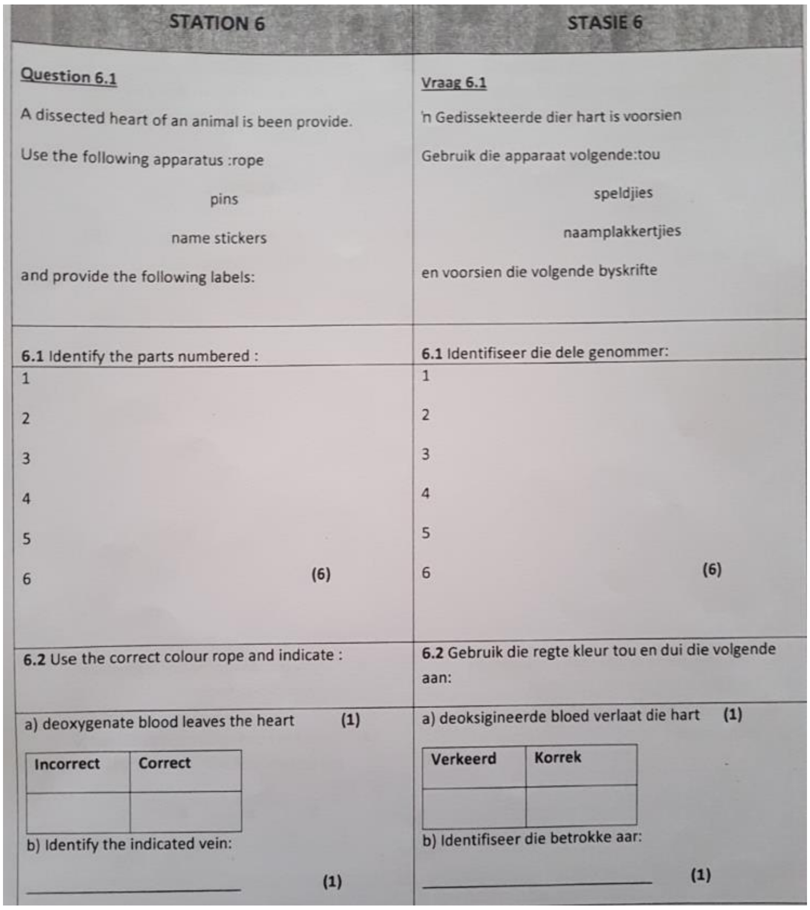


Figure 5.2.11.5 Further elaborations

The teacher handed out a five-page worksheet. She then explained the activity they were intended to complete with the two pieces of wool and the 'heart card' (a picture of a dissected animal's heart) (Figure 5.2.11.2) they had been given at the start of the lesson. Learners were to use the wool to show the blood flow through the heart, the red representing oxygenated blood and blue deoxygenated blood. Thereafter learners were given another activity (Figure 5.2.11.6) that they were required to complete on their own in class. This task required learners to identify various parts of the heart, and then to use the correct colour wool to illustrate the way deoxygenated blood leaves the heart as well as to identify the vein through which it passes.



STATION 6	STASIE 6
Question 6.1 A dissected heart of an animal is been provide. Use the following apparatus :rope pins name stickers and provide the following labels:	**Vraag 6.1** 'n Gedissekteerde dier hart is voorsien Gebruik die apparaat volgende:tou speldjies naamplakkertjies en voorsien die volgende byskrifte
6.1 Identify the parts numbered : 1 2 3 4 5 6 **(6)**	**6.1** Identifiseer die dele genommer: 1 2 3 4 5 6 **(6)**
6.2 Use the correct colour rope and indicate :	**6.2** Gebruik die regte kleur tou en dui die volgende aan:
a) deoxygenate blood leaves the heart **(1)**	a) deoksigineerde bloed verlaat die hart **(1)**
Incorrect / **Correct**	**Verkeerd** / **Korrek**
b) Identify the indicated vein: ______________ **(1)**	b) Identifiseer die betrokke aar: ______________ **(1)**

Figure 5.2.11.6 Revision activity

5.2.12 School 12 – Grade 11 (Alex)

Topic: Deforestation

Lesson outcomes

Learners should understand the impact humans have on the environment as well as the causes and effects of deforestation.

Classroom setup

The classroom setup was similar to that of school 2, described above.

Lesson summary

The lesson was conducted in Afrikaans. The lesson started with the teacher asking learners for examples and reasons why trees and bushes are burnt. A slideshow offering a discussion on deforestation (Figure 5.2.12) was then presented. The teacher's unfamiliarity and uncomfortableness using ICTs were evident in her presentation because she did not ‘click’ on the ‘start presentation’ button, therefore, it remained in ‘developer mode’. She stood in one position throughout the lesson and mostly read from the slides, in a monotonous tone. With the assistance of another teacher, who was in a room off the front of the classroom, she played a video clip on the effects of deforestation on climate. A mostly one-sided discussion followed by the teacher on the benefits of deforestation. She stated that deforestation creates jobs for people. She explained the process of mutualism, using the example of a bee and a flower. She described how bees gather seeds from flowers and, in the process, sometimes let some of these seeds fall to the ground. When a tourist walks past and steps on the seeds these are then carried on the soles of his shoes when he boards an airplane on his way home to America. She then stated that seeds might start to grow in America. The teacher moved on to speak about the ‘Port Shepstone’ tree and how it infests areas within South Africa, at which point some of the learners began to giggle. The teacher continued with her explanation until a learner raised her hand and asked, “*Miss don’t you mean the Port Jackson tree?*”. The teacher glared at her and continued the lesson without acknowledging her error. The point the teacher tried to make was that felling or burning indigenous trees often provides an opportunity for other tree species to germinate and spread. She asked the learners to provide her with more advantages or benefits of deforestation. Learners did not respond, and she continued to explain how the owner of the trees makes money, therefore capital generation is a benefit of deforestation, as well as providing shelter for animals seeking new habitats. The lesson ended 15 minutes before schedule and the teacher told the learners to read through the important sections of their notes for the remainder of the period.

Figure 5.2.12 Alex's presentation

The focus of the study was to understand the role presented by ICTs as a pedagogical resource used by student teachers to facilitate epistemological access. This chapter presented a detailed commentary on the lessons observed, together with an outline of the classroom setup. Chapter Six provides the data analysis and the interpretation thereof, using the analytical tool to gauge the level of epistemological access.

Chapter Six

Data analysis

6.1 Introduction

This chapter deals with emerging themes from the data collected by engaging empirical evidence with theory (internal language of description, in this case semantics) to make sense of the data. In doing so, I begin with an analysis of each lesson as supported by Chen and Maton (2014), who believe that this approach enables the researcher to obtain the 'stories' from the rich data gathered rather than 'smothering' them too soon, by imposing a theory on the stories. Pedagogic discourse was analysed in terms of semantics, in particular, semantic density (SD) to show the degree of condensation within socio-cultural practices such as terms, phrases, symbols, gestures, expressions, etc. Maton (2014:129) argues that the stronger the SD, the more meanings are condensed within practices, whereas a weaker SD has fewer condensed meanings.

Descriptive labels were given to the coding categories, such as 'weakening SD', 'semantic flatline' and 'reproduction of traditional pedagogy through ICT'. This labelling was followed by an interpretation of themes, using an analytic lens.
Overlapping themes are highlighted in blue.

The following themes emerged from the collected data: (Once again in this chapter the term 'teacher' refers to the participating student teachers.)

Theme	**Weakening semantic density (SD-)**	
Description	**The teacher is trying to simplify scientific concepts by drawing from every day or common-sense knowledge and fails to connect with symbolic or abstract scientific knowledge**	
Examples from data to show manifestation	**Code Identified**	**Indicator**
And looking forward to a holiday? Yes, I'm thinking Paris. Yes friend, ah lovely. Yah, biomes. Oh okay, oh yes. You know what? I have an excellent grade ten class here and ah they will help you find out about biomes is and the different biomes in South Africa. (Monica, Appendix E:293, see Appendices)	Connections	Failed to make a connection between the lesson introduction and the lesson topic, Biomes.
Biomes are regions of the world, it's similar physical environments… (Monica, Appendix E:293)	Simple Explanations	Simplistic definition of Biomes. No further elaboration.
The Nama is here, uhm just an indication, I'm from the Nama Karoo, uhm I'm from a small town called Beaufort West. We will look at uhm, I will hand you uh uh something regarding (Monica, Appendix E:294)	Segmented Learning	Conversational. Irrelevant to current lesson.

It's a nice elephant sucking on a nice [a] uh amarula fruit. It's a joy, the sun it's setting, it's wearing it's shades, the hat is there, everything is on fleek (Monica, Appendix E:295)	Explaining solely with examples	Simulated practice as learners are asked to identify (in this case a Biome) based on a picture. No further explanation.
I've shown you a little picture and that basically proves what he said uhm and why he said it's Savannah (Monica, Appendix E:297)	Explaining solely with examples	Biome is explained using only a picture.
…altitude, latitude, that's how high you are above sea level and how low (Monica, Appendix E:293)	Simple Explanations	Concepts altitude and latitude are explained in informal language.
… the Quagga, uhm which is a zebra, it's not a zebra but it looks like a zebra uhm but it's also a donkey (Monica, Appendix E:298)	Simple Explanations Common sense understanding	Simplistic explanation of a Quagga is given.
'Felling' is it is being destroyed by either animals that pass through or human interaction. In order to clear that specific area for specific reasons. (Craig, Appendix E:300)	Simple Explanations	Simplistic explanation of the term 'felling'.
…peat is almost like a liquid substance that is dark in colour* (Craig, Appendix E:300)	Common sense understanding	The explanation is given by the teacher for the term "peat". The discussion is also

*The discussion is the human impact on the environment focusing on deforestation. Deforestation is introduced as having a direct link to the amount of charcoal found in the area. The student teacher drifts further from the discussion by focussing on how coal is formed.	Segmented learning Simple Explanations	irrelevant as it does not link with the unit theme.
…something that has a nucleus (learner of Shafiek, Appendix E:312)	Simple Explanations	The teacher asks a question, Tell me what is eukaryotic? This is the learner's response. The teacher could have taken the explanation further by explaining that Eukaryotes are organisms whose cells have a nucleus enclosed within membranes. Instead the answer is left at a lower semantic density (SD)-
It doesn't have nucleus (learner of Shafiek, Appendix E:312)	Simple explanations	The teacher questions, 'tell me what is Prokaryotic?' A very simplistic answer is given without taking learners back to scientific expansions,

		such as for example, a Prokaryote is a unicellular organism that lacks a membrane-bound nucleus.
Each organism has 2 names, a generic and a specific name, if you want to look at it, the generic that would normally be your nickname right and your specific name, Let's for argument sake say you have a long name Johanna something, something, something right, and then you will have a generic name that will be just what they basically call you right (Shafiek, Appendix E:313)	Simple explanations	The teacher relates the generic and specific names to familiar concepts such as a name and a nickname, however, the explanation is not taken back up the semantic scale.
Sir, how can I say for example, like cancer, your elder will get cancer and then it will go like from generation to generation. Sir so they will say it is in your gene. (Elvin, Appendix E:329)	Answer solely with examples	Learners can only explain cancer using examples, the teacher does not expand.
Sir it it's like I'm tall because my grandpa is tall, so it's in my genes to also be tall. (Elvin, Appendix E:329)	Answer solely with examples	Learners can only explain genes using examples, the teacher does not expand.
Teacher: Most modern foods originate from selective breeding. You heard about this yesterday. Can anybody tell me what selective breeding entails? We still spoke about dogs…	Answer solely with examples Common sense understanding	The teacher probes the learners understanding on what selective breeding entails, when the learner answers with an example

Learner: You get a new dog Teacher: Ok so that the breed can get stronger… (Elvin, Appendix E:330)		'you get a new dog', the teacher does not expand beyond the example given. The teacher simply accepts the learner's limited understanding of what selective breeding entails, '… so that the breed can get stronger'.
I am going to make another example, you take two animals again, you cross breed the two dogs right, the one dog gets very sick quickly, but the other dog doesn't get sick quickly. So now what they do is they cross breed each other so that the offspring is a mixture of the two (Elvin, Appendix E:331)	Explaining solely with examples Common sense understanding	Selective breeding is explained using an example of a crossbreed between two dogs.
So you will always find that one dog maybe will have a nice fur and the other dog is stronger. Now you mix the two together so you can see if the dog will come out stronger with a fur coat. So do you get why we do selective breeding? (Elvin, Appendix E:331)	Explaining solely with examples Common sense understanding	Selective breeding is explained using an example, looking at the appearance and strength of dogs.

Teacher: Does anybody know what mutation is? Learner: That is when they come out with three legs. Teacher: …Ok any other answers? … mutation anyone? I am sure you watch X-Men. Learner: Yes sir, they call it a mutant. Teacher: Mutant right which means that their genes cross together Learner: The Zebra sir, it is a cross of a horse (Elvin, Appendix E:331)	Explaining solely with examples Answering solely with examples Common sense understanding	The term 'mutation' is explained referring to familiar objects such as X-Men and answered by learners using physical features such as having three legs as well as using examples of animals where perceived mutation occurred.
If I say the world is U-shaped whereas scientists say the world is round. The world is round! If I come and say the world is U-shaped the scientists will ask me to bring what? Evidence! The evidence that is needed so that we can show and believe that the world is U-shaped (Victor, Appendix E:339)	Explaining solely with examples	The student teacher's explanation on the term 'theory'.
We are not used to these phones. We were using telephones, we were writing letters and we used to fax them. If you wanted to communicate with someone it was difficult … so as generations are moving along as time goes on we have these phones today. (Victor, Appendix E:339)	Explaining solely with examples	The student teacher's explanation on the term 'evolution'.

He likes, 'fancy' means like, like a girl in the class. Now whenever he sees her, do you know what happens? His heart beat will go boom boom boom boom because it is the girl he likes, right? Is that what happens? So now he finally gets the courage to approach the girl right, remember we talked about how his heart races when he sees the girl and now he finally gets the courage to approach her and the girl says no sorry I don't want you and his heart goes (making aaahh sound) you know heartbroken. So Jacob where are you are you here? Can you show us how your heart looks? On the board, when you met that specific girl. (Freda, Appendix E:369)	Explaining solely with examples Conversational Figurative answer	The scenario sketched, in this case, causes the learner to draw a figurative heart, instead of a human heart, which the teacher required. The learner cannot distinguish the difference between the two 'hearts' as no clarity is provided.
Theme	**Segmented learning (segmentalism)**	
Description	**This is when the teacher teaches a concept without relating it to other concepts in a unit theme or lesson. Therefore, concepts are taught in isolation. It could also take the form of transmission/rote learning modes of teaching. Examples could be when concepts are taught or drawn from the internet or recapping concepts (power words) previously introduced without further elaboration and using mnemonics as an aid to memorise concepts.**	
Examples from data to show manifestation	**Code Identified**	**Indicator**
If I were to ask you to define deforestation, I want it to be in line with this … you just have to have a similar definition. (Craig, Appendix E:300)	Segmented Learning	Emphasis on knowing definitions, in this case, 'deforestation'.

… trees are very important so the first course of deforestation, urbanisation okay so when you study, study it like this simple one line and then another answer then you will know what urbanisation is, it's the cause of destruction (Craig, Appendix E:301)	Segmented Learning	
Felling is it is being destroyed by either animals that pass through or human interaction. (Craig, Appendix E:300)	Segmented Learning	Explains individual concepts in a simplistic, segmented manner.
Teacher: You guys know where coal comes from. Can anyone tell me? Student: It forms under pressure. Teacher: Forms under pressure okay she tells me under pressure okay what else happens? Student: fossil burns Teacher: Okay it's a fossil plant okay under pressure. What other things happen? Student: sedimentary Teacher: Okay so now we got key words okay we got sedimentary rock, we got dead plant materials that got fossilised after all the pressure has come into play and it takes a different form okay. The	Segmented Learning Simple explanations	

first form is obviously peat okay peat is almost like a liquid substance that is dark in colour. Teacher: bituminous, bituminous is another name for a different form fossil um most of the Charcoal that's found in the nib desert is bituminous with is about 80% carbon right and furthermore as it goes on it turns into its final stage with is anthracite and anthracite is also known as Charcoal right. So that is evidence that proves that that area had many trees. (Craig and Student, Appendix E:300)		
Carbon and coal we're talking about the same thing basically okay it is just a form that comes after a longer period than coal okay so if you compress coal. (Craig, Appendix E:302)	Segmented learning Simple explanations	Conversational, irrelevant
Teacher: Mineral mining you will find that in the desert okay or in Arab areas you will find a lot of minerals why do I say we can find many minerals in desert areas? Okay for instances I said for example in the Namib Desert they use the area also for	Segmented learning	The intention was to explain how increased mining could cause deforestation, instead, the conversation drifts to an explanation on how minerals

mining so if there is a re-evidence that they have charcoal there then what does that mean? There is more what? Student: Minerals. Teacher: right just remember how diamonds are formed. Diamonds are formed from? Student: Carbon. Teacher: Carbon and coal we talking about the same thing basically okay it is just a form that comes after a longer period then coal okay so if you compress coal. I can show you guys that video if I have time I'd like to show you how they make diamonds. (Craig, Appendix E:302)		are formed. The student teacher fails to progress to his initial point which was how increased mining could potentially cause deforestation. Content selection, sequence and relevance do not matter as long as the topic has a perceived relation to science and the teacher has time available it will be taught.
…in Kuilsriver you will see a lot of boor gat [Borehole] water okay so the water is underground so they can have wells also because there is lots of water there under right but now that there is water restrictions you will find lots of people is going to take that route of watering their plants with boor gat [Borehore] water because we can't use all the water we want. That is just some extra information I added. (Craig, Appendix E:304)	Segmented Learning Conversational	Here the conversation started with the effects of deforestation and quickly moved to a general discussion on the water table. After which the teacher makes clear 'just some extra information I added' Content selection, sequence and relevance do not matter as

		long as the topic has a perceived relation to science and the teacher has time available it will be taught.
Right the roots of the tree keeps the soil together right that's why there is so much Port Jacksons I spoke to you about the Port Jacksons there was so much lose sand that they decided they going to bring all the Port Jackson's to keep all the lose sand together and that's why we have so much Port Jacksons here in the area. The Port Jackson is an alien species that needs to be destroyed. (Craig, Appendix E:304)	Segmented Learning Conversational	Here the student teacher starts to explain soil erosion, he, however, moves to explain how the roots of trees keep the soil together, referring to the Port Jackson tree that was imported into South Africa to bind the lose sand. Now this tree is regarded as an alien species. Content selection, sequence and relevance do not matter as long as the topic has a perceived relation to science and the teacher has time available it will be taught.

This work is going to come to you next year and they'll be surprised to know that sir did speak about this work already. (Elvin, Appendix E:327)	Segmented Learning	Here we see a pattern of segmented teaching and learning. In all these extracts, the teacher knows that the work is not relevant to the specific lesson but teaches it anyway.
Teacher: Ad is a word you are going to do next year, "Adenin" and the 'sine' is part of ''cytosine'. Student: Sir, doesn't 'Adenin' have an 'e'? Teacher: Nice nice yes. Now these two things is work you are going to do next year and it has to do with genetics. You are going to speak about RNA and DNA. (Elvin, Appendix E:328)	Segmented Learning	
Ok so what is also significant about these elements. These elements, ok, come from here ok Polysaccharides. One of these will be a Monosaccharide. One. These are ring structures. You don't have to focus on that because you are not doing chemistry at the moment. (Elvin, Appendix E:328).	Segmented Learning	
Ok so polysaccharides are amino acids ok for next year. (Elvin, Appendix E:328)	Segmented Learning	
We get RNA and then we get DNA. These are things we need to know also because next year you will be examined on RNA and DNA. (Elvin, Appendix E:329)	Segmented Learning	

Nucleic acid ok. The R just stands for Ribose. Ribose okay, it comes from the word Ribosome. Ribosomes is also inside your cell and they have a specific function to play, ok, when they create a DNA cell, that will also be done next year. (Elvin, Appendix E:330)	Segmented Learning	
Now don't forget that because next year you are going to do it again.* (Elvin, Appendix E:330) **The teacher constantly loses focus of the lesson and goes 'off track' explaining concepts that are not part of the lesson.*	Segmented Learning No Learning	
Ok, I am only touching on there because next year we are going to work through this. (Elvin, Appendix E:330)	Segmented Learning	
What I explained to you now, right, condensation transpiration, condensation precipitation, you know what, say it with me because I think you guys are going to forget it. (Craig, Appendix E:306)	Memorising power words	The teacher either recaps concepts (power words) previously introduced without further elaboration or uses mnemonics to help learners memorise concepts.
What did I say how do you keep the order so that you never get confused? Rather keep it in the order, manera then? (Shafiek, Appendix E:312).	Memorising power words	

Once you keep that order you will remember how we described it and explained it everything will come in place you will remember it exact and you will get high marks from it so don't go off from what I told you yesterday right? Give me an example of fungi there in the light? (Shafiek, Appendix E:312)	Memorising power words	
Ecosystems, species and genetics. (learners of Shafiek, Appendix E:310)	Memorising power words	
Teacher: Right, they started off with 2, animals and? Students: Plants. Teacher: Plants right and then they went further and they changed it to 5, what is the 5? Students: Monera, Protista, Fungi, Plantae, Animalia. (Shafiek, Appendix E:313)	Memorising power words	
King Phuma came over for gogo's stew, right so when you go into an exam you just try to remember these things class either one whatever works for you right. (Shafiek, Appendix E:317)	Memorising power words	
I see in the textbook they advise us to remember it like this right, king, phylum, class, over, or gold and silver. (Shafiek, Appendix E:316)	Memorising power words	

We get RNA and then we get DNA. These are things we need to know also because next year you will be examined on RNA and DNA. (Elvin, Appendix E:329)	Memorising power words	
So what kind of reproduction will take place? Between organisms that take place that we cannot see? That are microscopically small. They are so small we cannot see it. I cannot believe it, it is strange that you don't know it. You can't remember! Can you remember the word cell division? (Elvin, Appendix E:334)	Memorising power words	
Binary fission, it was very important for you to know that. You guys are going to write that paper Thursday and I am worried already. That means you guys haven't started studying already. (Elvin, Appendix E:334)	Expected to memorise concepts to pass exams	
Remember KINGDOM is wide, they say PLANTAE is an entire KINGDOM of plants right, then they go further, right they go further they put them into a PHYLUM right where they share? What basic characteristics do they share, they put it even further what is the CLASS. Can they lay eggs? So they will organise these things into the certain groups. They go even further they go into ORDER, can that angles that they are now placed in, can they, do they, are they primates, are they ectotherm or are they endotherm? Do you	Strong teacher monologue	The student teachers explain for long periods with little or no input from learners.

understand what I am trying to say? They go on, they say the FAMILY, the cat belongs to the Felidae, the dog belongs to Candidae, the angle humans belong to the Hominidae and is divided, therefore, into the GENUS. They go even further right, they know, the group to which organisms belong, a domestic cat belongs to the GENUS Felidae, wild cats have Genus called Pantherea and humans have a GENUS called homo and this is divided even further into SPECIES right? This is now giving specific name right so a cat will be herbigesticus, your humans will be your sapiens and the lions will be your leo right? (Shafiek, Appendix E:314)			
Theme	**Poor quality education**		
Description	**a) The teacher provides incorrect information to the learners.** **OR** **b) Learners lack certain foundational knowledge, yet the teacher continues without building on the knowledge that is lacking.**		
Examples from data to show manifestation		**Code Identified**	**Indicator**
You know I am a teacher and I am human and we have seen that somehow someone has made a mistake and I asked the class do you agree and you said yes! (Freda, Appendix E:373)		Poor content knowledge (a)	Teacher makes excuses for providing incorrect information to the learners.

