An exploratory analysis of pedagogical practices in science classrooms: a case study

By

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Declaration

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An exploratory analysis of pedagogical practices in science classrooms.
I declare that the above thesis is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

SIGNATURE DATE

UNIVERSITY OF SOUTH AFRICA

Key terms:

National Curriculum Statements (NCS), Curriculum and Assessment Policy Statements (CAPS), Teaching, Learning, Pedagogy, Cooperative learning, Learner-centred approach, Teacher-centred approach, Science, Learner.

Abstract

This study sought to explore the pedagogical practices of teachers in science classrooms. In this study, pedagogical practices are taken as interactions between teachers, learners and learning tasks which aim to promote and facilitate learning of their learners

The study adopted an exploratory sequential mixed-methods design to collect both quantitative and qualitative data from the senior phase (i.e. grades 7-9) Science teachers. The teachers were purposively selected; two from rural schools and two from urban schools in the Limpopo Province of South Africa. Data on teachers' pedagogical practices were collected using survey questionnaire, focus group interview and lesson observation.

The main research question for the study is "what are teachers' pedagogical practices when teaching science?" This overriding research question was addressed by exploring the specific research questions: 1) how do science teachers teach their lessons? And 2) what informs teachers' pedagogical practice when teaching science?

The null hypothesis for this study was "there is no significant difference between teachers' qualification and their pedagogical practice when teaching science" while the alternative hypothesis was "there is significant difference between teachers' qualification and their pedagogical practice when teaching science".

The quantitative data collected by means of structured questionnaires was analysed using a computer package (i.e. SPSS version 22) while the qualitative data collected by means of focus group interviews and lesson observation was analysed using content and thematic analysis.

The findings from the study revealed that teachers in the study incorporate in varying degrees learner – centred; and teacher- centred pedagogies in their science lessons. Whilst majority of the teachers in the study expressed a behaviouristic view of learning, which indicates a predisposition to teacher – centred pedagogy in the classroom; however, other pedagogical practices indicated by the teachers and observed in the science lessons are consistent with constructivist or learner – centred pedagogy which

suggests strategies that may be used to provide a meaningful learning experience in science.

The study further found that there is a significant association between the educational qualification and their pedagogical practice when teaching science in the visited schools; therefore the alternative hypothesis is accepted and the null hypothesis is rejected.

Based on the findings of the study, the following recommendations are made:

i. In service training on subject content knowledge for natural science teachers, especially those without science qualifications so that they can grapple with the subject content knowledge.
ii. Science workshops to be organized from time to time to train teachers on effective teaching practices in the classroom.
iii. Outsourcing or involving more than one teacher in the teaching of natural science in schools.
iv. Equipping of schools with science laboratories so that teachers can carry out science experiments with learners.
v. The schools must ensure that only teachers with science qualifications are assigned to teach natural sciences in the senior phase.

Dedication

This thesis is dedicated in memory of my late parents Mr. Pius Nwosu (1931 – 2001) and Mrs. Josephine Nwosu (1933 – 2008). May their gentle souls continue to rest in peace.

Acknowledgements

The completion of this thesis has been a dream come true. I return all the glory to God almighty for keeping and sustaining me as it was by his grace that this work was completed. God has been with me throughout this journey and I can only say thank you Lord for your grace and mercies.

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CHAPTER ONE

INTRODUCTION

1.1 Introducing the study

In South Africa, the current Curriculum and Assessment Policy Statements (CAPS) advocates for a constructivist and a leaner-centred approach to the teaching of science (DoE, 2011). The South African Department of Basic Education (DBE) asserts that the teaching of science should be carried out through learner-centred approach and the application of scientific models, theories and laws in order to explain and predict events in the physical environment. However, critical analysis of public education has shown that irrespective of which subject or grade that one chooses to assess, most South African learners do not possess the depth of knowledge or skills they should be acquiring at school (Spaull, 2013). Indicators such as high dropout rates, low skills and knowledge levels among learners, low levels of learner engagement in school work and poor performance of learners in international bench mark tests are testament to poor state of teaching and learning in South African schools (Fleisch, 2008, Oludipe & Oludipe, 2010, Spaull 2013). The afore-mentioned learning inadequacies make a case for a paradigm shift in teaching and learning approaches in South African schools. This is in view of the fact that the performance of learners or quality of teaching the learners receive depends to a large extent on the teaching strategy adopted by teachers (Mnguni, 2013, OECD, 2005, Spaull, 2013).