Therefore, you know what a hypothesis is, it's when you guess. You guess something will be like this and you test it (Victor, Appendix E:339)	Poor content knowledge (a)	The teacher does not know what a hypothesis is.
Teacher: Effects of deforestation. What happens? What are the effects? Soil erosion now you all do Geography right. Students: No. Teacher: Okay some do History but I am sure you did it in Grade 9, 8, or 7 also right? Soil erosion occurs with rain or wind right. Those that does geography are you familiar with the term of run-off Students: Yes. Teacher: They speak about direct run-off okay, basal, okay those people that don't do geography basal is the flow of water from a high area down to the water table okay and then it is obviously run-off it either goes or stays on top and then rolls down into lakes or rivers that leads to the sea or it goes underground and then it is under the water table. (Craig, Appendix E:304)	Knowledge gap (b)	Learners lack foundational knowledge

I know you guys are not doing physical sciences so I will understand that but this is Phosphate. (Elvin, Appendix E:327)	Knowledge gap (b)	
One of these will be a Monosaccharide. One. These are ring structures. You don't have to focus on that because you are not doing chemistry at the moment. (Elvin, Appendix E:328)	Knowledge gap (b)	
I explained to the other class that was doing chemistry they would understand this also that Adinosine is made up of different words. (Elvin, Appendix E:328)	Knowledge gap (b)	
Teacher: Do you know what an enzyme is? Learners: Yes, we know what an enzyme is. Teacher: Ok, when you say yes you must come back with what is an enzyme Learners: What is an enzyme? Teacher: It is going to be interesting marking your papers. But an enzyme is a biological catalyst that speeds up a reaction. (Elvin, Appendix E:334)	Knowledge gap (b)	

Theme	Semantic Flatline	
Description	a) The teacher draws on everyday (unproven) knowledge solely without connecting to scientific knowledge OR b) The teacher tries to draw on indigenous knowledge systems, but instead of connecting with the scientific knowledge he/she goes on to explain with everyday knowledge. Even though the curriculum encourages student teachers to draw on learners IKS this is not used to facilitate epistemological access. In this way indigenous knowledge is not taught in relation to other knowledge. Learners are therefore unable to make connections. OR c) In over-simplifying the teacher explains with incorrect information	
Examples from data to show manifestation	**Code Identified**	**Indicator**
You know like once or twice in every two three weeks, we'll have summer rain, uhm it's extremely hot, like uh. There was one day I experienced forty-eight degrees, that's where you look at yourself and you look at yourself you don't know what to do with yourself. Do you think that will be the best holiday destination? (Monica, Appendix E:298)	Semantic Flatline (a)	Conversational. Regurgitation of everday non-scientific facts.

Okay so the Nama Karoo is out for summer right because we have extremes in temperature. I won't be able to enjoy myself and with our drought on hands, we won't be able to go to a swimming pool and you know waste water or we won't even be able to you know like play in front or on the grass uhm wetting each other with with the water hose or anything. You know like normal people do… (Monica, Appendix E:298)	Semantic Flatline (a)	
Unfortunately, people has the perception that Sangomas are actually fake doctors, but let me explain something to you. Something that will surprise you. At UWC you can study to become a Herbalist and what is a Herbalist also known as?... Sangoma, yes okay so you can dispense natural plants okay, from trees to help with your ailments. Your arrow plant, your hoodia that takes away your hunger, your hunger pains which means you can diet so much better! … okay so you don't have a hunger… you can find amber in trees, you can find glue in trees, you can find weed in trees. All these things you can use and actually dispense it". (Craig, Appendix E:303)	Semantic Flatline (a & b)	Conversational. Common sense teaching instead of drawing from knowledgeable others.

You can see lots of Rastafarians also use that. But you need to have a license and you need to get a quota and you need to get a, how can I say because these things many pharmaceutical companies use. You need to have a license to sell these products. You can't just steal. You find a lot of people they come and steal these plants and they sell it. I saw in Bellville they were sitting there with these plants. I don't know if they have a license for it, but it is illegal just to take any plant, which they just use for medical ailments. You can use the bark for fertilizer also. (Craig, Appendix E:303)	Semantic Flatline (a & b)	
At the moment there are certain trees that are going extinct because the demand for that kind of wood is increasing and because of that now we are also greedy and because of that you want to take all the trees off but we not supposed to do that so now they are protected trees you not supposed to cut that's okay so you can be jailed or fined right, so these are the things they do to curb things like that. Okay paper is also a problem I feel like I'm a victim of paper because you guys get a lot of paper we trying to save time with you guys so you don't have to write a lot of things and I'm sure you guys are thankful for it but in future we will try to take away the paper from you and try to give the documents to you electronically. (Craig, Appendix E:302)	Semantic Flatline (a)	

I'm going to try it in my other classes also but we need to recycle because at the moment the deforestation thing is actually serious okay because eventually it's going to cause many many ramifications and will go… (Craig, Appendix E:302)	Semantic Flatline (a)	
In SA at the moment, in 1998 we were sanctioned to plant maize, because maize is a staple food in SA and we eat it everyday. These things, these potatoes we eat everyday they were sanctioned by the International Board so that genetic modification can be done to that so that we can have more food in SA. Just remember in SA we are many, many people, ok, even in the years further on we are going to have an increase in natality rate and because there is a scarcity, a scarce amount of food they have to use genetic modification in order to make the animals survive longer. So there can be more offspring, so they can feed us. (Elvin, Appendix E:329)	Semantic Flatline (a)	
Carbon and coal we talking about the same thing basically okay it is just a form that comes after a longer period than coal okay so if you compress coal. (Craig, Appendix E:302)	Semantic Flatline (c)	Incorrect information given as coal is a naturally occurring form of carbon-based rock, with various amounts of impurities, such as oxygen, hydrogen, sulphur and nitrogen. Coal is also a fossil fuel, and is formed

		by dead plant matters from prehistoric times. Carbon is an element. Therefore, it cannot be the same thing as anything else.
They take a piece of coal and they compress it and they heat it up until it gets smaller and smaller and then then it becomes a very hard rock that is a diamond okay so that's what basically happens. (Craig, Appendix E:303)	Semantic Flatline (c)	Incorrect information given as coal does not play a role in the formation of diamonds.
I don't know in Stellenbosch there is an area called Pniel and across Pniel there is Kylemore. Kylemore was also a region with lots of trees. What happened is people moved in there and then when you buy your house you are going to pay an extra fee to take away all these bugs and insects and things like that. So that is the biodiversity that gets destroyed. (Craig, Appendix E:305)	Semantic Flatline (a)	Conversational. The teacher uses everday non-scientific facts.
Miss now what..? Can you give an example? Can you just ask her what was discovered [referring to African knowledge in science]? (Beauty, Appendix E:368)	Semantic Flatline (b)	Indigenous knowledge is not viewed as valid knowledge.
Can't we just get that [Indigenous knowledge systems] as a subject instead of adding it to science? (Beauty, Appendix E:369)	Semantic Flatline (b)	Indigenous knowledge is not taught in relation to other knowledge.

In order to change their glucose to glycogen… so this is what they do now, they do not use pig's insulin anymore because of religious reasons. You know it is "haram". Do you know it is "haram"? pigs? Now they can't inject it into us anymore (Elvin, Appendix E:333)	Semantic Flatline (b)	Conversational. Common sense teaching instead of drawing from knowledgeable others.
Theme	**Reproduction of traditional pedagogy through ICT and ICT as a tool to find information**	
Description	**ICTs are only used for example as a display**	
Examples from data to show manifestation	**Code Identified**	**Indicator**
Why don't I give South Africa something colourful and why don't I give my ten Bs, the special people in my life something colourful to look forward to. (Monica, Appendix E:295)	Display	Limited understanding of the affordances of ICT, merely used as a display.
I do apologise for the colour, it's not as vibrant or bright but I'll show you later on, on the computer and we have the Nama round here, the grassland here, as indicated previously, and then you have the Succulent Karoo around here. (Monica, Appendix E:295)	Display	
Behind me is a picture okay of a desert now who can tell me or name for me all the deserts that they know? (Craig, Appendix E:299)	Display	

What I'm going to do now is I'm going to play a clip for you, ok, explaining this work and then after that I'll explain to your worksheet that you have in front of you because I want you to focus on questions 6 and 7, ok? (Craig, Appendix E:306)	Verify facts	Technology used to verify facts.
I want us to take our writing books out and write it down (Shafiek, Appendix E:317)	Display	Limited understanding of the affordances of ICT, merely used as a display.
Namibia, obviously that is why I said we are going to focus on the name of this [pointing to the picture of the desert projected on the board]. (Craig, Appendix E:299)	Display	
I am going to give you some insights on genetically modified foods. (Video clip, Elvin, Appendix E:338)	Verify facts	Technology is used to verify facts.
Someone is on the internet, could someone please find out. (Monica, Appendix E:296)	Tool to find answers	Technology is used to find answers.
Adinosine, which is a compound of all the elements together. If you don't believe me type in google Adinosine and you will find that they will give you a lot of that elements together. (Elvin, Appendix E:328)	Tool to find answers	

Theme	Semantic Waves (key to cumulative knowledge)	
Description	Shows how to draw from scientific dense concepts and simplify relating to students' everyday knowledge and connects this back to symbolic or abstract scientific knowledge	
Examples from data to show manifestation	**Code Identified**	**Indicator**
..life started with chemicals in the air or gasses in the air which is nitrogen, carbon dioxide, ammonia, all those reacted with each other and formed these small organic compounds. So just think of a compound remembering that was like the first form of life and then it further developed into small microscopic bacteria and these bacteria had the property of photosynthesis meaning they took in carbon dioxide and released oxygen in the air and that build-up of oxygen allowed us, and allowed other forms of life to develop, and also just think of oxygen molecules binding with another one getting O3 and not O2 and that formed the ozone layer. So now earth has some ocean it has oxygen and it has a protective layer. It doesn't allow us to turn to a crisp, and earth is ready for other more complex life. That in essence is the history of life. (Jennifer, Appendix E:319)	Semantic Waves	Throughout the lesson we see the development of semantic waves. The teacher simplifies dense scientific concepts and connects back to symbolic or abstract scientific knowledge.

When the earth was formed, oxygen levels in the earth's atmosphere were very low. Modern theories suggest that the first life forms i.e. prokaryotes, which appeared 3.8 billion years ago, did not need oxygen, i.e. they were anaerobic, okay. Then between 3.5 and 2.5 billion years later bacteria arose, which I explained earlier. Which produced their own food through photosynthesis and therefore oxygen was released back into the atmosphere. So oxygen levels in the atmosphere resulted in an increased variety of living organisms". (Jennifer, Appendix E:320)	Semantic Waves	
So just to summarise that again. Oxygen levels were very low initially, okay, then we had our simple prokaryotes which did not need oxygen. Bacteria arrived, made its grand entrance into earth, releasing oxygen into the atmosphere. It increased the levels and then because of the increase of oxygen earth could accommodate a variety of organisms on earth. So that is all you need to know about the increase in the oxygen level on earth. Just that there was nothing previously, it was introduced through our prokaryotes and now it can sustain a variety of living organisms. (Jennifer, Appendix E:320)	Semantic Waves	

The following themes emerged from an analysis of the data: -

- Weakening semantic density (SD-)
    - Failure to create connections
    - Simple explanations
    - Explaining solely with examples
    - Common-sense understanding
- Segmented learning
    - Memorising power words
    - Strong teacher monologue
- Poor quality education
    - Poor content knowledge
    - Knowledge gap
- Semantic Flatline
- Reproduction of traditional pedagogy through ICT and ICTs as a tool to find information
- Semantic Waves

Chapter Seven provides an analysis and interpretation of the data in relation to the research question.

Chapter Seven

Interpretation and Discussion

7.1 Introduction

The purpose of this study was to understand the extent to which teacher education students used ICTs in teaching and their thinking of teaching and learning in order to meet the challenge of enabling epistemological access when teaching science. Epistemological access goes beyond what Morrow (2007) calls 'access to University goods' to meaningful access, in other words the valuable knowledge in fields of social practice. Data was collected through the analysis of video recordings and document analysis. The research was guided by the following research question.

To what extent are teacher education students using ICTs when teaching science to enable learners' epistemological access?

The interpretation of the themes that emerged in the previous chapter are discussed below.

7.2 Weakening semantic density (SD-)

Teachers and student teachers are expected to start with what the learners already know in order to understand abstract scientific concepts, Maton (2013) calls the practice a 'down escalator'. The weakening of the density is not a problem in itself, because the intention is to give learners access to knowledge in simpler terms in order to aid understanding, however the nature of science is that SD entails constellations of meaning in abstract concepts. To simplify, a concept should not be the end in itself, but further requires the teacher to move back towards abstract dense concepts to strengthen density. Below, are examples of this classroom practice that demonstrate how the participating student teachers are repeatedly 'unpacking' or discussing ideas without "moving back into the pedagogic discourse of the subject through 'repacking' explicated meanings and examples into terms or ideas" (Maton, 2013).

7.2.1 Failure to create connections

Student teachers failed to make connections between lesson introductions and content, for example, Monica could not move her learners from an introductory telephonic discussion on ‘planning a holiday to Paris’ (meant to familiarise learners with the scientific concept Biomes) to more abstract knowledge. The relevance or connection to the topic at hand was also lacking. Despite Biomes being taught as a theme within the ‘biosphere to ecosystem’ unit, Monica failed to link the topic to previous knowledge around the biosphere.

This same lack of connection is seen in Craig’s lesson as well, because he does not link his lesson on deforestation to other topics previously learnt in this Unit. Instead, Craig’s lesson starts from an everyday understanding of a link between the Namib Desert and his perceived understanding of where coal originates. A common-sense approach is evident in the content selection and content sequencing, which suggests weakly classified and framed educational knowledge. As a result, lesson participants failed to understand what exactly is being taught, how and why the content is relevant, the sequence in which it is taught, how the content is structured and why it is structured in that specific manner.

These two lessons revealed poor classification of educational knowledge.

7.2.2 Simple explanations

There is continued unpacking throughout the two lessons (described above) in which simple explanations of dense concepts are given, for example, Biomes “(are) regions of the world, it’s similar physical environments” (Monica, Appendix E:293). The observer expected an expansion on this explanation, such as highlighting the shared similar features in terms of their lithosphere and hydrosphere, which would link the topic to other scientific concepts related to the matter being discussed, thus strengthening the density. This linking does not happen and, thus, the teacher misses an opportunity to explain to learners the connection of the topic to the biosphere, such as that fact that the biosphere is divided into a number of Biomes. There is no engagement to make learners understand the complexities of Biomes, nor the provision of further content knowledge to connect Biomes to other linked concepts, such as climate, animals and plants. Other dense concepts, such as altitude and latitude, are explained in more informal language '*that is how high you are above sea level and how low*' and left there. While it might seem that Monica is strengthening SD by giving dense meaning, in this case using the term 'precipitation' to explain the everyday discourse 'rainfall', this term does not enable epistemological access as Monica's explanation remains basic,

These examples of simple explanations are seen in other lessons,

> *Each organism has 2 names a generic and a specific name, if you want to look at it the generic that would normally be your nickname right and your specific name lets for argument sake say you have a long name Johanna something, something, something right, and then you will have a generic name that will be just what they basically call you right... (Shafiek, Appendix E:313).*
>
> *…the quagga, which is a zebra, it's not a zebra but it looks like a zebra uhm but it's also a donkey. (Monica, Appendix E:298)*
>
> *…[it] is dark in colour. (Craig, Appendix E:300)*

All of the above lesson extracts suggest that instead of being exposed to specialised knowledge, learners are engaging merely with everyday, familiar, non-specialised knowledge.

7.2.3 Explaining solely with examples

The following extract shows how Elvin (Appendix E) weakens SD by explaining concepts solely with examples. Genetic modification is introduced as occupying a high position on the semantic scale: "*it is [a] complicated subject, because when it comes to genetic modification we are moving to Grade 12 work*", but then the SD is immediately weakened when Elvin explains the concept with examples,

Elvin:	*Now if I read this packet of chips, if I look at the pack there is this statement here ok, and the statement says, produced using genetic modification. Produced in factory that uses peanuts. Allergen controlled program in place.*
	[Elvin unpacks the statement read above further]
Elvin:	*So at the back they say they use genetic modification in this. So this packet of chips is made out of maze. Do you agree with me?*
Learners:	*Yes sir*
Elvin:	*Now this maze that they are using and the corn that they use to produce this chips they use genetic modification. Ok so they modify that mielies that they use for this chips. (Elvin, Appendix E:327)*

The illustrations provided below demonstrate how, in many of the observed lessons, the provision of knowledge remained context bound:

> *Sir how can I say, for example, like cancer, your elders will get cancer then it will like go from generation to generation. Sir so they will say it is in your gene (learner) and Sir it's like I'm tall because my grandpa is tall. So it's in my genes to also be tall… (Learner, Appendix E:329)*

> *He likes, fancy means like, like a girl in the class. Now whenever he sees her, do you know what happens? His heartbeat will go boom boom boom boom because it is the girl he likes, right? Is that what happens? So now he finally gets the courage to approach the girl right, remember we talked about how his heart races when he sees the girl and now he finally gets the courage to approach her and the girl says no sorry I don't want you and his heart goes (making aaahh sound) you know heartbroken. So Jacob where are you are you here? Can you show us how your heart looks? On the board, when you met that specific girl. (Freda, Appendix E:369)*

The above findings reveal that the knowledge taught in most of the observed lessons is context dependant, which means that when the situation changes, the learners will be unable to apply the knowledge to that new situation or elsewhere.

7.2.4 Common-sense understanding

The observed lessons exhibited a prevalence of common-sense understanding and drawn out explanations of terminologies while learners remained unsure as to the meaning. This practice is evident in the classroom dialogues highlighted below:

Elvin:	*The downside of selective breeding is that mutation can occur, does anybody know what mutation is?*
Learner:	*That is when they come out with three legs*
Elvin:	*They come out with three legs? Okay any other answers?*
Learners:	*(silence)*
Elvin:	*Mutation anyone? I'm sure you guys watch X-Men*
Learners:	*Yes sir*
Elvin:	*They call it mutant*
Learners:	*Oh 'ja'*
Elvin:	*Mutation right which means that their genes cross together*
Learner:	*The zebra sir, it's a cross of a horse (Elvin, Appendix E:331)*

Elvin:	*Does everyone in the class know what insulin is?* *So what do you know about insulin?*
Learner:	*It is a medicine*
Elvin:	*What do you say there at the back?*
Learner:	*It comes in something*
Elvin:	*It comes in something?*
Learner:	*You put it in a needle sir*
Learner:	*It's like a medicine sir, an antibiotic sir*
Elvin:	*Did sir discuss with you diabetes?*
Learner:	*Yes insulin and you do it with a needle*
Elvin:	*Yes now the picture is a drawing of insulin and the interesting fact of insulin they use to take the pigs insulin and insert it into humans that need insulin. (Elvin, Appendix E: 332)*

The explanation in the above classroom interactions is at an everyday, disconnected level. Explaining a concept in everyday language is not problematic in itself because it provides learners with initial access, however what is problematic is that this practice can lead to a series of downward semantic shifts, throughout the lesson, when the student teacher moves from highly condensed meanings (SD+) to simpler meanings, often drawing from everyday examples. The problem in the above dialogue is that after using examples and terminology that are non-technical, 'everyday' terms/language, the student teacher simply continues to the next point in the lesson in the same downward pattern, while very rarely, if ever, attempting to move back up the semantic scale through 'repacking'. This 'repacking' would require moving from 'everyday' language and examples to scientific terms or ideas. As a result, knowledge stays non-technicalised and segmented instead of condensed and technicalised and "plugged into the constellations of meanings constituting academic subjects" (Maton, 2013:14). This situation poses a problem because knowledge may remain context-dependant and disconnected.

Explaining concepts in simpler terms typically enacts only a limited number of the meanings it possesses within that explanation, which delocates "the term from its constellational relations with other terms in its semantic structure" (Maton, 2013:12). During his lesson Craig (Appendix E) could have explained to the learners that coal was formed millions of years ago from the remains of vegetation and trees. Trapped at the bottom of swamps, these remains accumulated layer after layer, and created a dense material called peat. However, the explanation cannot end there, the learners need to be taken up the semantic scale to abstract knowledge. The same downward escalation pattern is seen in Craig's (Appendix E) explanation of the term 'peat – "*almost like a liquid substance, ok it is dark in colour*". On the other hand, it could be argued that his extension of this discussion is completely irrelevant, because he should have connected this concept with the impact of coal mining on the environment, thus linking it to the Unit theme, which is the 'Human impact on the environment'. (His introduction of irrelevant facts indicates the occurrence of segmented learning.)

The implications of segmented learning is that while learners probably understand individual concepts they do not comprehend their connections and thus fail to build cumulative knowledge.

7.3 Segmented learning

The nature of scientific knowledge is hierarchical, meaning there are prerequisite knowledge and skills required to the learning of subsequent science knowledge a process that demands proper selection and sequencing of content knowledge to build a strong conceptual spine. However, education in South Africa has faced many challenges since apartheid that continue during the current times. These challenges include inadequate teacher knowledge and skills, resistance to change, lack of development and training, inadequate resources and disparities between rural and urban schools and lack of support and monitoring.

In 2000, the review of Curriculum 2005 led to the formation of the Revised National Curriculum Statement (RNCS) which was a simplified version of curriculum 2005 (C2005). The intention of this revision was to strengthen the implementation of Outcomes-based Education (referred to as OBE), human rights and inclusivity (DOE, 2002:2). RNCS focussed on comprehensive outcomes and assessment standards linked to skills and knowledge requirements. This curriculum statement was based on principles such as progression and integration, high levels of skills and knowledge for all, as well as social justice and inclusivity. This document made clear the need for learners to have meaningful access to science education. However, challenges remained with the quality of teaching and learning in schools (DOE, 2011:4) and this prompted the establishment of a task team, appointed by the Minister of Education, to implement a new policy called the Curriculum and Assessment Policy Statement (CAPS). CAPS was implemented in 2012. The Life Sciences (LS) curriculum in the CAPS document has specific aims, namely that learners are expected to have knowledge of the subject content, to engage in investigations and practical work and be able to apply LS knowledge to their everyday life (DoE, 2011:13).

This change in approach to the teaching of LS in South African schools should have shifted the emphasis of teaching and learning from rote learning to concrete educational results, called outcomes (Jacob, Vakalisa and Gawe, 2004:2). Moreover, we should see a change in the role of teachers from transmitters of knowledge to facilitators. The lack of understanding of content selection and sequencing is seen in one of the observed lessons (Craig, Appendix E, delineated above) with an everyday understanding of a link between the Namib Desert and a perceived understanding of where coal originates,

> *Once there was lots of trees there. That is why there is so much coal there. They export it to lots of different countries and make lots of money of that fossil fuel* (Craig, *Appendix E:300*)

In the extract below taken from the lesson 'The chambers of the heart' taught by Freda (Chapter 5), the link suggests weakly classified and framed educational knowledge.

There is a downplay of legitimate knowledge in the classroom:

> *You know I am a teacher and I am human and we have seen that somehow someone has made a mistake and I asked the class do you agree and you said yes! … and when miss looked at the answer number 2 is wrong, and then they swapped it. So what is the answer of number two? … . Thank you Jacob for alerting me to that answer. Because the answer was swapped around.* (Freda, *Appendix E:373*)

There is also an emphasis by student teachers throughout the observed lessons on learners knowing definitions,

> *If I were to ask you to define deforestation, I want it to be in line with this… you just have to have a similar definition. 'It [deforestation] is the permanent destruction of natural, indigenous trees and bushes by felling or burning',* (Craig, *Appendix E:300*).

> ….*study it like this simple one line and then another answer then you will know what urbanisation is it's the course of destruction,* (Craig, *Appendix E:301*).

> *What are the arteries? Write it down, question 1. What are the arteries? The arteries in your heart that carries …. Deoxygenated blood (pause). Then you leave a space,* (Freda, *Appendix E:372*).

There is a pattern in the observed lessons of student teachers explaining individual concepts, in a simplistic, segmented manner, for example the term 'felling' is described as:

> "*It is being destroyed by either animals that pass through or human interaction. In order to clear that specific area for specific reasons",* (Craig, *Appendix E:300*).

In this case, no mention is made to 'felling' being the process of humans chopping or knocking down a tree in its entirety, thus taking this concept back to the unit theme of 'Deforestation'. The trend of explaining concepts in isolation continues, with questions that follow, "*Can anyone remember how coal is created, how is it formed*", while the teacher continues to answer himself,

> *It is a fossil plant. It forms under pressure. Sedimentary. Ok so now we have key words there. We have sedimentary rock, we have dead plant materials that got fossilised after all the pressure came into play and it takes in different forms,* (Craig, *Appendix E:300*).

One could argue that instead of merely relating fossil fuel to dead plant matter, the student teacher should have outlined the transformation (coalification) process of this substance into peat, lignite, sub-bituminous, bituminous coal and finally into anthracite, to describe the sequential process of coal formation in LS, while simultaneously strengthening the SD to create constellations of meanings.

In another observed lesson the following highly abstract scientific concepts are explained in isolation – ‘carbon’, ‘nitrogen’ ‘hydrogen’, ‘phosphate’, (Elvin, Appendix E). There is an assumption on the part of many student teachers that the learners understand what they are saying, consequently, no consideration is given to understanding the number of concepts a learner must assimilate in order to fully grasp some of the ideas explained. The student teacher appears to be unaware of the complexity that the teaching of different sections of LS requires. Aspects frequently lacking in the teaching approach are; what content is being taught and how, why such content is being taught, why it is relevant, the sequence in which it is being taught and how and why the taught material is structured in a specific manner.

The implications of the above assumptions for learning is a failure to build cumulative knowledge over time. It seems as if some of the content taught has nothing to do with the lesson, but it is included because the student teacher has time to include it in the lesson, for example:

> *I can show you guys that video if I have time, I'd like to show you how they make diamonds,* (*Craig, Appendix E:303*).

The manner in which a connection and sequence is presented does not matter as long as it is perceived as part of the science concept that is being taught,

> *A – de – no – si. Adinosine. Ok, that was nice and close. Now this Adinosine, but nobody ever asked me sir but what is this Adinosine? Now ok, Adinosine is a compound of many, many elements. I explained to the other class that was doing chemistry they would understand this also that Adinosine is made up of different words. 'Ad' is a word you are going to do next year,* (*Elvin, Appendix E:328*).

In some of the observed lessons the student teacher was not concerned with building knowledge in learners, but rather with impressing the learners at the expense of building knowledge for instance:

> *This work is going to come to you next year and they'll be surprise to know that sir did speak about this work already,* (*Elvin, Appendix E:327*).

Again, in the extract below the student teacher seemed to be teaching for the sake of teaching rather than enabling learners to access knowledge:

> *You get man made diamonds and you get obviously naturally made diamonds. The man made diamonds looks almost exactly the same but they just make it different. They take a piece of coal and they compress it and they heat it up until it gets smaller and smaller and then then it becomes a very hard rock that is a diamond okay so that's what basically happens. So in areas that they usually find coal they will usually find other minerals okay there is gem stones and there is diamonds and rubies you will find that in areas that also has coal okay it is all interconnection with each other. You need to make sense of that, in areas where there use to be huge, massive area trees okay then all that sedimentary came down in to the ground the sedimentary mixed with it, it came down and more pressure is applied and eventually after millions of years past diamonds were formed, charcoal was formed this is the natural minerals, you will find in this area,* (*Craig, Appendix E:303*).

Access to the conceptual spine of knowledge is therefore compromised in many the observed LS lessons, as can be seen in the illustrations above.

7.3.1 Memorising power words

In South Africa during the apartheid era memorisation and drill characterised education i.e. the regurgitation of facts and rote learning (Hoadley, 2011:144). This practice resulted in to a failure to understand knowledge as ways of making meaning and, in that way, restricted certain individuals from participating in the construction of knowledge and meaning. Verwoerd, the architect of apartheid, discouraged the teaching of Mathematics and Science (Giliomee, 2012) in 'non-white' educational institutions. "*What is the use of teaching black child mathematics when they cannot use it in practice?"* (Verwoerd, 1953). Black people/learners were primarily expected to memorise material without the ability to connect it to their own knowledge. When OBE came into existence in South Africa in 1998, its purpose was to challenge 'talk and chalk', drills and the regurgitation of facts (Lekgoathi, 2010:107). Participatory learner-centred teaching was promoted, but, unfortunately, this practice only worked for middle class students/learners because educational institutions attended by students/learners from working class backgrounds needed more support and control (Jansen, 1999:149; Lekgoathi, 2010:108). In South Africa today many teachers and student teachers still focus on framing over pacing, hence learners are given no control over the rate of expected acquisition (Hoadley, 2005:259) as seen in the extract below taken from one of the observed lessons:

Learner:	*So sir now what is genetic modification?*
Elvin:	*we are going to get there, to that part… there is a reason we are looking at these things, (Elvin, Appendix E:335).*

Knowledge generation still is obscured by an emphasis on memorising terminology rather than understanding concepts, such as:

Shafiek:	*What three ways can we describe biodiversity?*
Learner*:*	*ecosystems, species and genetics*
Shafiek:	*Right, but remember when you answer it is 'ecosystem diversity', 'species diversity', 'genetic diversity', right. You are describing the variety of species", (Shafiek, Appendix E:310).*

Teaching power words and using mnemonics, such as creating patterns or rhymes in everyday examples, was prevalent during the observed lessons for instance,

> *King Phuma came over for gogo's stew, right so when you go into an exam you just try to remember these things class either one whatever works for you right,* (*Shafiek, Appendix E:317*).

Shafiek:	*What did they change, what was the 5 kingdoms? Right, they started off with 2, animals and?*
Learners:	*Plants.*
Shafiek:	*Plants right and then they went further and they changed it to 5, what is the 5?*
Learners:	*Monera, Protista, Fungi, Plantae, Animalia*, (Shafiek, Appendix E:313).

> *What I explained to you now, right, condensation transpiration, condensation precipitation, you know what, say it with me because I think you guys are going to forget it,* (*Craig, Appendix E:306*).

> *What does the A stand for? 'A', something with an 'A'! Can somebody in the class tell me what the 'A' stands for?* (*Elvin, Appendix E:327*).
> *So in your textbook on page 197 they are giving you a structure of the heart, as well as the labels right. I want you to read through that sequence for the next 5 minutes and then complete the activity on the next page.* (*Freda, Appendix E:374)*

> *Right we get RNA and then we get DNA these are things we need to know also because next year you will be examined on RNA and DNA",* (*Elvin, Appendix E:329*).

In the observed lessons emphasis was also placed on the meaning of acronyms used, which learners do not usually know:

Elvin:	*Does anyone know what DNA stands for?*
Learner:	*DNA Sir?*
Elvin:	*DNA*
Learner:	Deoxyribonucleic acid
Elvin:	*Oeeeh beautiful! I love it ok and RNA?*
Learners:	(*silence*)
Elvin:	*RNA? … RNA? …. RNA No one? Take a chance on me.*
Learners:	(*silence*)
Elvin:	*Take a chance on me please… RNA, It's so simple, Paul?*
Paul:	*Don't know.*
Elvin:	*Don't know? Take a chance on me. We know what RA stand for … Nucleic acid … The 'R' just stands for Ribo's* (*Elvin, Appendix E:329*).

Encouraging learners to merely memorise power words again shows SD- because this practice does not help learners to generate meaning. To clarify, memorising information is not a bad exercise, but it should not stop at only memorising concepts to pass examinations. It should be used to understand constellations of dense meanings to ensure students are able to participate as equals in knowledge construction. Science teaching should focus on understanding concepts rather than acquiring vocabulary, otherwise, it detracts from science as a process and puts learning for understanding in jeopardy. Both teachers and student teachers can easily be misled as to what knowledge learners have acquired.

7.3.2 Strong teacher monologue

During the observed lessons, there was still a dominance of teacher centeredness as seen in the strong teacher monologue, the 'talk and chalk' methods and the copying of notes. The student teachers wanted to show the learners what knowledge they can bring to the classroom as if they are the sole custodians of knowledge. The student teachers control the classroom management and there is no space provided for learner autonomy. For example in the extract presented below, between lengthy periods of teaching, Monica (Appendix E) would stop briefly and pose questions to the learners "*You know these kind of things right?*", "*You understand right?*", "*You are familiar with these phrases?*", "*I feel like I'm not alone in this you know?*" "*We got everything right?*", "*Are you sure?*", "*That's what we are getting to right?*", "*Can we do that?*", and "*Can I continue with this tomorrow?*" To all these questions the learners simply answered "*Yes*." in unison and the teacher would then move along with the lesson. The strong teacher monologue is further seen in this excerpt from Monica's lesson, (Monica, Appendix E:298).

Teacher:	*There was one day I experienced forty eight degrees, that's where you look at yourself and you look at yourself you don't know what to do with yourself. Do you think that will be the best holiday destination?*
Learners:	*No.*
Teacher:	*Okay so the Nama Karoo is out for summer right because we have extremes in temperature. I won't be able to enjoy myself and with our drought on hands, we won't be able to go to a swimming pool and you know waste water or we won't even be able to you know like play in front or on the grass uhm wetting each other with with the water hose or anything. You know like normal people do so that's how I or what I want you guys to do more or less. To save time let's let's let's cut it to one destination at least. Name the plant, animal, the weather pattern, where it's situated. Do we have a group that would like to present? Don't be shy. Please. I need to call my friend back before the end of this period.*
Teacher:	*Okay, let me talk to my group first. Guys, uh we would like, can I continue with this tomorrow?*
Learners:	*Yes.* (multiple voices)
Teacher:	*Thank you and then I also have a little exercise you can do at home, just to help you. Tomorrow I really have to call my friend and tell her, "finally my brain is on sleep, Thembi help me, we going to the forest or we going to Fynbos, we staying in in in the Protea Hotel in Cape Town, we going to uhm uhm Kirstenbosch, we going to visit Clifton picking strawberries, we tasting wine in Stellenbosch and uhm we will be having a ball of a time." Is that okay?*
Learners:	*Yes* (multiple voices)
Teacher:	*Thank you.*

Most of the dialogue in the above lesson revolved around the student teacher's experiences. Despite her attempts to have an interactive lesson there was little or no hands-on activities, the envisioned group work did not happen and there were few discussions to engage learners and encourage active participation. As a result, learners probably failed to make connections between the lesson and concepts that they had learned before, or when applying their knowledge to problem-solving situations (Lord, 1998). The strong teacher monologue and teacher centeredness is also apparent in the short extract from Victor's lesson seen below in which Victor asks for input from the learners, thus giving the impression of a learner-centered approach.

Victor:	*What is hypothesis? Hypothesis is a prediction of physical phenomena, which can be tested, by observations or experiment. First of all, I said it is a prediction. It is science as you are doing Life Science. When you get into varsity, you will be asked hypothesis when you do maybe your practicals. School based practicals. It is a prediction. Can anyone perhaps come with an example? Can you predict something? Okay, let me come first. I live in Khayelitsha, If I live in Khayelitsha, I say, Ok if I leave Khayelitsha by 6:30 am I will reach [the school] at 7:30 am. Did you hear what I said? If I leave Khayelitsha, if I leave Khayelitsha, which means I am not sure, right, I leave Khayelitsha by 6:30 am I will reach [the school] at 7:30 am. (Victor, Appendix E:338)*

However, when Victor asks a question, he then immediately proceeds to answer it himself. This dialogue is followed by a request for an example and four additional questions that, once again, Victor answers without giving learners a change to attempt to answer the questions or engage with the content.

Teacher:	*So class I hope you didn't fall asleep while watching the video. You need to open your notebooks now and I repeat and see what you have learnt. I will show you the questions that you need to copy in your textbooks. Remember we are only focussing on the external part of the heart and the first section of the video it shows the? … external part of the heart. So I will show you, I will give you three or four questions based on it. You need to write down and answer. I might play you that first section again for you to grasp the information. You can write down the heading and todays date in your notebook in the meantime. Your heading is the external structure of the heart. I don't know why technology does not love us today class so let me just read the questions for you. What are the arteries… Write it down, question 1. What are the arteries? The arteries in your heart that carries …. Deoxygenated blood (pause). Then you leave a space. Through what vein (pause) Number two yes (pause) Through what vein (pause) vein (pause) does deoxygenated blood flood to. And then how does the blood from your left atrium. That is number three yes. How does the blood flow from your left atrium to your left vein… ventricle sorry. Your left ventricle. I will talk to you guys just now. Yes there is the questions class. So the first question is, what are the main arteries in the heart that carries deoxygenated blood. I just rephrased but it is the same question.*
[learners write down the questions	
Teacher:	*Question number two where does the blood move … there is a typing error so you can say where does the blood move for oxygenated blood. Where does it go to get oxygenated blood. Are you done writing the questions down?...*
Learners:	*Yes miss*
	(Freda, Appendix E:371)

Freda's lesson (see extract above) also revealed strong teacher control and little active learner participation, other than writing down notes, despite Freda having used ICTs during her lesson.

Most of the observed lessons were taught in a traditional classroom setup, where the student teachers stood in front and the desks were arranged in rows facing them, an arrangement which promotes a focus on the teacher. The lessons revealed content recitation, with minimal time allowed for students to reflect upon the material presented and to relate it to previous knowledge or apply it to real life situations.

7.4 Poor quality education

In spite of reforms, education quality has remained inadequate. Surveys indicate that the level of achievement of the majority of South African learners in Mathematics and Science is alarmingly low (Baller et al., 2016). These researchers found that teachers' knowledge is not very far advanced beyond that of their learners (especially in schools in poor areas) and, consequently, learners fared well below the norm in tests. These results point to the enduring cycle of poor-quality schooling being provided in poor communities. This situation limits the ability of the education system to provide a means for poor children to escape the poverty syndrome into which they are born. In general, the current education system in South Africa continues to produce outcomes that reinforce patterns of poverty and privilege instead of challenging them (Chetty, 2019).

To address the under-preparedness of both teachers and learners, the Council on Higher Education (CHE) proposed a more flexible curriculum for universities and teacher education programmes in particular, (CHE, 2014). Universities are also driving efficiency by focusing on student throughput rates without engaging with what the students know. Extended curriculum programmes (ECPs) were designed to equip students, such as student teachers, who do not meet the minimum requirements in terms of the competencies necessary to be successful in their studies. These programmes are aimed to address students' 'under preparedness' when entering the university system. This is an example of interventions/initiatives that are driven to increase success rates (student throughput). Success is only framed in terms of numbers without engaging with knowledge and ideological inculcation (Alexander, 2005). The question arises "Whose interest is the knowledge serving or prejudicing?" This approach is an example of empiricism in which scientific discovery is simply based on what can be measured and observed in a closed system (Sonnergaard, 2013). Some researchers would argue that 'colonial' science is more positivistic in nature. However, in many educational systems, science is presented still as something that happens in a closed system and not in society, which is an open system.

The analysis of the findings of this study revealed that student teachers who lack sufficient content knowledge are teaching learners and the implications, thereof, are explored further below.

7.4.1 Poor content knowledge

Despite the fact that South Africa today is regarded as a democratic dispensation, educational inequalities continue to reproduce themselves in different ways and this can be demonstrated by the poor content knowledge of the observed student teachers for instance:

> *Therefore, you know what a hypothesis is, it's when you guess. You guess something will be like this and you test it,* (*Victor, Appendix E:339*).

Learners are not taught to generate their own meaning, instead they are taught to pass exams (as can be seen both in the previous theme, Segmented learning) and in the observed lessons:

> *As you can see everything is given to you it's just jumbled up right, so the exact same will happen in exams or when we write a test. We will give it to you but jumbled up right and what you have to do you have to put it according to this, right?* (*Shafiek, Appendix E:317*)

> *Once you keep that order you will remember how we described it and explained it everything will come in place you will remember it exact and you will get high marks from it so don't go off from what I told you yesterday right?* (*Shafiek, Appendix E:312*).

Science teachers seldom succeed in enabling learners to acquire a deeper level of understanding of key concepts and procedures because minimal attention is given to making explicit the link between concepts and the structure of knowledge in the discipline (Herbert, *et. al*., 2011). The recontextualising agent (the student teachers in this research study) has an important role to play in relating the specialised content that should be taught in conjunction with learners' everyday knowledge. The observed student teachers are not following this practice and, thus, the content taught remains at an everyday, basic and disconnected level.

Statistics obtained through research reveal that high failure, attrition and dropout rates continually affect the majority of learners attending schools situated in disadvantaged communities (Akoojee and Nkomo, 2007; Scott *et al*., 2007). These continually disadvantaged learners, therefore, remain marginalised despite the platforms intentionally created for the elimination of educational inequalities.

7.4.2 Knowledge gap

Both teachers and student teachers are aware that the learners lack certain foundational knowledge, yet continually fail to acknowledge this fact and so do not provide learners with the requisite background knowledge required for understanding new concepts as the following excerpts taken from the same student teacher illustrates:

> *I know you guys are not doing Physical Sciences"… but this is triphosphate. (Elvin, Appendix E:327)*
>
> *I explained to the other class that is doing Chemistry, they would understand this…. (Elvin, Appendix E:328)*
>
> *'Ad' is a word that you are going to do next year (Elvin, Appendix E:328)*
>
> *These are ring structures you don't have to focus on that because you are not doing chemistry at the moment. (Elvin, Appendix E:328)*
>
> *It is going to be interesting marking your papers, but an enzyme is biological catalyst that speeds up a reaction. (Elvin, Appendix E:334)*

Elvin:	*Right at the back you, you know how the cell multiply?*
Learner:	*It becomes sicker and sicker*
Learner:	*Does that not have to do with cell reproduction?*
Learner:	*I said that but what kind of reproduction?*
Elvin:	*Can you see the bacteria?*
Learner:	*No sir, it is microscopic*
Elvin:	*So what kind of reproduction will take place, between organisms that we cannot see?*
Learners:	*(silent)*
Elvin:	*between that are microscopic small! They are so small we cannot see it.*
Learners:	*(silent)*
Elvin:	*I can't believe it. It is strange that you don't know it. You can't remember! Can you remember the word cell division?*

In the above excerpt the student teacher does not stop to explain the missing links to the learners, thus it would seem this knowledge is not important. Instead of using pedagogic autonomy/reasoning to challenge the selection and sequence predetermined in the curriculum, student teachers simply comply with the content set ('go with the flow') even though they are aware that the information taught is not doing justice to the learners' ability to acquire knowledge. There is no room for autonomy with the set curriculum, both teachers and student teachers are told what to teach in South Africa and the sequence and the pacing of content presentation is determined by the curriculum. Teachers are thus only knowledge transmitters, merely 'doing what the master tells them to do". This results in the perpetuation of educational inequalities, because the teachers' lack of desire to interrogate knowledge is now extended to the learners. South Africa's supposedly 'democratic' education system has not yet developed teachers and student teachers who can engage with the colonial education structures that still determine the curriculum to be taught in South Africa's schools in 2019.

7.5 Semantic Flatline (ties into previous theme)

This theme looks at the use of everyday language and its connection (if any) to scientific and/or indigenous knowledge systems. Indigenous knowledge systems are presented as knowledge that can be developed separately from other knowledge (Ndlovu-Gatsheni, 2017) and are not used to engage with powerful or dominant colonial education (Luckett, 2015). Instead of showing how indigenous knowledge can contribute to other forms of learning there is a persistence of what Ndlovu-Gatsheni (2017) calls 'Ghettoisation' of indigenous knowledge systems. Despite researchers and educators being aware of these indigenous knowledges, they are not yet viewed as legitimate knowledge that can be taught in science. For indigenous knowledge to be considered valid knowledge, teachers and student teachers need to draw from the African archive, in other words, the more knowledgeable 'others' in the field, and engaging with the depth thereof rather than with their 'common-sense', an approach which is similar to how science develops, being some aspects thereof being discarded along the way (see Chapter Three, hierarchical knowledge structures). It is not enough for educators to merely value indigenous knowledge and teach it in isolation or from hearsay or common-sense, as can be seen when Craig (Appendix E) in his lesson on Deforestation (described in Chapter Five) moves to traditional medicines and conflates a Sangoma and a Herbalist. These vocations are completely different callings. A Sangoma is someone who goes through a special initiation period in response to a spiritual 'calling', whereas a Herbalist is someone who is inducted into knowing how to use herbs by knowledgeable others over time. A Herbalist develops a particular 'gaze' through working with the knowledgeable others and does not experience a spiritual calling.

Craig:	*Does anyone know a Sangoma, You know what a Sangoma do?*
Learners*:*	*A traditional healer!*
Craig*:*	*Unfortunately, people has the perception that Sangomas are actually fake doctors, but let me explain something to you. Something that will surprise you. At UWC you can study to become a Herbalist and what is a Herbalist also known as?... Sangoma, yes okay so you can dispense natural plants okay, from trees to help with your ailments. Your arrow plant, your hoodia that takes away your hunger, your hunger pains which means you can diet so much better! … okay so you don't have a hunger… you can find amber in trees, you can find glue in trees, you can find weed in trees. All these things you can use and actually dispense it. (Craig, Appendix E:303)*

The same common-sense teaching is seen in the following two excerpts during which the student teacher tries to draw from the 'African archive' but, unfortunately, only manages to teach nonsensical facts.

> *You can see lots of Rastafarians also use that. But you need to have a license and you need to get a quota and you need to get a, how can I say because these things many pharmaceutical companies use. You need to have a license to sell these products. You can't just steal. You find a lot of people they come and steal these plants and they sell it. I saw in Bellville they were sitting there with these plants. I don't know if they have a license for it, but it is illegal just to take any plant, which they just use for medical ailments. You can use the bark for fertilizer also, (Craig, Appendix E:303).*

> *In 1998 so we were sanctioned to plant maize because maize is a staple food in South Africa and we eat it everyday. These things, these potatoes, we eat everyday, they were sanctioned by the International Board so that genetic modification can be done so that we can have more food in South Africa. Just remember in South Africa we are many, many people okay, even in the year further on we are going to have an increase in natality rate and because there is a scarcity, a scare amount of food they have to use genetic modification…* (*Elvin, Appendix E:329*)

In one of the observed lessons, the student teacher's discussion on decolonised education illustrates that the content presented is based on common-sense and individual opinions (which is not problematic as an initial discussion to encourage learners' involvement in the lesson) but the lesson does not progress beyond these opinions. The student teacher does not make use of ‘knowledgeable others’ to draw conclusions or to make the lesson more constructive, instead the lesson is driven by emotions instead of facts,

> *‘Everybody is entitled to their opinions’, ‘Ok is there anyone else that has an opinion on what she has to say?”, ‘Dwayne, that is her own opinion’, ‘We all have our opinion’, ‘Do you guys have any opinions on it?’, ‘Please no one is insulting or racist or rude and if you are going to have an opinion it is going to be a logical thought out one’, ‘Unless you guys have an opinion…. And if you don’t have an opinion on what we are discussing then you keep quiet’. (Beauty Appendix E:366)*

There is an initial failure to understand on the part of the learners (and possibly the student teacher herself) as to the outcome of this lesson because is not a standard topic listed in the prescribed textbook/curriculum. Beauty alluded to the fact that she wanted the learners to start thinking about decolonised education because it is currently a heated topic in South Africa’s education circles. On 9 March 2015, a movement called Rhodes Must Fall (#RhodesMustFall) began, directed at removing a historic statue of Cecil John Rhodes at the UCT. Many people believe Rhodes was racist and his actions pathed the way for apartheid. The students’ campaign to remove the statue received global attention and soon led to a broader movement to ‘decolonise’ the education system in South Africa.

Despite the student teachers’ aim to persuade learners to think about indigenous knowledge systems and how all kinds of knowledge should be valued, they consistently (or perhaps deliberately) failed to understand the significance or value of these systems and, consequently, African knowledge was downplayed. The following excerpts illustrates how indigenous knowledge is not viewed as legitimate knowledge by the learners:

Beauty:	*She feels that we have been taught too much from a Western point of view [inaudible] not necessarily like in witchcraft … whatever happened in Africa as a continent you should also be learning about.* Learner: *No miss but Africa discovered nothing* Learner: *Africa discovered nothing!*
Learner:	*How do you know that?*
	[noise]
Beauty:	*Grade 10s!!*
Learner:	*Miss what can we give to society? African languages?*
[class laughing, tries to calm class down, laughing, talking] …	
Beauty:	*This is actually a very good suggestion. (Beauty, Appendix E:362)*

Learner: *So if science must fall, I am not trying to be racist or anything… South Africa is seen… if we look we have water conservationist… We are kind of … (developing country? Girl sitting next to her asks) no not that… you cannot attack South Africa. If you attack from the top you have to go through all the countries on top, if you attack from the bottom. What can I say … (navy? Girl sitting next to her answers) Navy. We have one of the best navies. So if there is no science we will be an unprotected country. So there will be no guns, no ships, no planes … no nothing… so … so … we will have… (Beauty, Appendix E:364).*

The student teacher was unable to engage with the complexity of the topic and legitimised the non-researched content from the video-clip presenter uncritically when the learners questioned her knowledge, 'S*he is not even a scientist so why is she there*?' (Learner, Beauty, Appendix E:366).

Beauty responded:

> *Anybody could go. She did science at school, it is not as if she didn't do any science. She might not have her facts completely straight because a lot of science came from the Middle East also not just Europe but that was open meetings held at each of the faculties. I know like you feel like why should she have an opinion on science if she doesn't do it but…* (Beauty, Appendix E:366)

The above comments are alarming because it would seem that accurate, researched and well thought out, knowledge is not valued in this particular Grade 10 classroom, as long as it is somebody's opinion. The learners are questioning the 'credentials' of the presenter because they do not understand why her opinion should be valued. The teacher's response is equally alarming because she 'legitimises' the speaker by merely saying '*she did science at school'*. There needs to be a separation between expert knowledge and opinions.