From a constructivist perspective which underpins this study, the primary role of a teacher is to create and maintain an exciting collaborative learning environment where learners are allowed to construct and build upon their existing knowledge (Alt, 2015, Ibraheem & John, 2013, Ndon, 2011). As described by Alt (2015: 54) “a constructivist learning environment is characterized by shared knowledge among teachers and learners, shared authority and responsibility among teachers and learners and small heterogeneous grouping of learners for collaborative learning purposes with the teacher as a guide or facilitator”.

Following this argument, Weimer (2012) proposed five features of teaching that make it learner-centred:

i. engages learners actively in the learning process,

ii. includes explicit skill instruction,

iii. encourages learners to reflect on what they are learning and how they are learning it,

iv. motivates learners by giving them some control over learning process and;

v. Encourages collaboration amongst learners in the learning process.

These features place the learner at the center of the teaching and learning process, and the teacher as the facilitator of learning rather than the narrow concept of instructor.

As indicated in the CAPS policy document, the natural sciences learning area aim to promote scientific literacy which is to be achieved through the development and use of science process skills in a variety of settings, the development and application of scientific knowledge and understanding; and the appreciation of the relationships and responsibilities between science, society and the environment (DoE, 2002a). However, realizing the purpose of natural sciences curriculum in the South African schools; especially in the GET band i.e. grades 0 - 9; remains a challenge as learners in the GET band are performing poorly in science (LDBE, 2011, Prinsloo et al., 2018, TIMSS, 2007). For instance, in the maiden TIMSS 1999 and 2003 studies, South African learners scored the lowest in science when compared to scores of learners from other participating countries. A remarkable feature is that in both years of participation in the TIMSS study, South African learners had a mean science score of 244 out of a maximum 800 (TIMSS, 1999). Whilst there was a slight improvement in the grade 09 natural sciences TIMSS 2011 scores, South African learners' performance was ranked the worst of all middle income countries that took part in the study (Spaull, 2013).

The national science study in 2009 that evaluated the performance of grade 09 learners in natural sciences indicated that learners under performed with a mean score of 21.4% (LDBE, 2011). Similarly, the 2011 provincial study by Limpopo department of education revealed that grade 09 learners underperformed in natural sciences with a mean score of 21.7%. A disturbing finding in the study is that the percentage of grade 09 learners who attained acceptable levels (>50%) in natural sciences was 1.89% (LDBE, 2011).

Some of the factors identified as contributing to the poor performance of learners in science include amongst others; ineffective teaching methods adopted by teachers, inadequate communication ability of teachers and learners in the language of instruction, large classes, disruption in class content coverage, lack of opportunities for professional development for science teachers, lack of infrastructure and teaching materials, lack of professionally qualified teachers, inadequate mastery of subject content by some teachers, and poor school safety (Aluko, 2008, Mokiwa, 2017, Mudau, 2013, Muraya & Kimamo, 2011, TIMSS, 2011).

Following the research findings above, the researcher contends that there is a mind-set amongst learners that science is a difficult subject to pass. This negative perception impacts on their self confidence in the subject, making them not to try hard enough in science tasks, hence poor performance.

On teaching approaches, some studies (see for example, Dudu, 2014, Bantwini, 2010, Lombard, 2015; Mokiwa, 2014a; Mokiwa, 2014b) claim that several teaching approaches can be used to realize the objectives of science learning, however traditional teaching strategy still dominate in South African schools. According to Dudu (2014) and Choudhury (2011), traditional teaching method is largely teacher centred with the teacher hogging the lime light, and lectures at length on particular topics in front of passive learners who listen with rapt attention. This is to say in a traditional teaching approach, classroom tends to resemble a one-man show with a captive but often comatose audience; classes are driven by "teacher talk" and depend heavily on textbooks for the structure of the course.

The prevailing idea is that there is a fixed world of knowledge with information which learners must know and this information is divided into parts and built into a whole concept. Furthermore, in a traditional teaching setting, teachers serve as pipelines and seek to transfer their thoughts and meaning to passive learners. There is little room for learner initiated questions, independent thought or interaction between learners; and the goal of the learner is to regurgitate the accepted explanations espoused by the teacher.