Currently in South Africa there is still a mistrust in indigenous African knowledge and, therefore, it is viewed in isolation instead of positioning African knowledge in relation to other knowledges of the world. This distrust is expressed by the Grade 10 learners when they verbalise their fear of losing their ability to find jobs if African knowledge is brought into science teaching.

Lucy:	*If we change our science 'thingie' then how are we going to be able to work overseas?*
Teacher:	*You see you might not have to change it completely, so maybe you can like have a parallel or have African history and science together with European science so that you are not only limited to working here because that is what they learn overseas. How do you think it affects you if they do? So that you don't think you will be able to work overseas?*
Learner:	*So some of us will want to study science, so where will that knowledge come from to study science? So how am I going to get a good salary?*
Teacher:	*So is it only people who study science only get good salaries, because you can study commerce and also get a very good salary.*
Learner:	*Miss but you are referring to science.*
Teacher:	*Yes I know that but the point is it is not like physics is the only subject that is going to get you to the point that you feel like it's going anywhere because look at me I am a physics teacher also. (Beauty, Appendix E:367)*

The following three comments were made by learners in response to the lesson of 'Science must fall' taught by Beauty (Appendix E).

> *They can divide it [African knowledge in science] into some African subjects. (Beauty, Appendix E:367)*

> *But now say for example you want African knowledge now what about the other [referring to former years] years? Where is the proof of it? Where is the evidence? (Beauty, Appendix E:367)*

> *If it was an African who discovered that and it wasn't [referring to the apple that fell on Newton's head]! So history is something you cannot change! (Beauty, Appendix E:368)*

From the beginning of this research project, the lessons taught did not fully engage with the themes indicated on the lesson plan (as can be seen in Beauty's lesson, in which there was no structured theme or build-up on any previous lesson). Student teachers were repeatedly explaining disconnected concepts and losing focus on the lesson aims. Specialist knowledge was not being taught. Learners were being socialised into the field, with a common sense understanding of LS. Instead of having access to powerful context independent knowledge, they merely received a reproduction of everyday, non-scientific facts.

7.6 Reproduction of traditional pedagogy through ICT and ICTs as a tool to find information

The findings of this research support the research on the reproduction of traditional pedagogy through ICTs (Cuban, 2001; Player-Koro, 2012a). In the observed lessons, technology is used merely a means of verifying facts already given outside the classroom environment. It does not affect the teaching, for instance:

> *ATP is an adenosine, which is a compound of all that elements together. If you don't believe me type in google 'adenosine' and you will find that will give you a lot of that elements together" (Elvin, Appendix E:328).*
>
> *So class I hope you didn't fall asleep while watching the video. You need to open your notebooks now and I repeat and see what you have learnt. I will show you the questions that you need to copy in your textbooks. Remember we are only focussing on the external part of the heart and the first section of the video it shows the? … external part of the heart. So I will show you, I will give you three or four questions based on it. You need to write down and answer. I might play you that first section again for you to grasp the information. You can write down the heading and todays date in your notebook in the meantime. Your heading is the external structure of the heart. I don't know why technology does not love us today class so let me just read the questions for you (Freda, Appendix E:371).*
>
> *I need you to listen attentively to the video class, it is not a period to sleep because most of you seem to be confused. So the first section of the video the questions were taken from that (Freda, Appendix E:372).*
>
> *You need to listen [to the video clip] in order to answer the questions (Freda, Appendix E:372).*

In Beauty's (Appendix E) lesson she explains and provides her opinion on the video before allowing the learners to watch the video. There is no opportunity for creativity or self-engagement with the video because the teacher already explained what happens in the video:

> *There is a part in the video where the lady says, you can send lightning to somebody. Stop laughing. Don't laugh. You see her thinking is that before Europeans came to Africa .. em.. the witch doctors helped people and it is not like what they did was wrong. It's just means that they are not being recognised and that is what she feels must be brought into our education system also. So for now, we are going to watch that video quickly and then we will have a discussion on it. So I need all you guys to pay attention. (Beauty, Appendix E:365)*

The Teacher's Guide for LS teachers suggests using videos, related to the topic, to enhance learners' understanding of the content and to experience the topic within a wider context. However, a limited understanding exists of the affordances of ICT as a pedagogic tool, for instance, "*why don't I give my ten B's, the special people in my life something colourful to look forward to*" (Monica, Appendix E:295). Here, the affordance of ICTs is seemingly narrowed down to a tool that allows for a colourful display instead of enhancing teaching, for example:

> *see here the purple which uhm indicates the forest, yellow around here its where we are, uhm which is the fynbos…,* and
>
> *it's not as vibrant or bright but I'll show you later on, on on the computer, (Monica, Appendix E:295).*

It is clear that the student teacher is not using these colours to make an analogy with the forest and the fynbos. She simply uses colours to delineate the different areas on the map. Instead of providing an explanation, or asking the learners to interact in the lesson, she puts more emphasis on the lack of brightness of the colours. No consideration is given to how the use of this IWB can add value to the teaching process. For example, it could allow for the whole class to jointly participate in adding colours to the map or editing documents, as well as experiencing interactive processes with the teacher as mediator which would provide added functionality. The purpose for which the IWB was used in this lesson, namely simply projecting information, could have been achieved using an overhead projector. Unfortunately, the teacher missed an excellent opportunity to engage the learners interactively. A mismatch exists between traditional teaching methods, such as the practice of handing out notes, and the use of overhead projectors and the intended ways in which ICTs can be used. Similarly, Craig uses a picture projected on the IWB to question learners' knowledge of the world's deserts.

Craig:	*Where do we get most of our coal from*?
Learner:	*Namibia*
Craig:	*Namibia obviously that is why I said we are going to focus on the name of this [pointing to the general picture of a desert].*
	(Craig, Appendix E:299)

It would seem that in the observed classes, technology is simply used as a medium to project a lesson. Craig also uses a YouTube video clip to explain the lesson topic, pausing in-between, as suggested by research, to optimise the use of the video (Hobb 2006). Evidence showed that the showing of videos can foster critical thinking and increase student engagement when correctly used (D'sa, 2005; Jenkins, 2006) and should not be used as a mere simplification of complicated problems (D'sa, 2005). While the video is easy to understand, Craigs' explanations remain basic and he uses simplistic reasoning, consequently he fails to stimulate any critical higher order thinking by the learners.

Shafiek's lesson also lacks knowledge on how technology (ICTs) can be used in teaching content by providing new and exciting ways of teaching LS. For example, instead of using cardboard boxes to explain classification he could have used the technology available in his classroom to enhance this exercise. "Educational technology does not possess inherent instructional value: a teacher designs into the instruction any value that technology adds to the teaching and learning processes" (Dexter, 2002:57). Each slide that Shafiek projected was packed with information and, thus, unclear which made reading and interpreting the slides and writing down notes from the slideshow (as requested by Shafiek) quite difficult. In this case, the PowerPoint presentation added no value to the lesson. The teacher still used the traditional whiteboard to draw maps and, at times, the slides were projected on top of other information.

7.6.1 Using ICTs to teach context dependent knowledge

During her lesson Monica (Appendix E) asked learners to identify a biome based on an image on the IWB, an activity illustrates how context dependent knowledge is taught:

> *There is a picture, I included a picture. Uhm since you guys are so familiar and well known with these uhm, with the biomes, can you please indicate uh by raising your hand uh, which biome this might be? It's a nice elephant sucking on a nice uh amarula fruit. It's a joy in the sun it's setting, it's wearing its shades, the hat is there everything is on fleek! (Monica, Appendix E:295).*

While arguments can be made that the teacher tries to relate the concept to everyday familiar things such as an '*elephant sucking on a nice … amarula fruit*' (as previously explained), to weaken the SD (SD-) to help the learners identify the Biome. In answering the question, the learner is merely engaging within the context of the illustration, by referring to the grass and shrubs he sees in the specific picture.

> Learner: *Grassland, there are few shrubs and trees and there's a lot of grass as you can see in the picture (Monica, Appendix E:295)*

The teacher merely gives the correct answer, being, the Savanna Biome and asks for reasons.

> Learner: *See when you go buy a Savanna bottle, there is that tree (laughing) and the grass, it's not green, it's brownish-e, yes it's brown which means its dry, ja, and there's an elephant. (Monica, Appendix E:296)*

The teacher directs the learners to use the Internet to find the reasons why the area in the picture is known as Savanna Biome. After searching the Internet for an answer, a learner confidently answers,

> Learner: *In the Savannah Biome there is two types of trees. A Marula tree and a Boabab tree. So that is why, the Boabab tree* (pointing to the picture). *(Monica, Appendix E:296)*

Without further elaboration, the student teachers' approval is echoed with a request for a round of applause. The approach is simple; students must find the right answers.

The Internet is used to do just that, regurgitation of facts, rather than promoting learning.

Muniege and Muhandji (2012) distinguish between traditional pedagogy methods which asks students to reproduce the same content and e-pedagogy which provides problem-based learning that enables students to be independent and develop critical thinking skills. The use of ICTs should develop strategies that promote deep learning and change the learning environment from a teacher- to a learner-centred one. In the observed lesson, Monica explains and engages within this context (picture), which is a simulated practice, and the responses that follow are given within the context of the picture. Meaning is made in appealing to familiar objects without further elaboration. This practice of teaching within contexts is presented using technology, which in this case, is the image, displayed on the IWB in order for the learners to name a specific Biome. Thus, using ICTs as a pedagogical tool to find answers (both from the picture and Internet), is merely a reproduction of traditional pedagogies.

Despite this student teacher trying to use ICTs to open-up access to knowledge in the classroom, in this case, it does not. The ICTs are used to simplify concepts, and, accordingly, create a downward escalation without (as previously mentioned) any 'repacking'. Monica is concerned merely with helping learners to produce the right answers but not with facilitating learning in order to enable learners to understand what is being taught. Learners are left with simplified answers, while the lesson moves along, thus highlighting a pattern of segmented learning. What is actually happening in this lesson is an example of context-dependant teaching using electronic pictures. The student teacher's explanation of a similar picture slide of the Savanna Biome; is merely that the picture proves the previous speaker's answer correct. The learners are left to make sense of what they see in the pictures (in this case the Baobab tree in both pictures). This approach might constrain cumulative knowledge and thus learners are unable to use their previously acquired knowledge within different contexts. This method of teaching does not prepare learners to function or be productive in the workplaces of today's society (Yelland, 2001).

7.7 Semantic waves (key to cumulative knowledge)

Semantic waves allows researchers/educators to model the transitions of knowledge from "contextualised and simpler understandings towards more integrated, manifold and deeper meanings (Maton, 2013:14). This process enables them to classify classroom practices by looking at both upward and downward semantic shifts. It also shows how meanings are transformed by bringing together different forms of knowledge within practices. This theme shows how teachers draw from scientifically dense concepts and simplify these by relating them to learners' everyday knowledge and connect this back to symbolic or abstract scientific knowledge.

Jennifer's lesson described in Chapter Five is an isolated case in which the observer can see the development of semantic waves. Jennifer explains concepts of the history of life on earth from a scientific perspective by examining scientific evidence of this phenomenon and condenses much meaning into scientific concepts. She links this information to learners' prior knowledge of life forms, specifically bacteria (prokaryotes) when she explains:

> *… life started with chemicals in the air or gasses in the air which is nitrogen, carbon dioxide, ammonia, all those reacted with each other and formed these small organic compounds. So just think of a compound remembering that was like the first form of life and then it further developed into small microscopic bacteria and these bacteria had the property of photosynthesis meaning they took in carbon dioxide and release oxygen in the air and that build-up of oxygen allowed us, allowed other forms of life to develop, and also just think of oxygen molecules binding with another one getting O3 and not O2 and that formed the ozone layer. So now earth has some ocean it has oxygen and it has a protective layer. It doesn't allow us to turn to a crisp, and earth is ready for other more complex life. That in essence is the history of life, (Jennifer, Appendix E:319).*

Further connections are then made to previous learnt topics such as 'photosynthesis', 'microscopic bacteria', 'oxygen molecules' hence continuing to strengthen the semantic density (SD+). In questioning learners' knowledge "*What is the estimated age of earth*?" and "*When did life on earth start*?" the student teacher encourages interactions from the learners, thus making downward shifts, weakening (SD-). She then makes upward shifts again, thus strengthening the SD+,

> *So "when the earth was formed, oxygen levels in the earth's atmosphere were very low. Modern theories suggest that the first life forms, namely prokaryotes, which appeared 3.8 billion years ago, did not need oxygen", because they were anaerobic, okay. Then between 3.5 and 2.5 billion years later bacteria arose, which I explained earlier. "Which produced their own food through photosynthesis" and therefore oxygen was released back into the atmosphere. So "Oxygen levels in the atmosphere resulted in an increased variety of living organisms", (Jennifer, Appendix E:320*).

Jennifer again provided evidence of more 'unpacking' (SD-), when she explains the above transactions in everyday language,

> *So just to summarise that again. Oxygen levels were very low initially, okay, then we had our simple prokaryotes which did not need oxygen. Bacteria arrived, made its grand entrance into earth, releasing oxygen into the atmosphere. It increased the levels and then because of the increase of oxygen earth could accommodate a variety of organisms on earth. So that is all you need to know about the increase in the oxygen level on earth. Just that there was nothing previously, it was introduced through our prokaryotes and now it can sustain a variety of living organisms*, (*Jennifer, Appendix E:320*).

The weakening of SD is not a serious issue because the teacher continues to move up the semantic scale to strengthen the SD, followed by unpacking and summarising of information that weakens the SD as to give learners access to knowledge. The same trend is seen throughout the lesson with the introduction of other concepts such as 'climate change' and 'continental drift'. Technology (video clip on continental drift) is used to weaken SD and to appeal to learners familiarity with similar concepts, which is good teaching practice because "students need points of entry into and guidance through the complex constellations of meanings that constitute academic subjects" Maton, 2014a:41.

The key to knowledge building over time is semantic waves. Relationality of knowledge, meaning knowledge is not simply indigenous knowledge or science knowledge but both/and ICTs can and should be used to challenge traditional pedagogies and to help learners think critically rather than to reproduce information.

I now discuss the key findings in relation to the research question (To what extent are teacher education students using ICTs to enable epistemological access when teaching science?).

7.8 ICT integration in lessons

The findings of the video lesson samples delineated above indicate that ICTs were used to reproduce traditional pedagogies regardless of the fact that ICTs are known for their potential to transform teaching and learning (Nivala, 2009). Despite the teacher's guide (provided by the NDOE based on the curriculum - CAPS) suggesting the use of videos to enhance learners' understanding of the content and to experience the topic within a wider context, student teachers were unable to implement this use of ICTs due to a lack of professional judgement on when and how to use technology in their teaching (and in some cases due to technical limitations within the schools in which they were presenting their lessons). For instance, the belief that ICTs will automatically transform the system (Player-Koro, 2012); requires knowledgeable student teachers who are able to use ICTs to facilitate knowledge building over time. The participating student teachers did not have the skills necessary to effectively integrate ICTs into their pedagogy because they lacked an understanding of the ways in which the content could be enhanced by the application of a particular technology and how teaching and learning changes in these instances. This lack of knowledge is seen in the limited ways in which ICTs were used. As mentioned earlier, Koehler & Mishra (2009) refer to this particular type of knowledge as TCK and TPK.

In the lessons, ICTs were solely used to display content, to give learners initial access to content or to simplify already basic concepts but not to facilitate higher order thinking (McMahon, 2009). ICTs were also used to enable learners to copy down notes. Despite evidence that technology can foster critical thinking (Sayed, 2017) and allow students to draw on the broad range of knowledge systems (in an open society), in the majority of the observed lessons, ICT were used to teach context specific knowledge. The implication for learners could be that they are only able to draw from the limited repertoire of examples taught in each lesson. When ICTs are not used as a tool to promote problem based, deep, meaningful learning, as well as changes in the learning environment to foster critical- and independent thinking skills, their use will continue to reproduce knowledge inequalities and traditional pedagogies. The integration of ICTs with content knowledge could have enhanced the development of learners' critical thinking skills (Sayed, 2017). In the lessons observed there is no evidence of the enhancement of critical thinking skills. The findings confirm the promotion of simplistic explanations, memorising words and common-sense understandings which are not questioned or interrogated by the learners. Learners merely accept uncritically what is taught. Thus, although participating student teachers claim to have integrated ICTs into their teaching practices, the use of them is not fulfilling its objective, because their implementation is conceptualised and executed in an extremely limited way. ICTS were more often used to weaken the SD when explaining concepts, by providing examples or recapping information in an attempt to make the work more accessible to learners. ICTs were seldom used as a facilitation tool to enable learners to acquire more concrete or abstract knowledge. Consequently, student teachers did not facilitate epistemological access through their limited and traditional use of ICTs.

7.9 Science depth

The findings of this research reveal that content taught in the observed lessons remains at an everyday, basic, disconnected level and that student teachers lacked sufficient content knowledge. Therefore, incorrect information was frequently taught. This is related to the student teachers' lack of knowledge depth of LS which could be conditioned by the historically structured nature of the education system. It also shows that the problem is bigger than the question of physical resources and requires educators and researchers to question the effects of the past in the present. Fagan (2014) found that student teachers are inducted into the field of education with a trained gaze, the implications of which were evident in their observed classroom practice. Context dependent knowledge is taught, and student teachers lack an understanding of content sequencing and selection. This deficiency constrains cumulative knowledge building and does not enable epistemological access for learners. Such practices result in poor quality education which perpetuates the cycle of unequal educational outcomes (Chetty, 2014). Learners are engaging with every day, nonspecialised knowledge (Hoadley, 2005) which means learners will struggle to go beyond their current contexts and participate as equals in knowledge production. Being able to participate in knowledge production is only possible if you have gained epistemological access.

7.10 Simplification of concepts

The findings of this study revealed a continued simplification of concepts. However, simplifying concepts should not be a lesson aim in itself, it is also necessary for the lesson to move further towards presenting abstract dense concepts to strengthen density. This process would require student teachers to understand the classification of educational knowledge, evidence of which is currently lacking in the observed lessons. Maton (2011) argues that while it is important for a lesson to connect with learners' lived experiences, it also requires an 'upward shift'. In the observed lessons there were dominant patterns of downward shifts without upward shifts. The patterns of downward shifts were seen in the simple explanations given to complex concepts and the use of examples to explain concepts. In the absence of upward shifts between plain, contextualised and condensed meanings there is no real indication of cumulative learning (Maton 2014b). Learners are learning segmentally because they may understand individual concepts without an understanding of the connections thereto and, therefore, would fail to build cumulative knowledge.

7.11 Disconnected and segmented knowledge

We have inherited unequal and racialised school systems and we therefore require different approaches to the curriculum. South Africa requires teachers and student teachers who possess the skills and knowledge to make epistemological connections to knowledge of people, their contextual life circumstances, indigenous knowledge systems, literacies, languages and ways of knowing, in order to enable epistemological access to different learners. The findings of this research revealed that student teachers are not adequately prepared to deal with diverse learner groupings. Student teachers tried to make connections between the knowledge in the curriculum and their everyday cultural experiences as can be seen in the semantic flatline theme. They produced empirical descriptions that are bound in contexts without the ability to link these to abstract knowledge. As much as the curriculum asks for the inclusion of indigenous knowledge systems the student teachers do not know how to make this connection. They have been inducted to value Western science knowledge over indigenous knowledge systems. This is an 'epistemic injustice' and, in particular, a 'hermeneutical injustice'. This injustice occurs because student teachers are trying to make sense of their social experience but are handicapped by a gap in understanding — “a hermeneutical lacuna whose existence is owing to the relative powerlessness of a social group to which the subject belongs” Fricker (2008:69). This situation is reflected through the disconnected and segmented knowledge that the observed student teachers possess. Similarly learners have been assimilated into the dominant worldview (Fataar, 2007), a fact which is seen in the learners’ opinions expressed in the ‘Science must fall’ lesson that ‘African knowledge should be viewed in isolation and that indigenous knowledge systems are not legitimate knowledge’ together with the fact that the student teacher could not engage with the complexity of this topic. In this lesson there was no evidence of the ‘positioning of African knowledge in relation to other knowledge’ (Le Grange, 2004).

This study found that in South African classrooms the inclusion of indigenous knowledge systems have been left to the discretion of the teacher, with little support from the DOE on how to do this. The student teachers lack an understanding of both the nature of science and the relation to and/or the nature of indigenous knowledge systems, which is required when teaching science. The study shows that student teachers have not yet begun to understand relationality (which Le Grange (2004) calls the ‘performative side of knowledge’) and, therefore, cannot be viewed to be facilitators of learners’ epistemological access. When a curriculum does not take account of the indigenous worldview of the learners, it may destroy the framework through which the learners will interpret concepts (Le Grange, 2007). Meaning construction comes through relational knowledge and critical pedagogy. This requires both teachers and student teachers who possess sufficient content knowledge in order to connect various knowledges, in Mignolo (2013)’s terms the ‘pluriversality’ necessary to solve world problems.

7.12 Epistemological access

The study revealed the presence of a continued ‘down escalator’ when teaching. Learners are exposed to segmented, non-specialised, everyday knowledge. Furthermore, content recitation was prevalent with little to no time for reflection or to relate the knowledge learned to previous knowledge. This deficiency is the result of the weakly classified and framed educational knowledge learners experience in the classroom. Learners are being socialised into the field with a common sense understanding of LS. This practice does not aid in enabling epistemological access for learners because teachers and student teachers are merely continuing the cycle of educational inequalities.

7.13 Summary

Teacher preparation programmes are tasked to ensure student teachers will know how to integrate ICTs in their classroom practices. This study highlights the inability of student teachers to use ICTs effectively in their teaching methods and the implication, thereof, is that learners are being denied opportunities for epistemological access. Most of the participating student teachers were not adequately prepared to use ICTs in the classroom despite attending courses aimed at teaching ICT integration at the Institution where they were trained (Fagan, 2014). ICTs were used to weaken density, display content, verify facts and as a tool to find answers. This use of ICTs when teaching LS did not enable learners' epistemological access.

An isolated lesson found traces of semantic waves, the student teacher was able to guide the learners between simpler understandings and deeper abstract knowledge. This process allows the learners to navigate between the complex meanings of LS.

The next and final chapter concludes the study and proposes recommendations for student teachers and teacher preparation programmes.

Chapter Eight

Conclusion and Recommendations

8.1 Introduction

The catalyst for this study was a desire to understand the student learning context in South Africa and was underpinned by the belief that to achieve social justice, teachers need to provide learners with meaningful access to knowledge which is not context-dependent, in other words, epistemological access. Epistemological access is both an educational and political issue in that it turns the focus to the unconscious and unquestioned processes of concept formation and knowledge acquisition. Enabling access to knowledge (epistemological access) when teaching could lead to successful schooling outcomes, yet the findings of both the reviewed literature and this study suggest that access to powerful knowledge still escapes the majority of South African learners from disadvantaged backgrounds, including those who participated in the observed lessons. The South African schooling system is complex; and twenty-five years after the demise of apartheid, South Africa remains an unequal society in which the physical conditions of schools and the contexts in which they are located differ greatly. Teachers' integration of ICTs within classrooms is seen as an opportunity for redress because it is viewed as a means to challenge conservative pedagogical practices, while facilitating the epistemological access essential for participation in today's knowledge society (Player-Koro, 2012b; Looi, Chen and Ng, 2010). Despite an increase in the numerous government initiatives equipping schools with ICT tools, a gap was identified this research in regard to how ICTs (when provided) are used in the classroom as a means of enabling learners' epistemological access, especially in disadvantaged communities.

South Africa's education system has three bands, General Education and Training (GET) which runs from Grades R – 9, Further Education and Training (FET) which runs from Grades 10 to 12 and Higher Education and Training (HET) which covers post-school education and training. Within the GET epistemological access has been explored concerning foundation phase education and has highlighted some 'negative cases' in which teachers essentially fail to enable epistemological access. In Du Plooy and Zilindile's (2014) research 'Problematising the concept epistemological access with regard to foundation phase education towards quality schooling', they interrogated the meaning of epistemological access and understood this term to extend beyond physical access to meaningful access. They, however, plea for more research "into pedagogical sites, where student teachers and learners interact for the purpose of teaching and learning" (Du Plooy and Zilindile, 2014:198).

Epistemological access has also been problematised in Higher Education, specifically in regard to the under-preparedness of disadvantaged students entering university. Case studies have been conducted on epistemological access in Extended Curriculum Programmes within Higher Education in South Africa (Bozalek, Garraway and McKenna; 2011). There is a considerable gap between the knowledge students bring from school and the knowledge they are expected to possess at University (Herbert, *et. Al*., 2011). Despite this well publicised knowledge gap, very little research has been undertaken with regard to epistemological access in the FET phase, especially concerning science education.

In conceptualising epistemological access (in terms of schooling) this study looked at what happens in the classroom, extending beyond mere physical access to giving learners meaningful access to knowledge. Maton's (2014c) concept of semantic waves provided useful insights into elements that are key to building knowledge over time, in other words, providing epistemological access. As the findings have made clear, this process does not simply involve indigenous knowledge or science knowledge but is also concomitant with a clear understanding of how to use technology effectively. Teachers and student teachers must understand the relationality of knowledge, improve their content knowledge and understand the interplay of different knowledges in the classroom (see the definition of TPCK in Chapter Three for elaboration). Only then will they start to facilitate epistemological access for learners when teaching science. This requirement ties into the decolonisation debate which raises critical issues regarding the relationship between power, knowledge and learning and the assumptions and values that underpin the conception, construction and transmission of knowledge in the classroom.

The ‘’drop-out’ rate of learners during their final year of schooling, Grade 12, is very high in South Africa. In 2018 out of 624 733 learners who entered Grade 12, a staggering figure of 111 998 learners dropped out (17.9%). In 2017 the percentage of learners who dropped out was 15%, slightly lower than the 2018 statistic (NSC Examinations Technical Report, 2018:52-64).

A policy on progression was introduced in South Africa in 2013 under which learners are not allowed to be held back more than once between Grades 10 and 12. This policy intended to minimise the high school dropout rates and to maximise school retention and thus in 2018, 128 634 of the 624 733 learners who entered Grade 12 progressed to matric (Grade 12) through this progression policy. Of those learners who progressed in this manner, only 33 412 wrote the matric examinations and 60.2% of these learners passed (NSC Examinations Technical Report, 2018:67). Furthermore, only 53% of the 1 186 011 learners who started Grade 1 in 2006 entered Grade 12 in 2017 (NSC Examinations Technical Report, 2018:53). These statistics reveal a failure of the schooling system, not just for learners in Grade 12, but long before they reach the final year of school. South Africa is among the poorest performers in terms of education internationally, having been placed last in Grade 9 Science and second-last place in Mathematics out of 39 countries in the 2015 TIMSS, (Reddy *et al*., 2016:3).

The current curriculum statement (CAPS) for South African schools is underpinned by a social justice agenda, meaning inclusion, recognition and affirmation for all learners. The study shows that the quality of teaching and learning seems to be deteriorating (for example poor classification and framing of knowledge, segmented learning, non-technicalised and segmented knowledge, and poor content knowledge) instead of improving over time despite the DOE’s aim to enable learners’ access to epistemological access, a situation which could have severe economic consequences for those affected. The study has also demonstrated that the provision of technological equipment and physical access to ICTs does not automatically provide quality education.

I trust that this study will prove useful in allowing educators to think somewhat differently about success and epistemological access for learners in the sciences, and also have an influence on teachers and student teachers' classroom practices. Based upon the findings of this study, teacher education institutions may have to relook at teaching practices and introduce transformative and more productive ways to view knowledge in this post-apartheid era.

8.2 Summary of findings

The key findings were:

- Student teachers lacked sufficient content knowledge, which could continue the cycle of educational inequalities.
- The continuing presence of a 'down escalator' when teaching. Learners are mostly exposed to non-specialised, everyday knowledge, which will remain context dependent.
- Learners are also exposed to segmented learning which suggests the student teachers possess weakly classified and framed educational knowledge.
- Learners practice content recitation with little to no time for reflection or to relate the knowledge learned to previous knowledge.
- Learners are being socialised into the field with a common sense understanding of LS and, furthermore, unable to link Indigenous Knowledge Systems to other knowledge.

Despite having access to ICTs, the majority of participating student teacher used these tools to reproduce traditional pedagogies with the unintended consequence of merely generating context dependent knowledge. An isolated lesson found traces of semantic waves, during which the student teacher was able to navigate between simpler understandings and deeper abstract knowledge. This process allowed learners to access the complex meanings of the LS content being taught.

8.3 Recommendations

8.3.1 Teacher preparation programmes

There seem to be challenges in the manner in which student teachers are prepared for the teaching profession. The current duration of teaching practice experience is too short and there is a lack of mentors (Phillips and Chetty, 2018). Student teachers should not merely be taught computer skills, instead, they should be taught to effectively integrate ICTs into their teaching practices (Goktas, Gedik and Baydas, 2013). ICTs in education should be internalised in such a manner that it can be used effectively across the curriculum and should not simply be used as a means to project information or to 'add colour' to a lesson. Educators need to ensure that student teachers understand how content can be altered by technology, as well as how teaching and learning can be enhanced through the effective use of ICTs. Student teachers should have a sound grounding in the use of ICTs as well as knowledge of ICT pedagogy.

It appears from the classroom observations conducted during this research that when teaching, many student teachers have little grasp of disciplinary knowledge because their subjectivities or identities have been marginalised in the South African education system. Student teachers are trying to make a connection between dense concepts (SD) and the context of disadvantaged learners, which requires a weakening of SD. Unfortunately, this situation challenges student teachers because their own subjective being is marginalised throughout the entire education system. Both at school and university they are taught that knowledge cannot be related to themselves and their cultural systems and, in turn, this idea is what they present to learners. Both student teachers and learners need to understand the importance of relationality, involving the use of indigenous knowledge together with science knowledge.

The study has implications for extended educational programmes as well. As mentioned in Chapter Six Extended Curriculum Programmes at South African Universities have been designed to assist students who do not meet the necessary entrance requirements. As shown in the study, lesson outcomes should not be driven by success rates, instead, they should focus on what the student teachers already know and still need to know.

8.3.2 ICT integration into lessons

Student teachers cannot merely focus on verifying facts outside the classroom environment using ICTs. Nor should ICTs be used as a tool to interest learners, a medium to project information nor to simply weaken SD by forcing learners to engage with the context (see Chapter Seven – Explaining solely with examples), as shown in the findings of this study. Student teachers should be helped to realise the importance of creating semantic waves and pedagogic support when teaching with ICTs. For change to happen, current teaching practice cannot simply be a reproduction of traditional pedagogy using ICTs. ICTs should be used to challenge traditional pedagogies and to help student teachers and their learners think relationally, thereby, respecting 'pluriversality' (Mignolo, 2013) as a powerful ingredient of a just and equitable society, rather than just reproducing information. The current use of ICTs in classrooms is not fulfilling its objective of transforming teaching practices (McMahon, 2009; Nivala, 2009), because it is conceptualised and implemented in extremely limited ways. The findings are consistent with those of Player-Koro (2012a) who found that traditional subject culture is merely perpetuated using digital technology. When the recontextualising agent (in this case the student teacher) lacks professional judgement on when or how to use ICTs they unfortunately will not have any pedagogic benefit (Livingston, 2010; 2012). During the observed lessons it was obvious that 'technology is simply consumed into existing ways of working instead of transforming teacher pedagogies' (Glover and Miller, 2001).

8.3.3 Science depth

There is a knowledge gap in both the learners' and student teachers' knowledge base. Student teachers need to significantly improve their content knowledge of the subject matter being taught in order to create semantic waves when teaching. Koehler, Mishra and Yahra (2007) maintain that teachers/student teachers should think of content knowledge (CK) in relation to the other knowledge needed to use ICTs effectively. When teachers/student teachers are able to create semantic waves, this will open up their own and learners' access to more powerful knowledge and allow for cumulative learning (which is currently lacking). Learners should not continue to simply memorise concepts for the purpose of passing examinations, they need to understand that learning science requires constellations of meaning (Maton, 2013). Similarly, teachers and student teachers need to understand that teaching science, requires them to give learners access to the many constellations encapsulated in science concepts, and they can only do this if they understand these constellations themselves. In the observed lessons science was taught as memorisation "… scientific formulas and definitions" (Tsai, 2002:775) therefore knowledge is solely transferred from the textbook and the teacher to learners. Freire (2008) criticises this 'banking' system[7] as he believes that this type of education reinforces a lack of knowledge ownership and critical thinking in learners which reinforces oppression.

8.3.4 Simplification of concepts

Cumulative learning is key to epistemological access. Learners should be taught to construct meaning, and not merely to pass examinations as the research findings shows. Paulo Freire states that it is important for learners to share in the learning process, as this involvement empowers the learners with a critical consciousness of themselves as meaning makers (Freire, 2005). To use Maton's term, this process entails 'constellation' of meanings (Maton, 2014b:148-170). In other words, teachers and student teachers need to strengthen SD which necessitates relating lesson concepts to other concepts in its hierarchical structure to build meaning and also to move learners from everyday non-scientific knowledge to abstract meanings. Teaching cannot simply involve the simplification of complicated problems (D'sa, 2005). Cumulative learning will enable learners to transfer knowledge across contexts and through time (Maton, 2009).

[7] The 'banking' system is used as a metaphor of learners as containers into which student teachers must put knowledge (Freire: 2008:243).

8.3.5 From disconnected and segmented knowledge to a less unequal and racialised school system

The challenge currently facing South African educators and researcher is how knowledge is recontextualised at the university level. If the curriculum is not changed or developed at the Education Faculty level, the universities will continue to propagate traditional and colonial forms of education, which will filter down to school level when the student teachers graduate. We need to disrupt the current process so that when student teachers go out to schools they have tools and skills for professional judgment and have the ability to identify valuable knowledge. Not all 'valuable' knowledge can be included in the curriculum, but proper selection processes should be adhered to (Fataar, 2018; Fagan, 2014). Fataar (2018) calls for cognitive justice through which the Western knowledge canon is expanded to encompass knowledge pluralisation, through which the complex ways of knowing practised by previously excluded groups, are included in the body of knowledge. In the absence of this process, schools are simply reproducing educational inequalities, despite the provision of adequate material and financial resources. Learners are deprived of the discursive knowledge (access to various knowledge systems/epistemological access) needed to solve the problems of the world. The curriculum should be culturally responsive (Slonimsky and Shalem, 2006) and for teachers and student teachers this would necessitate drawing knowledge from various cultures as well as including different cultural perspectives in their lessons. Educators need to engage seriously with the recontextualising systems and strive to promote what should be valued and the power relations at play in that process if they are to interrupt the reproduction of education inequalities in South African society. To withhold epistemological access (knowledge) from learners is to silently reinforce the inequality which perpetuates imbalances of power in society, especially with regard to social class. In today's knowledge-based economy, access to quality education is considered one of the equalisers in an extremely unequal society (Thomas and Li, 2008). Knowledge is power and educators have a social responsibility to assist the distribution of that power equally.

8.4 Contribution of the study

This study offered a rich and in-depth theoretical engagement with knowledge construction relating to the use of ICTs in education. The twelve observed lessons illustrated current teaching practices in schools in which ICTs are used as a pedagogical resource and showed how some aspects of the student teachers' pedagogical practices did not help learners' epistemological access and thus need to be improved. These practices relate to content knowledge and the interplay of pedagogic and technology knowledge (Koehler *et al*., 2007). The study sensitises educators to the complexities of integrating technology into pedagogy and the transactional relationship between the components of knowledge. Through the findings, teachers and student teachers will be encouraged to value the movement of discourse between everyday and scientific knowledge when teaching science subjects. Through the use of semantic waves, this study provides useful insight into the key requirements of building knowledge over time when teaching. It also deepens educators' understanding of critical realism within a science teaching context. Currently, there is very little to no literature on epistemological access in the FET phase, therefore, this study makes a humble contribution to understanding epistemological access within a science teaching context in this particular schooling phase.

A meaningful contribution of the study's findings is to help teacher education institutions to re-think and re-construct their teaching programmes in order to ensure that pre-service teachers are provided with adequate skills and knowledge to enhance their training and, thus, improve their teaching practice.

8.5 Summary

This study does not refute the validity of other studies cited in this research but adds an additional dimension. Much of the cited research contributed information on the lack of ICT usage, lack of resources, technical support and infrastructure (Mlitwa and Koranteng, 2013; Sedibe, 2011; Van der Berg, 2008) and a need for donor funding in disadvantaged schools (Chigona *et al.*, 2010). This study, however, highlights a very important issue around epistemological access when ICTs are available to both teachers and learners, a subject which has been generally neglected in studies around the value of ICTs as a learning tool in South Africa.

In answering the question 'to what extent are teacher education students using ICTs to enable epistemological access when teaching science?', this study found that generally ICTs are not effectively integrated into their lessons. Although all of the participating schools were equipped with the necessary infrastructure, student teachers failed to understand the powerful potential of ICTs to facilitate epistemological access because most of the findings showed that they are not being used for this purpose.

The study revealed that the challenges faced by student teachers when using ICTs in teaching science subjects cannot be divorced from their knowledge base of science and illustrated that when student teachers lack content knowledge, they cannot enable learners' epistemological access. Student teachers need to improve their science knowledge base. When concepts are continually simplified, as the findings of this study revealed, epistemological access is not enabled because learners are not given access to powerful knowledge. When student teachers do not provide learners with a deeper level of understanding of key concepts and procedures, they perpetuate the cycle of unequal educational outcomes and, consequently, learners will be unable to operate as equals in the current knowledge society. The importance of creating semantic waves is seen in an isolated lesson, during which the student teacher was able to navigate between simpler understandings and deeper abstract knowledge (complex meanings of LS).

The study also revealed the importance of creating semantic waves when teaching with ICTs to open powerful knowledge (epistemological access) to learners. It should be acknowledged that the sample involved in this study was disadvantaged schools, hence the history of a racialised and unjust education system has to be considered.
At a deeper decolonial level, the study notes the marginalisation of 'othered' knowledge in the Western academy and shows that resolving this issue is larger than

bringing ICTs into the classroom, but rather necessitates using these ICTs to facilitate epistemological access to excluded knowledge. The challenge to all South African educators is to attempt to find new ways of thinking about teaching in South Africa if they are to meet the challenge of enabling epistemological access for all learners. The most important and meaningful contribution of the study's findings is to encourage teacher education institutions to research ways to disrupt educational inequality in teacher training instead of focusing on the 'idealised' classroom with suitably qualified teachers and student teachers and learners from advantaged communities. Teacher training should foreground the 'disadvantaged' classroom given the fact that the majority of schools in South Africa fall within this category. The irony is that the majority of the current teacher education students come from poor contexts and, once trained, they go back to the same type of disadvantaged schools that they attended as learners, which perpetuates a vicious cycle of inequality and racialisation.

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List of Appendices

Appendix A: Lesson plans

Monica's lesson plan

LESSON PLAN: [redacted] FURTHER EDUCATION AND TRAINING			
Name of student:	**LESSON NUMBER:**	**Date:**	**Lesson duration: 45 minutes**
Subject: Life Sciences		**Grade: 10**	**Number of learners: 46**
Topic: Biomes		**Evaluator's Signature:**	

OBJECTIVES for this lesson. (Write your own objectives. Do not copy from CAPS.)

1. Distinguish between the different biomes
2. Name characteristics of different biomes
3. Understand terminology and key concepts
4. Use new information in real life context.

Teaching methods (tick appropriate block/s)			Media / resources (tick appropriate block/s)	
1. Direct instruction:	**4. Co-operative learning:**			
x Teacher presentation and explanation	☐ Jigsaw	☐ Brainstorming	☐ Textbook	☐ Magazines
x Question and answer	☐ Work in groups	☐ Hot Potato	x Chalkboard	☐ Flip charts
☐ Class Discussion	☐ Pairs	☐ Gallery walk	x Whiteboard	☐ Flash cards
☒ Group discussion	☐ Numbered heads	☐ Thinking hats	☐ Smart Board	☐ Exhibits
☐ Practice	☐ Co-op Co-op	☐ Debates	x Posters	☐ Television
2. Inquiry	☐ Round Robin	☐ Quiz bowl	x Handouts	☐ Slide presentation (PowerPoint)
☐ Investigation	☐ Pass the hat	☐ Jumbled letters	☐ Board charts	☐ Video
Problem solving	**5. Other**		☐ Graphs	☐ Recordings
3. Simulation	☐ Practical work	☐ Drama	☐ Pictures	☐ Radio
☒ Role play	☐ Game	☐ Story telling	☐ Overhead projector	
			☐ Data projector	
			☐ Newspapers	

35 minutes	**DEVELOPMENT** **Supply brief list of new concepts/ content under this heading** **(Full notes should be attached)** **<u>Definitions of concepts:</u>** **Biome** –. Biomes are very large ecological areas on the earth's surface, with fauna and flora (animals and plants) adapting to their environment. Biomes are often defined by abiotic factors such as climate, relief, geology, soils and vegetation. **Ask help from learners to define fauna and flora** Fauna - Animals. Flora – plants. Power Point Presentation • Teacher leads lesson go through slide show with leaners • Handing out of lesson content notes **Teacher asks learners to form groups and have short group work activity in class to get learners understanding of topic at hand**	Explaining of different concepts to learners Tell learners that they can make notes as lesson progress	Learners should listen to the explanations of the different concepts . Make notes until the end of the lesson **Learners form groups and participate in lesson.**

Learners' existing knowledge: ***(previous knowledge and skills to which this lesson will link)***

- Test learners on their knowledge of biomes

	ATTACHMENTS on separate pages →	Attach planned Questions with answers Attach Content (your own work) (no copies from textbooks or powerpoint slides)	Attach copies of Handouts
Time Slots	LESSON PHASES ⇩	ACTIONS OF EDUCATOR (e.g. asks questions, explains, demonstrates, lectures)	LEARNERS' ACTIVITIES **(e.g. answer questions, take notes, complete worksheet, debate, group work)**
5 minutes	**INTRODUCTION.** **Role play to introduce lesson** **Lesson objects:** 1. Define term biome : Biomes are very large ecological areas on the earth's surface, with fauna and flora (animals and plants) adapting to their environment. Biomes are often defined by abiotic factors such as climate, relief, geology, soils and vegetation.	**Question and answer** What is a biome? **Expected answers** Biomes are very large ecological areas on the earth's surface, with fauna and flora (animals and plants) adapting to their environment. Biomes are often defined by abiotic factors such as climate, relief, geology, soils and vegetation.	Learners give expected answers Make notes where needed

5 minutes	**CONCLUSION** **Emphasize outcomes** Class activity (can be completed as homework)	Teacher goes through the concepts again to refresh learners . Ask mind questions to see whether the learners understood the work	Learner let teacher know where they experience problems. Do class activity in notebooks

Full names and authors of sources used (book, journal, internet, PowerPoint presentation, Encarta, etc. If you created it, supply your own name):

Ppt : Biomes of South-Africa by [redacted]

Evidence of achievement/Daily assessment

Task Number	**Nature of Task**	**Assessed by (peer or teacher)**	**Answer to assessment (attach)**
1.	Activity	Peer	Memorandum

Craig's lesson plan

LESSON PLAN: [redacted] FURTHER EDUCATION AND TRAINING			
Name of student:	LESSON NUMBER:	Date: 21 October	Lesson duration: 45 minutes
Subject: Life Sciences		Grade: 11C	Number of learners:35
Topic: Deforestation		Evaluator's Signature:	

LESSON OUTCOMES for this lesson.

By the end of this lesson, the learner will be able to:

1. Define the term Deforestation
2. Explain the causes of Deforestation
3. Explain the effects of Deforestation
4. Apply the information about Deforestation in a relevant case study, graph or table
5.
6.

Teaching methods (tick appropriate block/s)

1. Direct instruction:
   - ☒ Teacher presentation and explanation
   - ☒ Question and answer
   - ☐ Class Discussion
   - ☐ Group discussion
   - ☐ Practice
2. Inquiry
   - ☐ Investigation
   - ☐ Problem solving
3. Simulation
   - ☐ Role play
4. Co-operative learning:
   - ☐ Jigsaw
   - ☐ Work in groups
   - ☐ Pairs
   - ☐ Numbered heads
   - ☐ Co-op Co-op
   - ☐ Round Robin
   - ☐ Pass the hat
   - ☐ Brainstorming
   - ☐ Hot Potato
   - ☐ Gallery walk
   - ☐ Thinking hats
   - ☐ Debates
   - ☐ Quiz bowl
   - ☐ Jumbled letters
5. Other
   - ☐ Practical work
   - ☐ Game
   - ☐ Drama
   - ☐ Story telling

Media / resources (tick appropriate block/s)

- ☐ Textbook
- ☐ Chalkboard
- ☐ Whiteboard
- ☐ Smart Board
- ☐ Posters
- ☒ Handouts
- ☐ Board charts
- ☐ Graphs
- ☐ Pictures
- ☐ Overhead projector
- ☒ Data projector
- ☐ Newspapers
- ☐ Magazines
- ☐ Flip charts
- ☐ Flash cards
- ☐ Exhibits
- ☐ Television
- ☒ Slide presentation (PowerPoint)
- ☒ Video
- ☐ Recordings
- ☐ Radio

Learners' existing knowledge: *(previous knowledge and skills to which this lesson will link)* *Knowledge of Gaseous Exchange*			
	ATTACHMENTS on separate pages →	**Attach planned Questions with answers** **Attach Content (your own work)** **(no copies from textbooks or powerpoint slides)**	**Attach copies of Handouts**
Time Slots	**LESSON PHASES** ⇩	**ACTIONS OF EDUCATOR** **(e.g. asks questions, explains, demonstrates, lectures)**	**LEARNERS' ACTIVITIES** **(e.g. answer questions, take notes, complete worksheet, debate, group work)**
5 mins	**INTRODUCTION.** **Link to existing knowledge**	Educator will ask learners to look at the first power point slide and ask the learners what they see. Expected answer: A desert Educator will then ask learners to tell him which desert is situated in Namibia Expected answer: The Namib Desert or Kalihari Desert	Learners are expected to answer question posed by the educator.
30 mins	**DEVELOPMENT** **Supply brief list of new concepts/ content under this heading** **(Full notes should be attached)**	The educator will then explain to learners that we get the best charcoal from Namibia. Also known as Athracite. The educator will ask learners another question, "If there is so much charcoal coming from Namibia what does that indicate about the area?" Expected answer: There used to be a forest there a long time ago. The educator will now continue with the power point presentation coving the following headings: The definition of Deforestation The causes of Deforestation The impact of Deforestation The educator will play a video clip about Deforestation. Pause it during parts to explain more in detail.	Learners are expected to listen attentively and answer questions the educator asks. They are allowed questioning in between questioning.

10 mins	**CONCLUSION** **Emphasize outcomes**	Educator will ask learners to do questions 6 and 7 handed to them in class or for homework	Learners are expected to do their class work activities or do their homework at home over the weekend.
<u>Full names and authors of sources used</u> **L. Sterrenberg, H. Fouche, 2015. The Answer Series 3 in 1 grade 11. The Answer. Claremont**			

Shafiek's lesson plan

LESSON PLAN

School Name: **Date:** **Grade**: 10 **Duration:** 60 minutes
Subject: Life Sciences **Theme:** Biodiversity and Classification Topic: History of Classification

Specific Aim(s):
Skills:
At the end of the lesson the learners will be able to:
Give the scientific sequence of naming organism according to taxa
Use the scientific sequence to rearrange the order of a specific organism according
Be able to define each term of taxa
Teaching Methods:
Teacher Presentation
Question and Answer
Class Discussion

Learning and teaching support materials (LTSM): [please tick relevant box]

	Chalkboard	Overhead projector	
	Flashcards	Posters/charts	
	Newspapers/magazines	Radio/tape recorder	
X	Worksheets/activity	Television and/or DVD or CD player	
X	Toys/puzzles	Data projector	
	Smartboard	Whiteboard	X
	Internet	Computers/laptops	
X	Slide Presentation(PowerPoint)	Textbooks	

Lesson Structure

Lesson content (notes and questions)	**Methodology**	**LTSM (Resources)**	**Teacher Activities**	**Learner Activities**	**Assessment Method/Strategy**	**Classroom and time management**
<u>Introduction</u> In the introduction, the teacher will tap into previous knowledge from previous lessons by posing a questions to the learners. What is biodiversity? What is prokaryotic? What is endemic? Name the 5 kingdoms of scientific classification?	Question and Answer method	PowerPoint	The teacher will pose the question and give a brief explanation from the PowerPoint once the learners give answers based on prior knowledge.	The learners will receive a question posed by the teacher and using prior knowledge the learners should attempt to answer the question.	Verbal assessment	Learners will sit individual 6 minutes

Body The teacher will instruct learners to pay attention to the PowerPoint explanation on the history of classification. The teacher will give a demonstration using cardboard boxes in order to explain the process of taxa. The teacher will instruct learners to write down the PowerPoint slides in their notebooks.	Teacher Presentation Teacher Demonstration	PowerPoint Whiteboard Cardboard Box PowerPoint Whiteboard Notebooks	The teacher will present the PowerPoint presentation to the learners and instruct them to write down work from the PowerPoint. The teacher will ensure that the learners follow instructions given verbally. The teacher will have a class demonstration using cardboard boxes. Learners will have to complete an exercise given.	The learners are required to write down the explanation from the PowerPoint slides into their notebooks.	Individual	Learners will sit individually while they complete writing down the work from the PowerPoint.
The learners will have to complete an exercise on the rearranging of taxa of the given organisms.	Class Activity	PowerPoint Notebooks		Learners are required to complete the exercise in their notebooks.	Individual	Learners will sit individually while they complete writing down the work from the PowerPoint. **50 minutes**

<u>Conclusion</u> The teacher will conclude the lesson by recapping on the lesson.	Question and answer	PowerPoint	The teacher will ask the learners to give explanations on terms covered in the lesson	The learners will provide the teacher with the explanations on the terms covered in the lesson	Class discussion.	Learners will sit individually. 4minutes.