Critics of traditional teaching strategy argue that it is ineffective pedagogic approach as it relies on transmission of knowledge, recall, repetition, recitation, copying from the board, choral response and exposes learners to rote learning and memorization of facts and concepts without understanding or relating to their real life or prior knowledge (Lombard, 2015, Moloi et al., 2008). Zhao (2003) argues that traditional teaching method is out dated as it can hinder the development of individual learner's active and creative abilities and learners who experience only this model of education may no longer be considered ideal for the needs of a future educated citizenry.

The researcher contends that teachers should adopt teaching strategies that maximize opportunities for active and meaningful learning so that learners are able to apply the knowledge they acquire in school to variety of situations they encounter in their lives. For teachers to make a paradigm shift from traditional to learner centred approach, they would require to familiarize with various teaching strategies, including constructivist approaches as stipulated in the CAPS document.

The need to improve the quality of teaching and learning of natural sciences in the GET band has necessitated this study which seeks to explore alternative, viable and effective teaching strategies for natural sciences. Therefore, this study seeks to explore teachers' understanding of methods relevant to teaching science topics. Specifically, the study aims to explore the different methods teachers currently use in science teaching with the aim to develop a framework within which different methods can be integrated for a viable teaching strategy. It is also envisaged that findings from the study would provide insights on teachers' knowledge and understanding of different approaches to teaching and learning that may indicate what interventions can be appropriate in different contexts.

Furthermore, it would help science teachers especially those that teach in the GET band to make informed decisions on effective teaching strategies that can be used to improve the performance of learners in science in their different teaching and learning environments.

1.2 Rationale

The rationale for this research study emanates from my personal experience as a science teacher and contextual based evidence. I have been teaching science in South Africa for the past 10 years. Over the years I had an opportunity to interact with science teachers and I noticed that some have been teaching the subject for many years but they were not professionally qualified. In the South African context, a qualified teacher must have a minimum of matric certificate plus a teaching qualification i.e. a diploma or a degree.

With regards to science teaching, I noticed that some teachers believe in drill work and memorization of past examinations memoranda as an ideal way to learn science concepts. I argued that such views and practice are ineffective ways of teaching and learning as learners may be relying on just memorization in order to pass their examination and get promoted to the next grade without really understanding the learning content. Furthermore, science incorporates many abstract terms and concepts which must be understood for a meaningful learning to take place and relying on drill work may be ineffective as learners may not be able to apply knowledge in different situations especially when faced with higher cognitive tasks.

The contextual reasons are related to learners' poor participation and performance in science. In South Africa, the poor performance of science learners in the National Senior Certificate (NSC) examination can be directly linked to shortage of qualified science teachers (Grayson & Kriek, 2009). Most teachers are products of poor education practice under the Bantu Education Act, which rarely considered Science as a necessity for black South Africans (Muwanga-Zake, 2004).

1.3 Context of the study

The current study was carried out in Limpopo which is one of the 9 provinces of South Africa. The province is situated at the North Eastern region of South Africa and shares borders with Botswana, Zimbabwe and Mozambique. The province is predominantly rural and the basic education is run by Limpopo Department of Education which consists of five districts: Capricorn, Mogalakwena, Sekhukhune, Waterberg and

Vhembe. The Limpopo Department of Education runs seven Further Education and Training (FET) colleges and approximately 4015 public ordinary schools, accommodating over 1400 000 learners (LDBE, 2011). The provincial head office is located in Polokwane and consists of 4 branches headed by Senior General Managers, 12 Chief Directorates headed by General Managers and 33 Directorates headed by Senior Managers and FET colleges headed by CEO's (Senior Managers).

The current study explored science teachers' pedagogical practices in the classroom. The teachers in the study all teach natural sciences in public schools in Sekhukhune district. The schools are predominantly rural, located in the same geographical area, and cater for learners from low socio-economic backgrounds.

1.4 Statement of problem

Policy initiatives in South Africa are focusing on teaching science to make learners aware of their environment and to equip them with investigating skills relating to physical and chemical phenomena. The current Curriculum and Assessment Policy Statements (CAPS) which is a single, comprehensive policy document that replaced the subject learning areas statements, Learning Programme Guidelines and Subject Assessment Guidelines for all subjects listed in the National Curriculum Statement (NCS), contains the prescribed content to be taught per subject per grade from Grades R to 12 (DBE, 2011b).