Jennifer's lesson plan

	ATTACHMENTS on separate pages	Addendum X: Evidence from CAPS Addendum A: Classroom Notes	
Time Slots	**LESSON PHASES** ⇩	**METHODOLOGY / ACTIONS OF EDUCATOR** What you will do during the various stages of the lesson **(e.g. asks questions, explains, demonstrates, lectures)**	**LEARNERS' ACTIVITIES** What learners will do and the learning material they will use. **(e.g. answer questions, take notes, complete worksheet, debate, group work)**
5 mins	**INTRODUCTION.** The story told about life on Earth links to learner's prior knowledge on life forms as explained in the previous lesson, specifically bacteria (prokaryotes).	➢ The lesson will be introduced with the educator instructing learners to envision how life on earth started. This will be achieved with a short story telling method.	➢ Learners will close their eyes and paint a picture with the words the teacher is using to explain the history of life on earth
25mins	**DEVELOPMENT** ☺ Question learners on their knowledge of the age of earth and existence of life on earth ☺ Note how the geological timescale relates to the lesson ☺ Examine all the subjects noting its contribution to the history of life on earth	➢ Ask learners: - What is the estimated age of earth? - When did life on earth start? - What elements are essential to sustain life on earth? ➢ Mention what subsections will be covered in the lesson (learners to note the headings) ➢ Hand out the notes and a colour copy of the geological timescale (make reference to the time scale) ➢ Examine the notes on: - The increase in oxygen levels - Discuss climate change - Show learners the video clip on continental drift and define continental drift. - Examine the effects of biogeography	➢ Answer questions asked by the educator ➢ Note what will be covered in the lesson ➢ Receive the hand out and paste it in their notebook. ➢ Highlight key points and make additional notes ➢ Watch the video ➢ Ask questions
10 mins	**APPLICATION** - Direct assessment on lesson content taught	➢ Hand out the lesson activity and read through the questions to ensure that learners understand what needs to be done. Instruct all learners to work independently through the questions. ➢ Check the answers to the exercise by asking individual learners to respond	➢ Work through the activity independently ➢ Check their answers to the questions by allowing their peers to share what answers they have

5 mins	**CONCLUSION** - Summarises lesson	Show learners a video: Man Vs Earth by Prince EA. The video speaks about the history of earth and the turmoil earth is in because of man.	View the video, comment on the video.

Full names and authors of sources used (book, journal, internet, PowerPoint presentation, Encarta, etc. If you created it, supply your own name):

- Gebhardt, A., Preethlall, P., Pillay, S. & Farham, B. 2012. *Study & Master Life Sciences Grade 10: Learners Book.* Cape Town: Cambridge University Press.
- South Africa. Department of Basic Education. 2011. *Curriculum and Assessment Policy Statement: Life Sciences: Further Education and Training Phase Grades 10-12.* Pretoria: Government printer
- Sterrenberg,, L & Fouche, H. 2011. *Grade 10 Life Sciences 3 in 1 IEB.* Claremont: Answer Series.

Addendum X: evidence from CAPS

36 CURRICULUM AND ASSESSMENT

TERM 4				
5 weeks (20 hours)	History of Life on Earth	**Life's History:Change throughtout the history of life on Earth** • Changes in the composition of the atmosphere (eg. increases in the levels of oxygen) • changes in climate (eg. ice ages) • geological events (eg. movements of continents) and their effect on the distribution of living organisms (biogeography) Evidence for changing sea level and rise and fall of the land (eg. 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 periods are each divided into periods *(Names of periods not to be memorised)*:	• 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.	

LIFE SCIENCES GRADES 10-12

ADDENDUM A : Notes

UNIT 2: HISTORY OF LIFE ON EARTH

HISTORY OF LIFE

Scientists estimate that the earth came into existence approximately 4,6 billion years ago.

1 billion = 1 000 million
∴ 4,6 billion = 4 600 million

According to scientists, life on earth started 3,8 billion years ago with a unicellular, prokaryotic cell similar to a bacterial cell. Multicellular organisms only developed a few billion years later.

Scientists try to make sense of the history of life on earth by relating it to other important events, such as:

- increase in oxygen levels in the Earths atmosphere
- climate change
- Geological events
- Fossil evidence

↖ learners fill this in on their personal notes

INCREASE IN OXYGEN LEVELS

- When the earth formed, oxygen levels in the earth's atmosphere were very low.
- Modern theories suggest that the first life forms, i.e. the prokaryotes, which appeared 3,8 billion years ago, did not need oxygen. They respired **anaerobically** and therefore obtained energy from their food, without using oxygen.
- Between 3,5 and 2,5 billion years ago different types of bacteria arose, which could produce their own food through photosynthesis. Carbon dioxide, which occurred in large quantities in the atmosphere, was used and oxygen was released.
- Oxygen levels in the atmosphere started to increase and oxygen-dependent organisms (**aerobic** organisms) developed.
- The increase in oxygen levels in the atmosphere resulted in an increased variety of living organisms on earth.

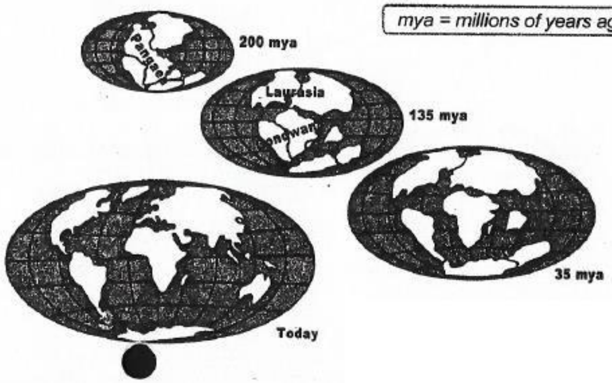
CLIMATE CHANGE, e.g. ICE AGES

- Ice ages are long geological periods of drastic decrease in the temperature of the earth's surface and atmosphere.
- Glaciation takes place because large ice sheets form due to cooling temperatures.
- There is evidence of at least four ice ages since the origin of the earth.
- During the ice ages, many species that could not adapt to the low temperatures died out.
- Some species were forced to migrate towards the equator where temperatures were higher.
- The climate was drier because most of the water was trapped in snow and ice. Many terrestrial species became extinct due to the dry climate.
- Due to ice formation, the sea level dropped. This resulted in decreased habitats and the extinction of many aquatic species.
- Ice ages therefore affected life on earth due to the extinction and redistribution of species.

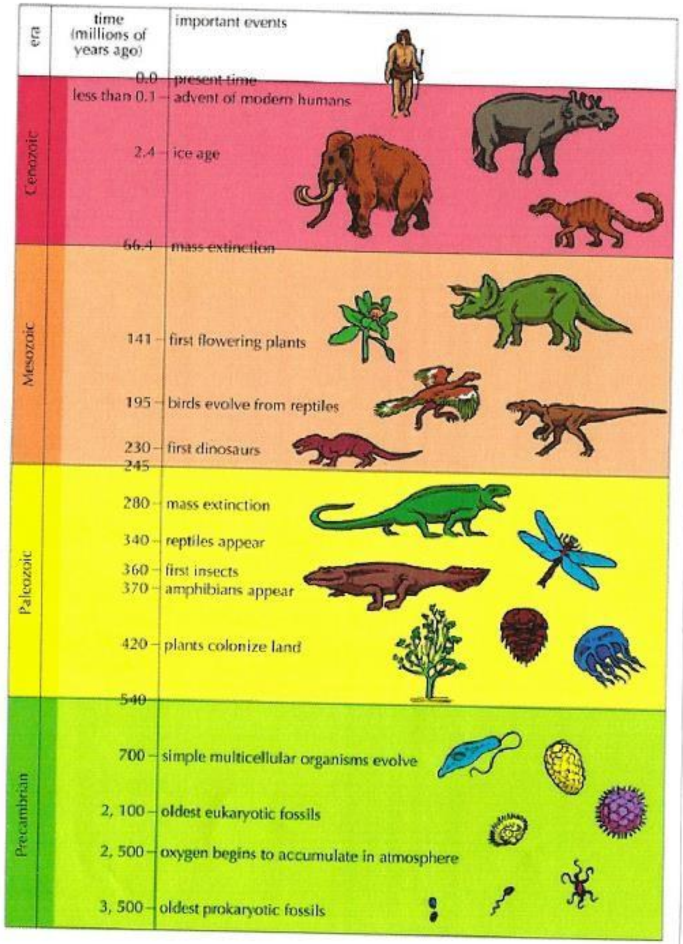
GEOLOGICAL EVENTS e.g. CONTINENTAL DRIFT

- Up until 200 million years ago all the continents were fused to form one giant continent, Pangaea. Pangaea broke up into two super continents: Laurasia in the north and Gondwanaland in the south.
- Approximately 120 million years ago these two super continents broke up even further into the continents we know at present.

mya = millions of years ago



ADDENDUM A: colour note



Elvin's lesson plan

LESSON PLAN: [redacted]: FURTHER EDUCATION AND TRAINING			
Name of student: [redacted]	LESSON NUMBER:	Date: [redacted]	Lesson duration: 45 minutes
Subject: Life Sciences		Grade: 11C	Number of learners:35
Topic: Genetic Modification		Evaluator's Signature:	

LESSON OUTCOMES for this lesson. By the end of this lesson, the learner will be able to:
1. Define Genetic Modification
2. Relate to previous lessons on photosynthesis
3. Predict what will happen when genetic modification is used by all plants and animals
4. Discuss the ethical and religious views on Genetic engineering
5.
6.

Teaching methods (tick appropriate block/s)

1. Direct instruction:
- ☒ Teacher presentation and explanation
- ☒ Question and answer
- ☐ Class Discussion
- ☐ Group discussion
- ☐ Practice

2. Inquiry
- ☒ Investigation
- ☐ Problem solving

3. Simulation
- ☐ Role play

4. Co-operative learning:
- ☐ Jigsaw
- ☐ Work in groups
- ☐ Pairs
- ☐ Numbered heads
- ☐ Co-op Co-op
- ☐ Round Robin
- ☐ Pass the hat
- ☐ Brainstorming
- ☐ Hot Potato
- ☐ Gallery walk
- ☐ Thinking hats
- ☐ Debates
- ☐ Quiz bowl
- ☐ Jumbled letters

5. Other
- ☐ Practical work
- ☐ Game
- ☐ Drama
- ☒ Story telling

Media / resources (tick appropriate block/s)
- ☐ Textbook
- ☐ Chalkboard
- ☐ Whiteboard
- ☐ Smart Board
- ☐ Posters
- ☒ Handouts
- ☐ Board charts
- ☐ Graphs
- ☐ Pictures
- ☐ Overhead projector
- ☒ Data projector
- ☐ Newspapers
- ☐ Magazines
- ☐ Flip charts
- ☐ Flash cards
- ☐ Exhibits
- ☐ Television
- ☒ Slide presentation (PowerPoint)
- ☒ Video
- ☐ Recordings
- ☐ Radio

Learners' existing knowledge: *(previous knowledge and skills to which this lesson will link)* Photosynthesis and starch production			
	ATTACHMENTS on separate pages →	**Attach planned Questions with answers** **Attach Content (your own work)** **(no copies from textbooks or powerpoint slides)**	**Attach copies of Handouts**
Time Slots	**LESSON PHASES** ⇩	**ACTIONS OF EDUCATOR** **(e.g. asks questions, explains, demonstrates, lectures)**	**LEARNERS' ACTIVITIES** **(e.g. answer questions, take notes, complete worksheet, debate, group work)**
5 mins	**INTRODUCTION.** **Link to existing knowledge**	Educator will ask learners to recall what happens when photosynthesis occurs. Educator will then ask learners a question. What is ATP? Expected answer: Adinosine Tri Phosphate Educator will then explain that learners would probably know that the P stands for Phospor but whats does the Adinosine stand for?	Learner are expected to listen attentively. Learners are expected to answer the question posed by the educator.
30 mins	**DEVELOPMENT** **Supply brief list of new concepts/ content under this heading (Full notes should be attached)**	Educator will give explain to learners that Adinosine is a combination of elements. These elements combine and form amino acids through multiple reactions. Education will explain to learners the term, "you are what you eat", meaning that everything you eat has an effect on your gene structure. This will link to genetic modified foods. The educator will discuss: • The impact on the gene pool • Genetic engineering • Advantages and Disadvantages of GM food The educator will then put on a video clip about Genetic Modified foods. Educator will tie his lesson when is played on the clip.	Learners are expected to listen attentively. They are also expected to ask questions during the lesson.

10 mins	**CONCLUSION** **Emphasize outcomes**	The educator will summarise the lesson by explaining to the learners what was explained in the video clip. Educator will ask learners whether they are for GM foods or not?	Learners are expected to voice their opinions about GM foods

<u>Full names and authors of sources used</u>

L. Sterrenberg, H. Fouche, 2015. The Answer Series 3 in 1 grade 11. The Answer. Claremont

Victor's lesson plan

LESSON PLAN: B.Ed.: FURTHER EDUCATION AND TRAINING			
Name of student: [redacted]	Lesson number: 10	Date: [redacted]	Lesson Duration: 45 minutes
Subject: Life Sciences	Lesson Topic: Evolution	Grade: 10	Number of learners: 55

Specific Aim(s):

- To enable learners to know evolution
- To equip learners with knowledge of key biological concepts of evolution
- To enable learners to enquire knowledge of the theory and its main purpose

Skills:

- Debate against or for one of the two theorists
- Differentiate between theory, hypothesis and evolution
- State the differences of the two theories

Teaching methods:

- Telling method
- Questioning method
- Group and class discussion

Learning and teaching support materials (LTSM): [please tick relevant box]

x	Chalkboard	Overhead projector	x	Toys/puzzles	
	Flashcards	Posters/cards		Smart board	
	Newspapers/magazines	Radio/tape recorder		Internet	
	Worksheets/activity sheets	Television and/or DVD or CD player		Computers/laptops	

x	Whiteboard	Data projector	x	Textbooks	x
	Dictionaries	Other (specify)			

Lesson Structure

Methodology and Time	**LTSM (Resources)**	**Teacher Activities**	**Learner Activities**	**Classroom and time management**
➢ Questioning and telling method	➢ Chalkboard	➢ Explains	➢ Listening and observing	➢ Learners sitting in pairs 5 minutes
• **Hypothesis** • Is a prediction of physical phenomena, which can be tested by observations or experiment • **Theory** • Is an explanation of physical phenomena. Firmly founded on observations and experiment, which continues on to be investigated. • **Evolution** Evolution is to unroll, to disclose, to develop, to unravel, to change				
➢ Telling method Class discussion	• Chalkboard • Textbook	• Explain terminologies for the • Learners • Ask questions based on the content	Learners are given a change to debate	45 minutes

<table>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Body (Lesson presentation)</td></tr>
<tr><td colspan="5">

The theory of evolution states that all species of living things that exist today (and many more which are now extinct) have evolved from simple life form which first developed more than 3 billion years ago.
Two theorists Lanmarck & Darwin they agree on one thing that “all species evolve from older species” Lanmark (law of use & disuse), inheritance of acquired characteristics)
if organisms use a structure often, it becomes bigger/grows.
if they don’t use it at all, it becomes smaller and may disappear. He called this the “law of use and disuse”
2. The offspring of organisms inherit the characteristics their parents acquired during their lifetime. Lanmarck called this the “inheritance of acquired characteristics”.
Is a process where better adapted organisms tend to survive and produce more offspring and those that are not adapted die out.
Variation (difference) of species
In a population, more offspring are produced change/modifications occurring in the lifetime of an organism is passed on to further generations.

Keywords

Many offspring
Variation
Competition
Survival of the fittest
Natural selection
Population change

</td></tr>
<tr><td colspan="5">Summary (Emphasis the most important parts and some key words)</td></tr>
</table>

➢ Telling method	➢ Smart board ➢ Whiteboard	➢ Ask questions and explains main points.	➢ Learners write down the main points	➢ 10 minutes

Sipho's lesson plan

LESSON PLAN: [redacted]: FURTHER EDUCATION AND TRAINING			
Name of student: [redacted]	**LESSON NUMBER:**	**Date:** [redacted]	**Lesson duration: 60 mins**
Subject: Natural Science		**Grade: 8**	**Number of learners: 37**
Topic: Energy flow and nutrient cycles		**Evaluator's Signature:**	

LESSON OUTCOMES for this lesson. (do NOT use the Learning Outcomes and Assessment Standards from the old NCS)

By the end of this lesson, the learner will be able to:

1. **Describe different feeding relationships**
2. **Draw food chains to show energy flow**

Teaching methods (tick appropriate block/s)

1. Direct instruction:
- ☒ Teacher presentation and explanation
- ☒ Question and answer
- ☐ Class Discussion
- ☐ Group discussion
- ☐ Practice

2. Inquiry
- ☐ Investigation
- ☐ Problem solving

3. Simulation
- ☐ Role play

4. Co-operative learning:
- ☐ Jigsaw
- ☐ Work in groups
- ☐ Pairs
- ☐ Numbered heads
- ☐ Co-op Co-op
- ☐ Round Robin
- ☐ Pass the hat
- ☐ Brainstorming
- ☐ Hot Potato
- ☐ Gallery walk
- ☐ Thinking hats
- ☐ Debates
- ☐ Quiz bowl
- ☐ Jumbled letters

5. Other
- ☐ Practical work
- ☐ Game
- ☐ Drama
- ☐ Story telling

Media / resources (tick appropriate block/s)
- ☒ Textbook
- ☐ Chalkboard
- ☐ Whiteboard
- ☐ Smart Board
- ☐ Posters
- ☐ Handouts
- ☐ Board charts
- ☐ Graphs
- ☐ Pictures
- ☐ Overhead projector
- ☒ Data projector
- ☐ Newspapers
- ☐ Magazines
- ☐ Flip charts
- ☐ Flash cards
- ☐ Exhibits
- ☐ Television
- ☒ Slide presentation (PowerPoint)
- ☐ Video
- ☐ Recordings
- ☐ Radio

Learners' existing knowledge: ***(previous knowledge and skills to which this lesson will link)***

Learners know what a food chain is.
Learners know how living organisms get energy.

	ATTACHMENTS on separate pages →	**Attach planned Questions with answers** **Attach Content (your own work)** **(no copies from textbooks or PowerPoint slides)**	**Attach copies of Handouts**

Time Slots	LESSON PHASES ⇩	ACTIONS OF EDUCATOR (e.g. asks questions, explains, demonstrates, lectures)	LEARNERS' ACTIVITIES (e.g. answer questions, take notes, complete worksheet, debate, group work)
10 mins	**INTRODUCTION.** **Link to existing knowledge**	Introduce the lesson by looking at how living organisms acquire and use energy. Explain to learners that the main source of energy is sunlight. Initiate a short discussion on how living organisms use sunlight for energy.	Learners listen attentively and make notes in their books. Learners participate in the discussion of sunlight.
40 mins	**DEVELOPMENT** **Supply brief list of new concepts/ content under this heading (Full notes should be attached)**	Using a powerpoint presentation, explain to learners that all living organisms are classified into either producers or consumers and provide definitions as well as examples of key terms such as: • Producers – organisms that make their own food • Consumers – organisms that feed on other organisms • Predator – catches and eats live animals • Scavenger – feeds on dead remains • Decomposer – breaks down dead remains into simple substances when feeding Introduce an example of a food chain and explain to the learners how energy is transferred.	Learners listen attentively to the teacher's explanation and take down notes in their books. Learners ask questions to their understanding of the content and also answer questions asked by the teacher.
10 mins	**CONCLUSION** **Emphasize outcomes**	Give learners an exercise to start on in class.	Learners complete exercise. They may consult the teacher if they need further help.

<u>Full names and authors of sources used (book, journal, internet, PowerPoint presentation, Encarta, etc. If you created it, supply your own name)</u>:

- **Via Afrika Natural Sciences Grade 8 Learners Book – J.J.J de Beer, D.B Gibbon, R Jones, F.T Kunene, M.E Patrick, J.A Sampson**
- **Powerpoint presentation – MT Van Dyk**

Cecelia's lesson plan

LESSON PLAN

School Name: **Date**: 20 October **Grade**: 10 **Duration:** 50 minutes

Subject: Life Science **Strand:** Strand 3- Biosphere to ecosystems

Topic: The biosphere

Specific Aim(s):

Specific Aim 1; Acquiring knowledge of Life Science.

Specific Aim 3; Understanding the applications of Life Science in everyday life.

Aim: Biosphere and ecosystems. Ecologist study the biosphere.

Skills:

At the end of the lesson the learners will be able to:

Acquire knowledge

- Access information from a variety of sources.
- Select key ideas obtained from resources.
- Recall and describe knowledge related to Life Science.
- Analyse, discuss and debate the ethical and legal issues surrounding biotechnology

Teaching Methods:

The Telling Method- Deliver an oral presentation about the topic. The aim is to clarify concepts so that learners are able to understand them

The Questioning Method- It is a teaching- learning situation. This method is used to direct the attention of the learners to what is to be presented.

The Scaffolding Method – Teach the learners skills.

Content	Teacher Methodology	Learner Activity
Introduction: 5 minutes		
Part of the Earth where humans and other organisms are able to live is called the **biosphere.** Biosphere consist of : atmosphere, hydrosphere, lithosphere, 1.1. Atmosphere: Gasses that keep environment stable. Helps with respiration, photosynthesis and filtering the sunlight to protect organisms from harmful or strong sun rays. 1.2. Hydrosphere: Aquatic/water part of biosphere. Ocean, rivers, lakes. Habitat of many aquatic organisms as fish. 1.3. Lithosphere Outside crust of the Earth. Formed rocks and soil. Source of the ions which living organisms need.	Questioning Method. This is a recap on previous work. Before books are taken out Educator will ask questions to test their knowledge on the topic of biosphere. 1.1 What do we call the part of earth where all living organism live and form the whole of earth? 1.2. Define and explain Atmosphere. 1.3Define and explain hydrosphere. 1.4. Define and explain Lithosphere	1.1. Biosphere. 1.2. The gasses in the environment which consist of oxygen, carbon dioxide which help with respiration and photosynthesis and protects us from sun rays. Aquatic part of earth. Consist of lakes riveres and a habitat to many aquatic organisms. Outside crust of earth formed of rocks and soil. Is a source of ions which living things need.
Body: 40 munites		
Biosphere as a linked system. Organism: Single form of life and the habitat is where it lives. Population: A group of organisms of the same species living in a specific area at the same	Educator explain all the following terms to learners and some can read it from textbook. I printed pictures of the biosphere divided on smaller pieces. A few learners will stand in front of the class with the pictures and the class has to decide how to arrange the pictures from the most	Read a few parts out of textbook. Identify pictures group them from most simple form to complex.

time. Ecosystem: Communities of plants and animals interacting with each other and with their non-living environment. E.g. all the plants, animals, soil,water and other non-living things. Biological community: All the population of different species in a place. Biome: Large area with a certain climate and species of plants and animals; made up of smaller ecosystems. Biosphere: Where life is found on earth; atmosphere,hydrosphere,lithosphere.	simple form to complex.	
Conclusion : 5 minutes A picture will be given and they have to identify what they learned during the lesson and label the picture	Educator shows the picture on projector. 1. Identify the living things. 2. Identify non-living thing. 3Identify relationship between living things. 4. In what ways do the living things need the non living things?	Lerner identifies. 1. Fish and plants 2.Sunlight,water,soil,air 3. Big fish eat small fish. 4. Plants need water and sunlight for photosynthesis. The living things need air for respiration. Plants need soil to grow.

Homework activity added

Freda's lesson plan

LESSON PLAN

Grade: 10B

Subject: Life Science

Strand: **Topic**: External structure of the heart

At the end of the lesson the learners will be able to:

Learners will be able to identify the external structure of the heart
Learners will be able to label the external structure of the heart
Learners will know where the heart is situated in the human body

Teaching methods:
Question and answer
Explaining

Learning and teaching support materials (LTSM): [please tick relevant box]

	Chalkboard	Overhead projector	
	Flashcards	Posters/charts	
	Newspapers/magazines	Radio/ tape recorder	
	Worksheets/ activity sheets	Television and/or DVD or CD player	
	Toys/puzzles	Data projector	
	Smartboard	Whiteboard	
	Internet	Computers/ laptop	
	Dictionaries	Textbooks	
	Other (specify)		

Lesson Structure

Lesson content (notes and questions)	**Teacher Activities**	**Learner Activities**
Introduction Create a scenario and ask learners to draw the shape of a heart. Introduce to learners the topic of the day – External structure of the heart	Let a learner go draw the shape of a heart to. Make use of question and answer, method.	Learners go draw the shape on the board
Body Inform the learners that the heart have a total different shape as to how people normally illustrate the heart	Ask learners where they think the heart is situated in the body Ask learners how big they think the heart is Ask learners to pay attention as questions will be based on the video Give learners an activity to complete based on the video Ask learners to label the external structure of the heart	Possible answer: In the middle of the chest cavity Possible answer: size of closed fist Learner's listen intensively Learners complete activity Learners label external structure of the heart
Conclusion Summaries lesson by emphasizing on outcomes of the lesson	Ask random learners questions based on the lesson and what they have learned	Possible answer: how the external heart looks like and the labels of it

Alex's lesson plan

LES PLAN

Graad: 11

Vak: Lewenswetenskappe

Onderwerp: Ontbossing

Aan die einde van die les sal die leerder kan:

Definisie gee van ontbossing.
Die oorsake van ontbossing kan gee.
Die gevolge van ontbossing kan identifiseer.

Metodes
Vrae en antwoord
Verduidelik

Ondersteuning materiaal (LTSM): [merk asseblief die relevante blokkie]

x	Dataprojektor/ Data projector		

Les struktuur

Les inhoud	**Juffrou Aktiwiteit**	**Leerder Aktiwiteit**
Inleiding/ Introduction Verbind les met bestaande kennis	Juffrou toets kennis oor ontbossing.	Leerders word verwag om die vrae te beantwoord.

Ontwikkeling/ Body Verduidelik wat is ontbossing. Verduidelik oorsake van ontbossing. Verduidelik gevolge van ontbossing.	Gebruik relevante voorbeelde.	Toets leerders se kennis.
Einde/ Conclusion Som les op en toets wat leerders geleer het.	Vra leerders om oor belangrike werk te gaan.	Leerders moet oor die belangrike werk in hul notas gaan.

Alex's lesson plan with English translation

LES PLAN *(Lesson plan)*

Graad: 11

Vak : Lewenswetenskappe *(Life Science)*

Onderwerp: Ontbossing *(Deforestation)*

Aan die einde van die les sal die leerder kan
(At the end of the lesson, the learner will be able to)

Definisie gee van ontbossing. *(Definition of deforestation).*
Die oorsake van ontbossing kan gee. *(Can give the causes of deforestation).*
Die gevolge van ontbossing kan identifiseer. *(Identify the effects of deforestation)*

Metodes *(Methods)*
Vrae en antwoord (Question and answer)
Verduidelik (Explain)

Ondersteuning materiaal: [merk asseblief die relevante blokkie]
Support material: [please mark the relevant box]

x	Dataprojektor/ Data projector		

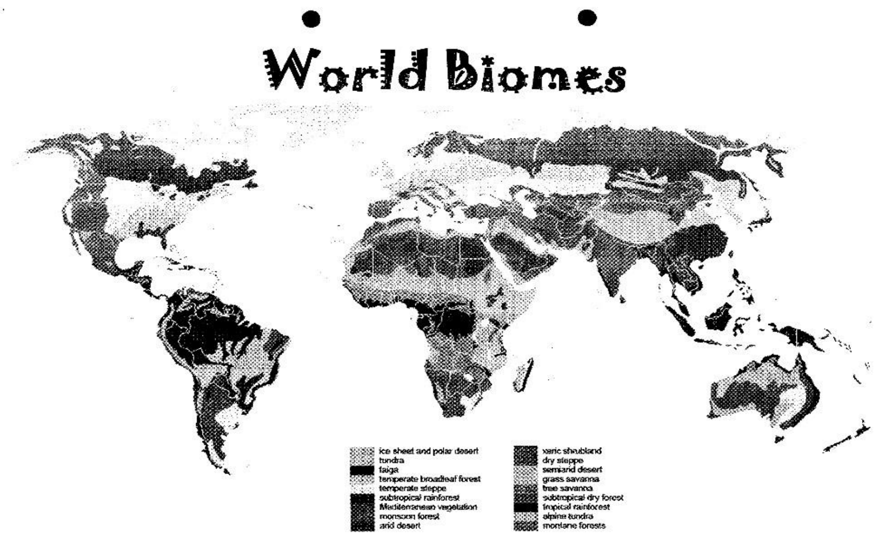
Les struktuur (Lesson structure)

Les inhoud *(Lesson content)*	**Juffrou *(Teacher)* Aktiwiteit *(Activity)***	**Leerder *(Learner)* Aktiwiteit *(Activity)***
Inleiding/ Introduction Verbind les met bestaande kennis	 Juffrou toets kennis oor ontbossing.	

(Connect lesson with existing knowledge)	*(Teacher test knowledge on deforestation)*	Leerders word verwag om die vrae te beantwoord. *(Learners are expected to answer the questions.)*
Ontwikkeling/ Body Verduidelik wat is ontbossing. Verduidelik oorsake van ontbossing. Verduidelik die gevolge van ontbossing. *(Explain deforestation.* *Explain the causes of deforestation.* *Explain the effects of deforestation)*	Gebruik relevante voorbeelde. *(Gebruik relevante voorbeelde)*	Toets leerders se kennis. *Test learners' knowledge.*
Einde/ Conclusion Som les op en toets wat leerders geleer het. *Summarise the lesson and test what learners have learned.*	Vra leerders om oor belangrike werk te gaan. *Ask learners to over important notes in their books.*	Leerders moet oor die belangrike werk in hul notas gaan. *Learners must go over important work in their notes.*

Appendix B: PowerPoint presentations (if provided)

Monica's PowerPoint presentation



Biomes

- Regions of the world with similar physical environments
- Named for most conspicuous types of vegetation
- Climate factors
  - Rainfall (precipitation)
  - Temperature
  - Altitude
  - Latitude
- Boundaries are indistinct

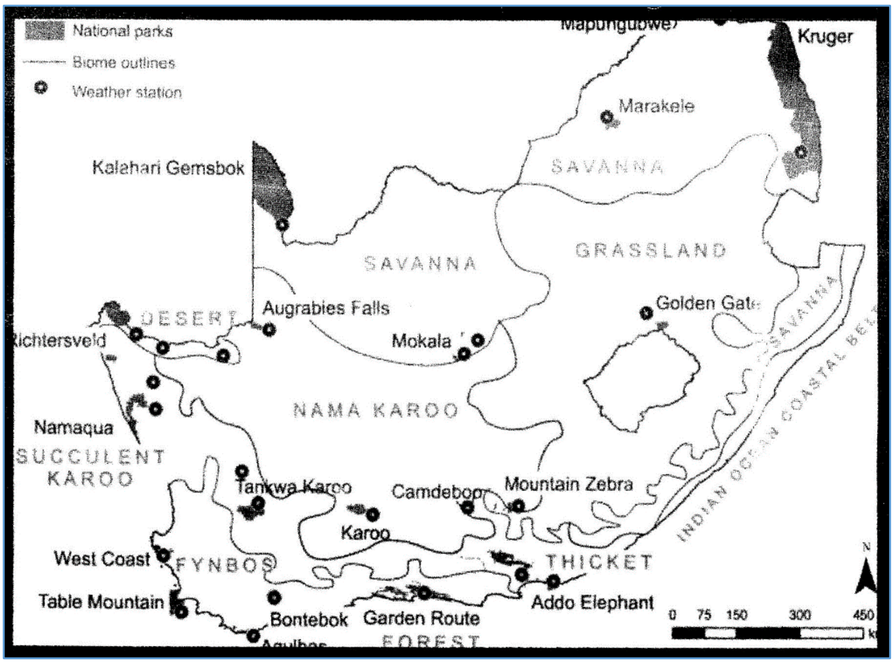
Six Major Biomes

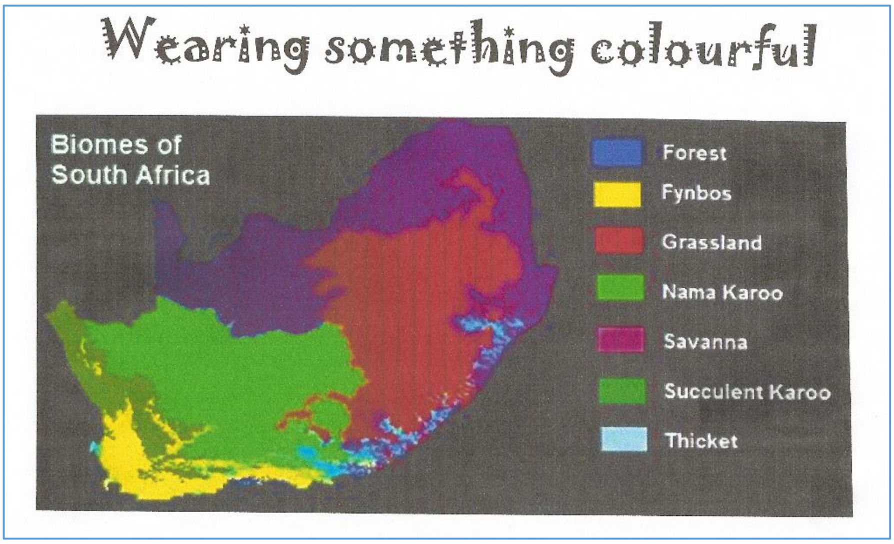
- Tropical Rain Forests
- Grassland
  - Tropical/Subtropical Grassland
  - Temperate Grassland
- Desert
- Temperate
  - Temperate Deciduous Forest
  - Temperate Rain Forest
- Taiga

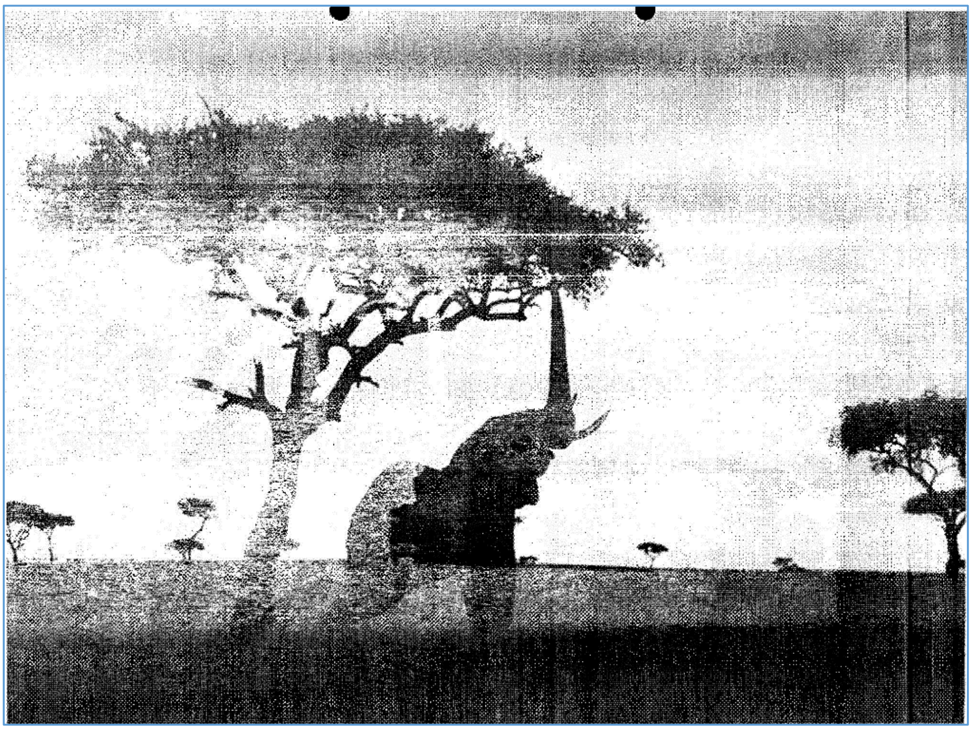
South-African Biomes

- There are eight major terrestrial biomes in South Africa:

- Nama Karoo,
- Succulent Karoo,
- Fynbos,
- Forest,
- Thicket,
- Savanna,
- Grassland, and,
- Desert.


National parks
Biome outlines
Weather station
Mapungubwe
Kruger
Marakele
SAVANNA
Kalahari Gemsbok
SAVANNA
GRASSLAND
Augrabies Falls
DESERT
Richtersveld
Mokala
Golden Gate
SAVANNA
NAMA KAROO
INDIAN OCEAN COASTAL BELT
Namaqua
SUCCULENT KAROO
Tankwa Karoo
Camdeboo
Mountain Zebra
Karoo
West Coast
FYNBOS
THICKET
Table Mountain
Bontebok
Garden Route
Addo Elephant
FOREST
0 75 150 300 450

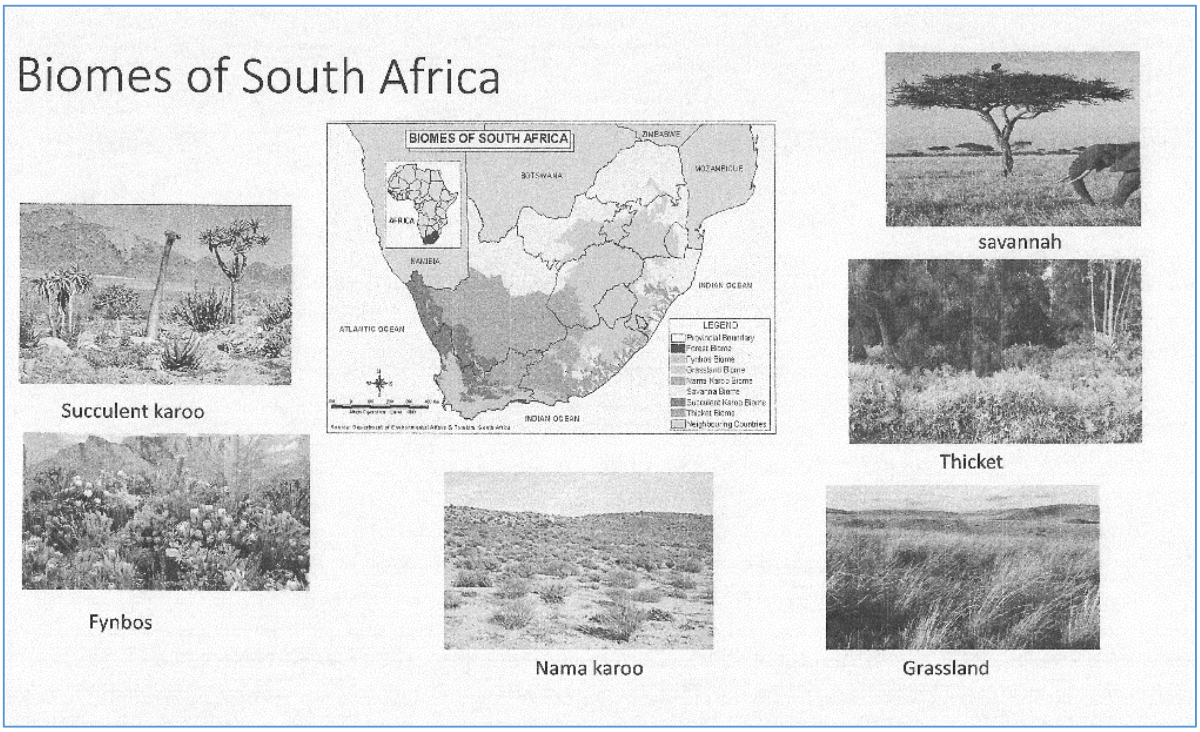

Wearing something colourful
Biomes of South Africa
Forest
Fynbos
Grassland
Nama Karoo
Savanna
Succulent Karoo
Thicket



Why am I so important?

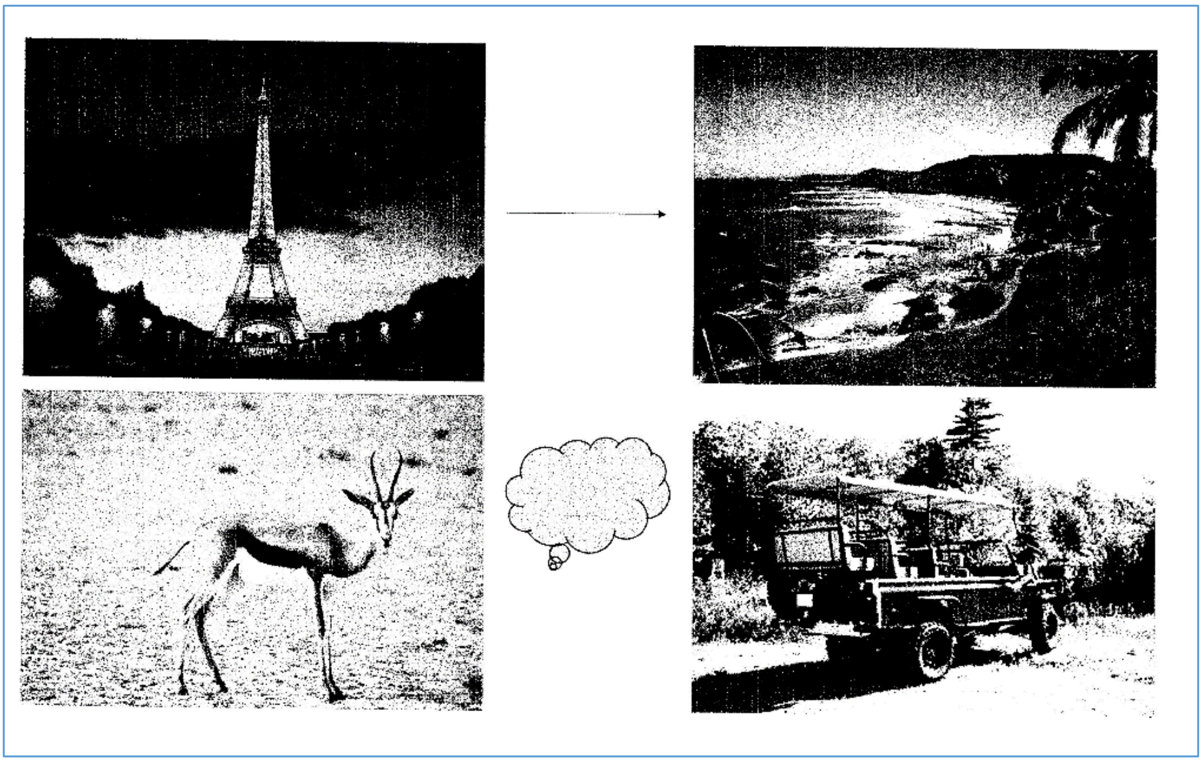
Importance of Biomes:

We share the world with many other species of plants and animals, we must consider the of plants and animals, we must consider the consequences of our actions. Over the past several decades, increasing human activity has rapidly destroyed or polluted many ecological habitats throughout the word.



Holiday!!

- Miss. and friends is going on their annual holiday (Vacmetion)
- Form a group of 6
- Please help Ms. and friend choose the best holiday destination for this time of the year



Craig's PowerPoint presentation

So many deserts

Deforestation

- Is the permanent destruction of natural, indigenous trees and bushes by fellling or burning in order to clear an area for other purposes

Causes of Deforestation

- Urbanisation – Increase in human settlements
- Agriculture – Space needed for farming
- Wood for fuel – For firewood or fossil fuel
- Timber – for furniture, paper and building materials
- Mineral mining – Cleared space for mining
- Traditional medicines – Barks and roots

Effects of Deforestation

- Soil Erosion and Degradation - soil erosion leads to infertile soil
- Floods – No absorption of water by trees
- Loss of Biodiversity – Animal habits destroyed therefore animal will either migrate or become extinct

Disruption of water cycle

- With no trees to absorb water
- The water will not be absorbed so that it can be transpired
- Therefore no evapouration – no condensation – no transpiration leading to an increase in temperature

Shafiek's PowerPoint presentation

HISTORY OF CLASSIFICATIONS

- Carl Linneous, a Swedish scientist, classified all living things based on shared features ,Categorizing Them in two kingdoms- **PLANTS AND ANIMALS**
- He introduced a binomial system, which is a two part naming system- Each organism has 2 names: a generic and a specific name

  EG: Humans - Homo sapiens, Lions - Pantheroleo
- The **FIRST NAME** is the **GENUS** (group to which the organism belongs to)
- The **SECOND NAME** is the **SPECIES** (SPECIFIC NAME-kind of organism)
- He used the system with 7 groups/ taxa to show that some organisms shared similar **PHYSICAL CHARACTERISTICS**

THERE ARE 7 TAXA:

1. **KINGDOM** – to which the organism belongs to and divided into phylum

Eg: MONERA, PROTISTA, FUNGI, PLANTAE, ANAMALIA

2. **PHYLUM/DIVISION** – organism that **share basic characteristics** and divided into class (for example: whether the animal is a vertebrate or not)
3. **CLASS** – lays eggs or gives birth to live young, divided into orders

Eg: MAMMAL, FISH, REPTILE, BIRD, AMPHIBIAN

4. **ORDER** – What they eat: Carnivore/ Primate (omnivores with thumbs). Can be ectotherms/endotherms, have body hair and produce milk for their offspring and divided into families

5. **FAMILY – Word ends in AE**

Eg: cats belong to fildae, dogs belong to canidae, humans to hominidae and it is divided into genus

6. **GENUS – The group to which the organism belongs**

Eg: domestic cats have a genus called felidae, wild cats have a genus called panthera and humans have a genus called homo and it is divided into species

7. **SPECIES – Specific name**

Eg: cats (domesticus), humans (sapien)and lions (leo)

EXAMPLE: HUMAN BEINGS

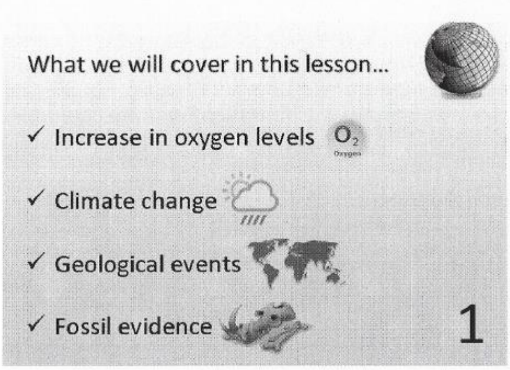
- KINGDOM – **ANIMALIA**
- PHYLUM – **CHORDATA**
- CLASS – **MAMMALIA**
- ORDER – **PRIMATE**
- FAMILY – **HOMONOIDAE**
- GENUS – **HOMO**
- SPECIES - **SAPIENS**

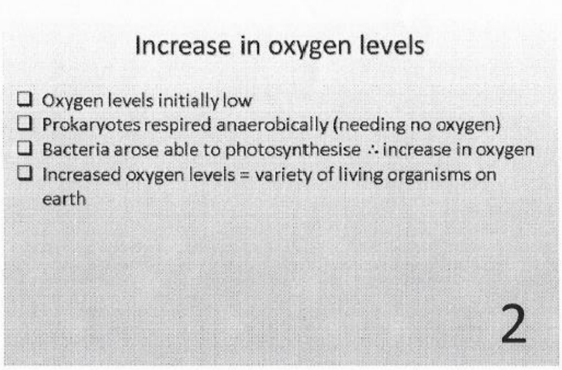
Remember it like this:

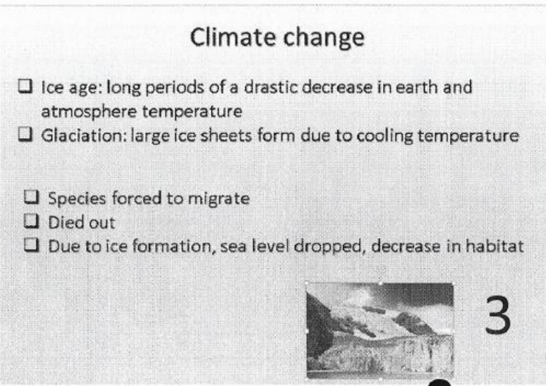
King Phillip Crossed over For Gold & Silver