Both documents i.e. NCS and CAPS advocate the use of learner-centered approach to teaching science. However, the current teaching does not reflect these changes as most teachers still teach science as a body of factual knowledge with emphasis on drill work, memorization of facts; with little or no connection to learners' daily lives and experiences. This pedagogical approach is ineffective, disempowering, and deprives learners of essential skills such as critical thinking, problem solving, communication and collaboration; which are important throughout life. Learning for understanding in science transcends drill work and require active, empowered, self-reflective and self-responsible learner who take initiative and play active role in the teaching and learning process.

However, the problem with the current science teaching is characterized by some teachers not engaging their learners in collaborative learning; where learners can work in small diverse ability groups to accomplish a learning task. Collaborative learning ensures active cognitive processing of information which equips learners with interpersonal skills which will help them in the society (Woolfolk, 2010). This is to say that effective teaching of science requires a learner- centred approach that ensures active participation and provides multiple opportunities for learners to acquire scientific knowledge and skills and be able to apply them in variety of contexts. Science plays an increasingly important role in the lives of South Africans as it impacts on scientific and technological development, and necessary for the country's economic growth and the social wellbeing of its people; It is therefore imperative that effective teaching and meaningful learning of science is promoted at the school level to ensure that learners are prepared for future scientific learning in different science fields. Hence this study seeks to explore teachers' pedagogical practices to gain insight on the methods used to teach science topics in the senior phase (Grades 7- 9)

1.4.1 Research questions

The primary research question for this study is "What are teachers' pedagogical practices when teaching science?"

I addressed this overriding research question by exploring the following specific research questions:

1. How do science teachers teach their lessons?
2. What informs teachers' pedagogical practice when teaching science?

1.5 Aims and objectives of the study

The main objective of the study is to explore the teachers' pedagogical practices in the teaching of science; whereas specific objectives are:

1. To explore the teaching of science lessons, and
2. To explore reasons behind teachers' pedagogical approaches.

1.6 Research hypothesis

Research questions are not the same as research hypotheses. According to Ary, Jacobs, Irvine and Walker (2018) research questions state what a researcher wants to learn whereas research hypothesis refers to the statement of the researchers' tentative answers to those questions. A hypothesis provides the researcher with the necessary guide or direction in searching for the solution to the problem under investigation. A null hypothesis is a hypothesis, which states that no difference or no relationship exists between two or more variables. It is a hypothesis of no effect or no difference (Ary et al., 2018). Thus, the hypotheses for this study are:

1. There is no significant difference between teachers' qualification and their pedagogical practice when teaching science.

On the contrary, alternative hypothesis was raised in case the null hypothesis was rejected or not confirmed. The alternative hypothesis is:

1. There is significant difference between teachers' qualification and their pedagogical practice when teaching science.

1.7 Significance of the study

Addressing the issue of poor standard of teaching and learning of science amongst others, requires an insight on teachers' perception of effective methods to teaching science; and how they enact the teaching of the subject in the classroom. The current study contributes to this effort as it explored pedagogical practices in the teaching of science. The study is significant in that it makes a case for a paradigm shift in teaching and learning approaches as it explores alternative, viable and effective teaching strategies in science. By exploring the different methods teachers currently use in science teaching, the study aims to develop a framework within which the different methods can be integrated for a viable teaching strategy. The findings of the study may be beneficial to the universities especially those that offer curriculum studies as it would help them to design courses on teaching methods that will be used to bring about a meaningful learning in the classroom. The study findings may be resourceful to the department of education as it would help them to make informed decisions when organizing in- service training and workshops for teachers on pedagogy. The school management may also benefit from the study findings as it would help them to devise teaching strategies that can be used to improve the performance of learners in science. The study findings may be of immense value to curriculum experts and teachers as it would help them to make informed decisions on effective teaching methods that can be used to improve the teaching and learning of science in schools. In addition, the study would contribute to the body of knowledge on teaching and learning of science.