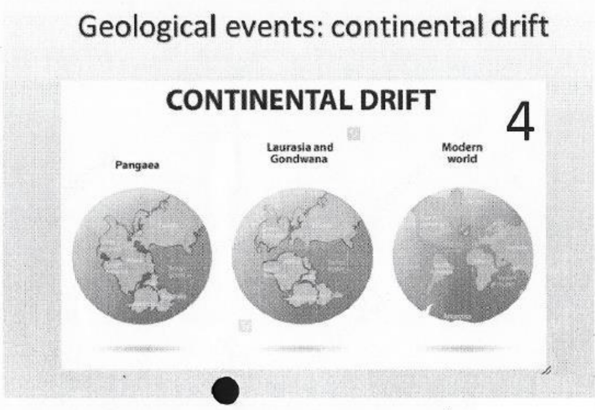
King Phuma Came Over For Gogo's Stew

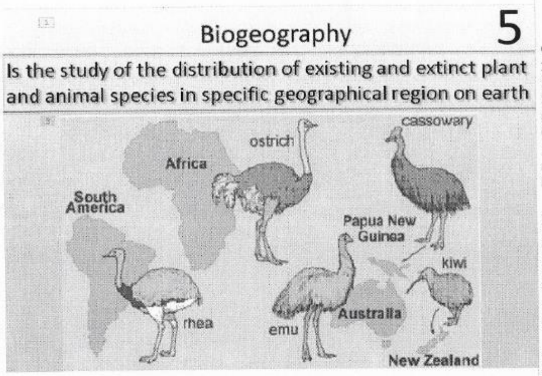
Jennifer's PowerPoint presentation

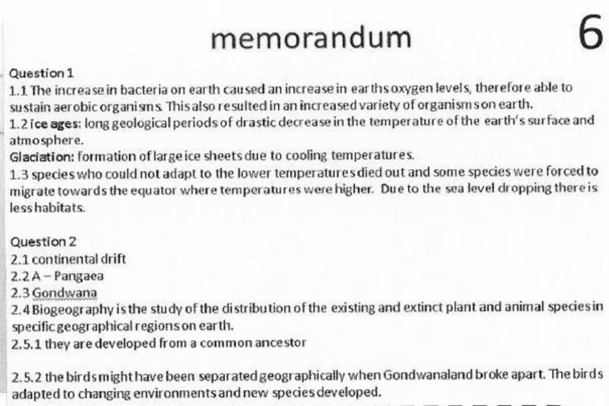


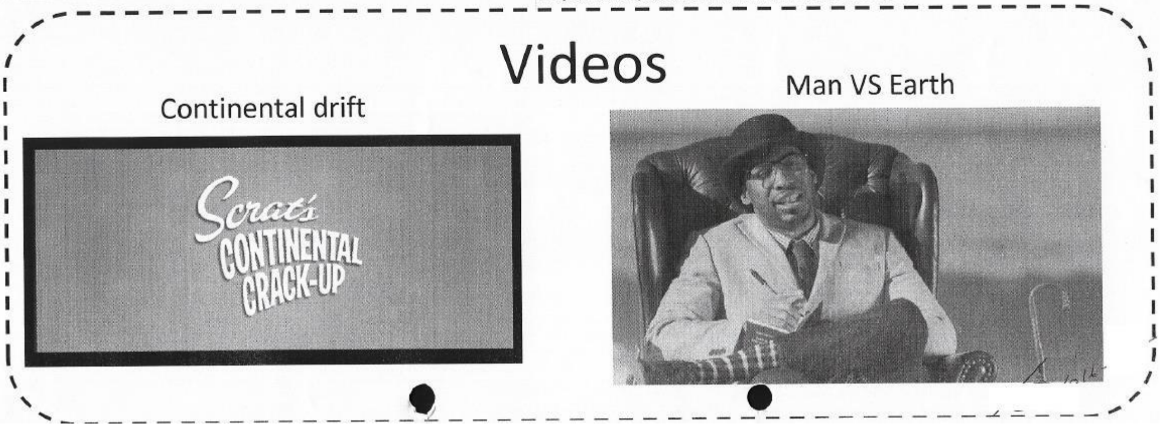




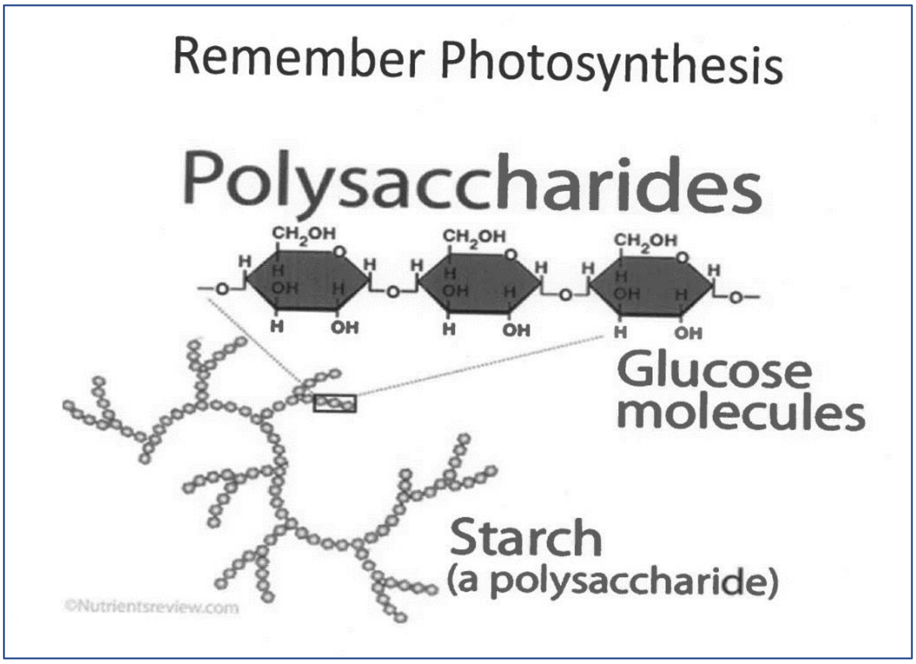


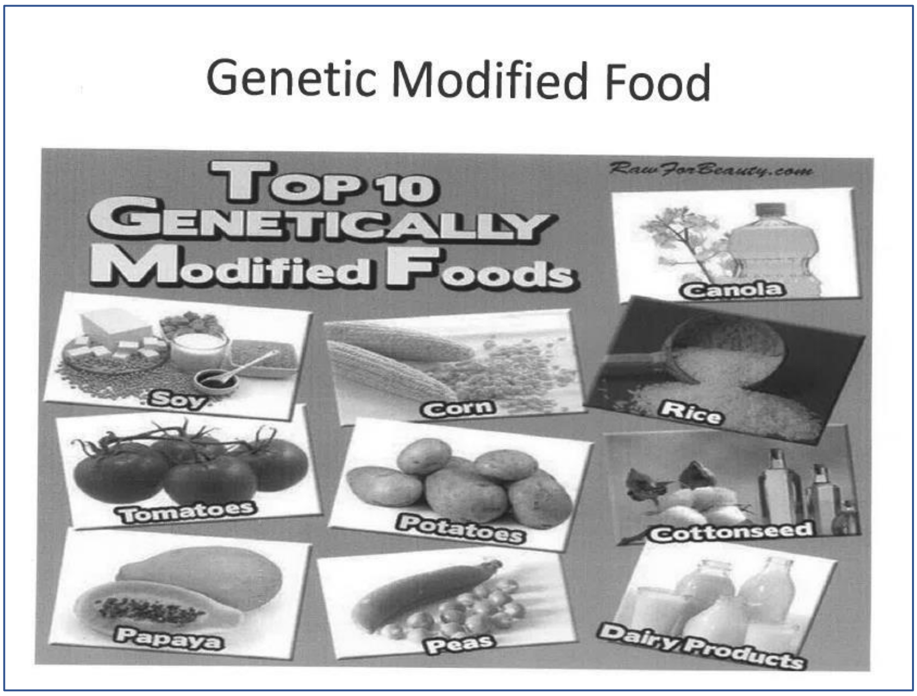






Elvin's PowerPoint presentation

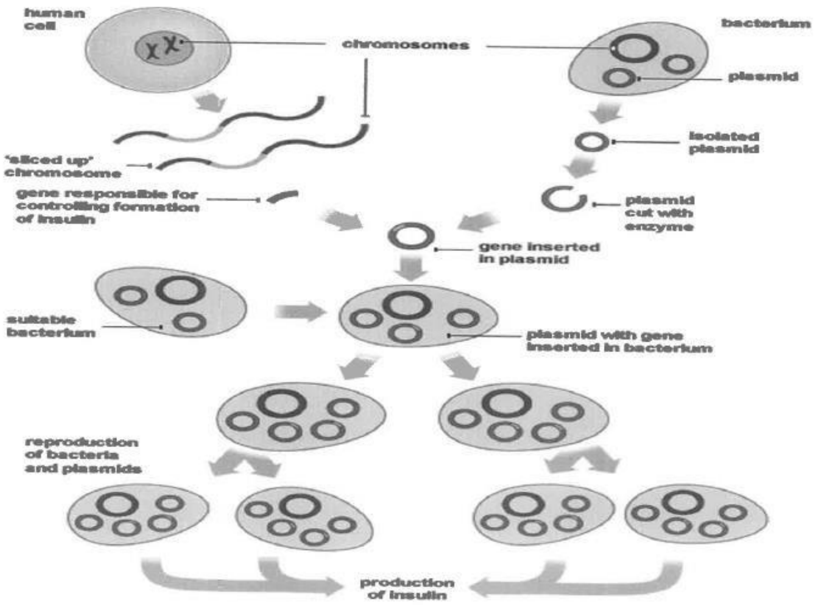




Impact on Gene pool

- Most Modern foods originate from selective breeding
- Improves growth, disease resistant to climate conditions
- The downside of selective breeding is that a mutation can occur can the animal or plant could die because of changing environments

Genetic engineering



GM Right or wrong

Advantages

- Deliver great crops yields
- Often have high nutritional value
- Some crops are drought resistant
- Pest resistant
- Herbicide resistant
- Longer shelf life
- Disease resistant

Disadvantages

- Has an effect on other plants e.g. crops affecting weeds and creating super weeds which are resistant to herbicides
- High cost in production
- Ethical and religious veiws

Victor's PowerPoint presentation

Important terminology

- **Hypothesis**

Is a prediction of physical phenomena, which can be tested by observations or experiment

- **Theory**

Is an explanation of a group of physical phenomena. Firmly founded on observations and experiment, which continues on to be investigated

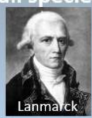
- Evolution

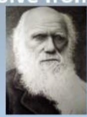
Evolution is to unroll, to disclose, to develop, to unravel, to change

---

- The theory of evolution states that all species of living things that exist today (and many more which are now extinct) have evolved from simple life form which first developed more than 3 billion years ago.

- **Two theorists Lamarck & Darwin they agree on one thing that "all species evolve from older species"**



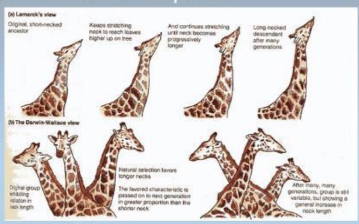


- **Lanmarck (law of use & disuse, inheritance of acquired characteristics).**

- if organisms use a structure often, it becomes bigger/grows.

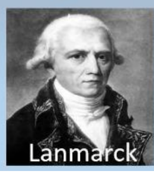
If they don't use it at all, it becomes smaller and may disappear. He called this the "law of use and disuse"

The offspring of organisms inherit the characteristics their parents acquired during their lifetime. Lanmarck called this the "inheritance of acquired characteristics".



Lanmarck theory was rejected why?

- Organisms cannot change/ adapt because they want to- the environment determines any changes.
- There is no sufficient evidence to prove that change/ modifications occurring in the lifetime of an organism is passed on to further generations.



Key words

- Many offspring
- Variation
- Competition
- Survival of the fittest
- Natural selection
- Population changes over several generation

Sipho's PowerPoint presentation

ENERGY FLOW IN ECOSYSTEMS

ENVIRONMENTAL STUDIES

WHAT IS ENERGY?

What is Energy

- The ability to do work or cause a change is called energy.
- When an organism does work some of its energy is transferred to that object.

ENERGY in an ecosystem

- All living organisms need energy
- Sunlight – main source of energy
- Photosynthesis

FEEDING RELATIONSHIPS

- Organisms classified according to what they eat
- Producers/consumers
- Producers → basis of food chain – independent of other organisms
- Consumers – dependent on other organisms

PRODUCERS

- Photosynthesizing organisms
- Plants that change light energy from the sun into food
- Photosynthesis
- Example – green plants

CONSUMERS

- Organisms that depend on other organisms for food
- Herbivores – dependent on plants (vegetarians)
- Example – cows/sheep

CONSUMERS

- Carnivores – dependent on other animals

- Three types of carnivores:
- Predators – kill other animals to feed on them
  - example: lion/leopard
- Scavengers – feed on dead animals
  - vultures/hyenas
- Insectivores – feed on insects and vertebrates only
  - many amphibians and reptiles

CONSUMERS

- Omnivores – feed on both plants and animals

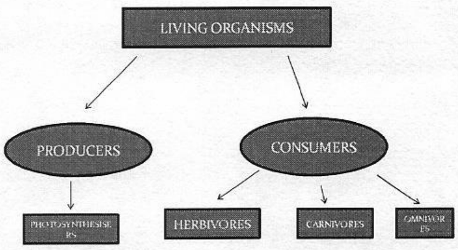
- Example – humans and baboons

DECOMPOSERS

- Break down dead organisms

- Recycle important nutrients in the environment

- Example – bacteria, fungi and earthworms



FOOD CHAINS

SUN ⟶ GRASS ⟶ RABBIT ⟶ EAGLE

- Describes a group of organisms where each member of the group is dependent on other members for survival

- Each organism in the food chain belongs to a trophic level

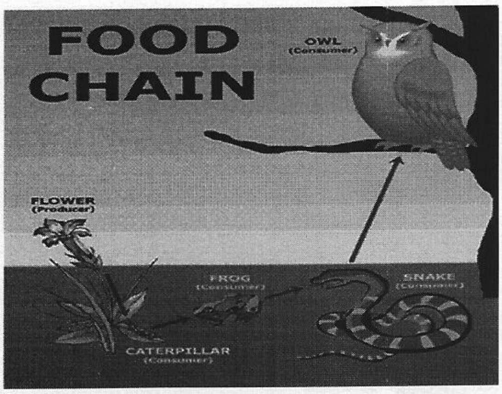
- The arrows mean 'is eaten by'

- Arrows also indicate the energy transfer between organisms

REMEMBER...

Energy flows through an ecosystem in <u>one</u> direction from producers to various levels of consumers

12



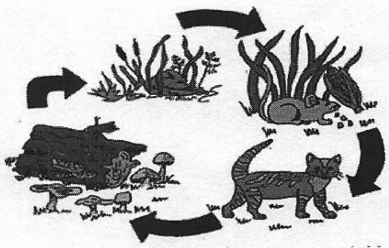
EXERCISE

- Identify 3 reasons why organisms need energy?
- Where does the energy for most ecosystems originate, and how is this energy converted into the energy in food?
- Describe the basic movement of energy through an ecosystem?

EXERCISE CONTINUED

COLUMN A	COLUMN B
1. GOAT	a. Producer
2. GRASS	b. Scavenger
3. LEOPARD	c. Herbivore
4. VULTURE	d. Predator

Name the Producer, Consumers & Decomposers in this food chain:



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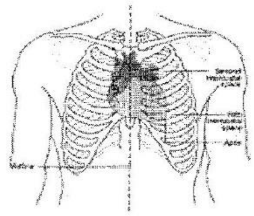
Freda's PowerPoint Presentation

External structure of the heart

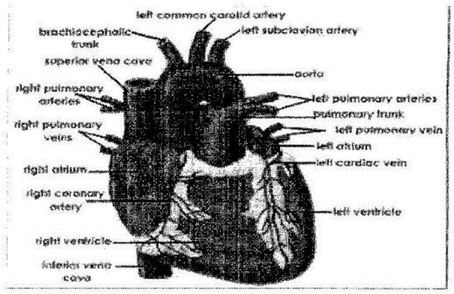
Position of heart



Video

- https://www.youtube.com/watch?v=ESFPSHCDDZU

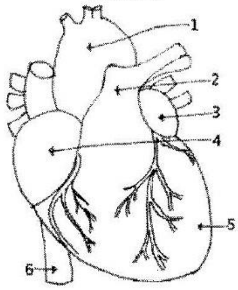
External structure of the heart



Activity

- ***Questions based on video***
- What are the only arteries in the heart that carries deoxygenated blood
- Where does the blood moves to for oxygenated blood
- Through what does the oxygenated return to the heart
- The heart is covered by a strong double membrane known as?

Label the external structure of the heart



Answers

- 1-aorta
- 2-pulmonary drunk
- 3-left atrium
- 4-right atrium
- 5-left ventricle
- 6-inferior vena cava

Answers based on video

- Pulmonary artery
- The lungs
- Right and left pulmonary veins
- pericardium

Alex's PowerPoint presentation

Appendix C: Consent form

Faculty of Education Ethics informed consent form

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Category of Participants (tick as appropriate):

Principals		*Student teachers*		*Parents*		*Lecturers*		*Students*	**x**
Other (specify)									

You are kindly invited to participate in a research study being conducted by **D Fagan** from the University of the Western Cape. The findings of this study will contribute towards (tick as appropriate):

An undergraduate project		*A conference paper*	
An Honours project		*A published journal article*	
A Masters/Doctoral thesis	**x**	*A published report*	

Selection criteria

You were selected as a possible participant in this study because you meet the following criteria (give reason why candidate has been chosen):

- 4th year student
- Physical Science or Life Science subject major
- Teaching practice at disadvantaged schools in the Western Cape

The information below gives details about the study to help you decide whether you would want to participate.

Title of the research:

Using ICTs to facilitate epistemological access in science with teacher education students.

A brief explanation of what the research involves:

Consent form

This study aims to investigate the role presented by ICTs as a pedagogical resource used by student teachers to facilitate epistemological access in science subjects in disadvantaged schools in the Western Cape, South Africa. The focus will be on observing pedagogical practices while teaching.

Procedures

If you volunteer to participate in this study, you will be asked to do the following things: (The researcher must complete the section below. For example: 'Each research participant will be interviewed by the researcher or his/her assistants or collaborators [provide names of interviewers]. Briefly explain how many interviews, the duration of the interviews, place, date, etc.)

Two classroom sessions will be observed and recorded by the researcher during your teaching practice session. I will also require the lesson plans for the particular class session, as well as a copy of the course/subject outlines. The date and time will be negotiated based on your teaching schedule.

Potential risks, discomforts or inconveniences

(Researcher please briefly describe any foreseeable risks, discomforts or inconveniences likely to affect research participants)

I do not foresee any discomforts, however you have the right to withdraw at any time should you no longer wish to participate in the study.

You are invited to contact the researchers should you have any questions about the research before or during the study. You will be free to withdraw your participation at any time without having to give a reason.

Kindly complete the table below before participating in the research.

Statement	Tick the appropriate column Yes	No
1. I understand the purpose of the research.		
2. I understand what the research requires of me.		
3. I volunteer to take part in the research.		
4. I know that I can withdraw at any time.		
5. I understand that there will not be any form of discrimination against me as a result of my participation or non-participation.		
6. Comment:		

Please sign the consent form. You will be given a copy of this form on request.

Signature of participant	Date

Researchers

	Name:	Surname:	Contact details:
1.	Dominique	Fagan	xxx xxx xxxx
2.			
3.			

Contact person: D Fagan	
Contact number: xxx xxx xxxx	Email: xxxxxxxxx@xxxxxxxxx

Appendix D: Ethics letter to respondents

Dominique Fagan
(PhD Candidate)
Research Unit: Literacy development and poverty
FACULTY OF EDUCATION
MOWBRAY CAMPUS
P O Box 652, CAPE TOWN, 8000
Highbury Road, MOWBRAY, 7700
Tel: +27 xxx xxx xxxx
Email: xxxxxx@xxxx.ac.za

Consent letter to Participants

Dear Participant

I am a PhD Candidate in Literacy Development and Poverty in the Faculty of Education at the University of the Western Cape. I am currently engaged in a research project on school and community issues around literacy and poverty. I also want to investigate the role presented by ICTs as a pedagogical resource used by student teachers to facilitate epistemological access in science subjects in disadvantaged schools in the Western Cape, South Africa. My research focus is on observing student teachers' pedagogical practices while teaching.

I humbly request your assistance as a participant in this project. I have received approval from the Western Cape Education Department and the Ethics Committee in the Faculty of Education for this research project.

If you agree to participate in this research project you will:

- Sign a consent form to participate in the research;
- Allow yourself to be observed during two classroom sessions; Be prepared to be video-recorded for data collection purposes; and
- You will receive the transcripts to peruse before it is analysed.

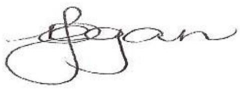
All the information you provide will be strictly confidential and no names will be revealed, i.e. all participants will remain anonymous. Please bear in mind that you may, at any time during this research, withdraw and stop participating in the study. All information provided will be used solely for research purposes and that anonymity of all is guaranteed.

If you would like to know more about this research project, please feel free to contact me, Dominique Fagan on 021 xxx xxxx.

I envisage that the research will contribute significantly to literacy development in poor communities.

I trust that you will consider my request favourably. Thanking you in anticipation.

Yours in education



D Fagan

Consent form:

I, ………………………………………………………………………………………………….., hereby consent to participate in the research project, Literacy Development and Poverty.

Date: ………………………………

Appendix E: Transcripts

<u>School 1: Monica (Biomes)</u>

<u>Teacher</u>: And looking forward to to a holiday? Yes, yes, yes, yes I'm thinking Paris. Yes friend, ah lovely. Yah, biomes. Oh oh okay, oh yes. You know what? I have an excellent grade ten class here and ah ah ah they will help you find out about biomes is and and the different biomes in South Africa. But I thought we were going to Paris? Yes friend, no, no, no indeed, indeed okay friend. Okay no, you know what? Let me let me ah ah ah put my holiday gear on snap, yes friend, okay will see you soon. Bye. Okay, no no, you know what we'll talk soon. You know my class is so excellent, ah ah ah they will they will they will have me, uhm they will get information instantly. Ten B, mm smart, mm clever, mm lovely uh-m uhm. Okay friend, let me on sleep now and start teaching. Ah ah I will call you. Okay bye friend. A,a,a,a, I'm not going on holiday anytime soon, my friend talked about animals and and and plants so let me let me put these on sleep and uh, uh, uh you guys are going to help me find out what uh, uh, uh biomes are. The different biomes uhm and so we will be continuing on, on please watch the PowerPoint slide presentation. Uhm these uhm are the world's biomes, not only do we have biomes in South Africa but we have biomes all over the world. South Africa is merely like, it's almost like we zoomed in on the the world.

Biomes are regions of the world, it's similar physical environments, uhm factors that uhm uhm uhm influence bio uhm uhm that determines and that, dis…where it can distinguish, what or which kind of biome you are dealing with are the rainfall, you also know its precipitation, ah temperature, altitude, latitude, that's how high you are above sea level and how low uhm and then the boundaries of the biomes normally are uhm uhm distinct, meaning they is, it's unlimited. There's no limit to it, it can actually be as large as uhm South Africa. There are six major biomes in the world, that's a tropical rainforest, the grassland which includes the tropical and sub-tropical grassland and a temperate grassland and then we have the desert, we have the the temperate which is temperate temperate deciduous which includes the temperate deciduous uhm forest and the temperate rainforest uhm and I am so, right now I'm kinda looking forward to my holiday uhm because you guys, you you you know these kind of things right?

Transcripts pages 294 – 403 omitted

Appendix F: Declaration of editing

DECLARATION OF LANGUAGE EDITING of a

A thesis submitted in fulfilment of the requirements for the degree

of Doctor of Philosophy **entitled**

Using ICTs as a pedagogical resource to facilitate epistemological access in science with teacher education students

submitted by **Dominique Fagan - 2019**

Faculty of Education - University of Western Cape

Supervisor: Professor Rajendra Chetty

has been subjected to an English language edit by

Dr Barbara Basel

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MA Potchefstroom University,
BA UNISA
Member of the Council of English Academy of Southern Africa
Associate Member Professional Editors' Guild
Lecturer in English Literature, Linguistics, Communication and Business English for 10 years at Pearson Institute for Higher Education (previously Midrand Graduate Institute), Cape Town Campus.
Academic Editing – MBA Theses, MEd Theses, MPM Theses, Master in Graphic Design Thesis, External Examiner for MEd Thesis.

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Barbara Basel

21 September 2019