1.8 Clarification of terms and concepts

The National Curriculum Statements (NCS) are guidelines that state what each learner should achieve in terms of learning outcomes and assessment standards by the end of each grade. In this study the term 'NCS for natural sciences' describes the curriculum for natural sciences as a subject that is taught in Grades 7 to 9.

Curriculum and Assessment Policy Statement (CAPS) is a single, comprehensive and concise policy document that replaced the subject learning areas statements, Learning Programme Guidelines and Subject Assessment Guidelines for all subjects listed in the National Curriculum Statement Grades R-12 (DBE, 2011b). CAPS contain the prescribed content to be taught per subject per grade from Grades R to 12 (DBE, 2011b).

Teaching

Teaching is the process of attending to learners' needs, experiences and feelings, and making specific interventions to help them learn particular things. Interventions commonly take the form of questioning, listening, giving information, explaining some phenomenon, demonstrating a skill or process, testing understanding and capacity, and facilitating learning activities (Smith, 2016).

Learning

The process through which experience causes permanent change in knowledge or behaviour (Woolfolk, 2010). Learning can also be defined as the process of gaining understanding that results in modification of attitudes and behaviors through acquisition of knowledge, skills and values through study and experience (De Houwer et al., 2013).

Pedagogy

A sustained process whereby somebody acquires new forms or develops existing forms of conduct, knowledge, practice; and criteria from somebody or something deemed to be appropriate provider or evaluator (Bernstein, 2000).

Cooperative learning

It refers to a teaching strategy in which learners engage in communal learning in group context to ensure that group members engage in joint learning and achieve group outcomes at the end of the cooperative learning lesson (Gawe, 2004). In cooperative instructional strategy, heterogeneous grouping, positive interdependence, and individual accountability are emphasized.

Leaner - centred approach

A pedagogical approach that shifts the role of the instructor from giver of information to facilitator of student learning. It situates the learner as the main character in the learning process who takes the initiative, controls the learning process and actively learns in a socially interactive way (Liu et al., 2010). In addition to active participation, learners must cooperatively negotiate other aspects of their study; and in this capacity must question, contribute, critique and involved in decision making (Morrison, 2009).

This pedagogical approach has many associated terms (e.g. constructivist, student – centred, participatory, active), and generally draws on learning theories suggesting that learners should play an active role in the learning process. Learners therefore use their prior knowledge and new experiences to create knowledge. The teacher facilitates this process, but also creates and structures the conditions for learning (Vavrus et al, 2011).

Teacher - centred approach

A pedagogical approach in which the teacher is the main focus of the lesson and solely responsible for what is learned and how it is learned. In this approach, the teacher remains in control of the knowledge (what is to be learned) and the learner remains a passive listener (Lionel & Michael, 2016). Teacher centred pedagogy relies on methods such as whole- class lecture, rote memorization and chorus answers.

Science

Systematic and organized inquiry into the natural world and its phenomena (Sheldon, n. d.).

Learner

Any person ranging from early childhood development to the adult education phase who is involved in any kind of formal or non-formal education or training activity. The term learner also refers to persons studying in ordinary public schools (Mothata, 2000). In the current study, the terms learner and student will be used interchangeably.

1.9 Research design and methodology

This study adopted a mixed approach research design. According to Creswell (2014), a mixed research design entails collecting and analysing both quantitative and qualitative forms of data. The rationale for mixed methods in the study is that it combined the strength of both quantitative and qualitative approaches for a better understanding of teachers' pedagogical practices in science. In addition, it allowed for triangulation of data in the study; and in so doing provides rigor which improves the integrity of the results (Wisdom & Creswell, 2013). The research instrument for the study comprises of survey questionnaire, lesson observation and focus group interviews. These are well explained in chapter three. The quantitative phase of the study involved the use of survey questionnaire to explore wide range of issues that pertain to science teachers' pedagogical practices in the classroom. On the other hand, the qualitative phase made use of focus group interview and lessons observation to provide further insight on how science teachers go about their teachings in the classroom.

1.10 structure of the study

The study is structured in the form of six chapters:

Chapter 1: This chapter presents the introduction and rationale for the study, statement of the problem, research questions, purpose of the study, aims and significance of the study and also the definition of terms used in the study.

Chapter 2: This chapter presents a review of relevant literature on teaching and learning of science; conceptual and the underpinning theoretical framework.

Chapter 3: Presents the research methodology and discusses the sampling procedures, research instruments and data collection methods, research rigor and ethical considerations.

Chapter 4: This chapter presents the data analysis.

Chapter 5: Presents the results and discussions.

Chapter 6: This chapter presents the summary, recommendations and conclusions.

1.11 Summary

This chapter presented the introduction of the study on exploratory analysis of pedagogical practices in science classrooms. The discussions in the chapter focused on the background to the study, rationale and context of the study, statement of problem, aims and significance of the study. The chapter concluded with the operational definitions of the key terms in the study and chapter summary.

The next chapter presents the literature review and the theoretical framework.

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

This chapter presents a review of the literature on pedagogical practices in science classrooms. Whilst there are diverse pedagogical approaches in science, the concern is the kind of learning experience they provide as the use of ineffective teaching methods may deprive learners the opportunity to develop a sound knowledge of the nature and value of science (Walsh, 2011). In line with this viewpoint, the discussions in this section would focus on teaching and learning of science, the contexts, and factors that impact them. The section further discusses the frameworks and theories that underpin teaching and learning of science.

2.2 Teaching and learning of science

In the context of teaching and learning in the classroom, there seem to be no generic definition of effective teaching (Amy et al., 2011). Most of the definitions predicate effective teaching on measurable or quantifiable teaching outcomes such as learners' academic performance; however the 2005 Global Monitoring Report on quality (UNESCO, 2005) includes creative, emotional and social development as indicators of quality learning. In this discourse, Robert et al. (2014), define effective teaching as that which leads to improved learner achievement using outcomes that matter to their future success. According to this definition, teaching is deemed effective if it improves academic performance of learners; and ineffective if learners perform poorly after being taught.

The limitations of the definition by Robert et al (2014) are three folds. Firstly, it does not take into account the contexts in which teaching and learning takes place. Secondly, the assessment of learner performance may not fully capture the range of the outcomes that might specify proficiency in a given subject or desirable aims for education (Popham & Ryan, 2012). Thirdly, there are other factors that influence the academic performance of learners, for example learners' backgrounds or socioeconomic status, characteristics of the school, teaching practices, teaching and learning support materials, parental support, competence in the language of teaching and learning, teacher's subject content knowledge, and Pedagogical Content Knowledge (PCK) (Mmotlane et al., 2009, Robert et al., 2014). Despite the highlighted limitations, learners' academic performance may be used as a yardstick to measure the effectiveness of a teaching method.

From a constructivist perspective, Sadig (2000: 3) defined effective teaching as "the process by which trained teachers use learner centred approaches in a well-managed classrooms, and skilful assessment strategies to facilitate learning and reduce disparities". This study found Sadig's definition of effective teaching more encompassing as it advocates a learner – centred approach and emphasised the role of the teacher in the classroom as facilitator of learning rather than instructor in a teacher centred approach.

As to what constitutes effective teaching, Grow (in Haave, 2014) argues that good teaching is situational, in other words it caters or responds to the needs of learners. According to Westbrook et al (2013), effective teaching incorporate practices such as:

i. appropriate use of whole class, and collaborative work where learners work in small groups to accomplish a learning task
ii. meaningful use of relevant teaching and learning support materials in addition to textbooks
iii. multiple opportunities for learners to answer and elaborate on their answers to questions
iv. demonstration and explanation, drawing on sound Pedagogical Content Knowledge
v. adequate use of local languages and code switching during lessons
vi. Planning and adopting a flexible lesson with varied lesson activities.

Similarly, Hackling and Prain (2005) listed five characteristics of effective science teaching:

i. learners experience curriculum that is relevant to their lives and interests

ii. classroom science is linked with the broader community
iii. learners are actively engaged with inquiry in which ideas and evidence are challenged to develop and extend meaningful conceptual understandings
iv. assessment facilitates learning and focuses on outcomes that contribute to scientific literacy
v. Information and communication technologies are exploited to enhance learning of science.

As high quality or meaningful learning experiences are facilitated by effective teachers, it is essential to illuminate on the features of effective teachers. In this regard, the Centre for High Impact Philanthropy (2010) claims that effective teachers:

i. Impact positively on student learning and development through a combination of content mastery, command of variety of pedagogical skills, and communications/interpersonal skills,
ii. life-long learners in their subject areas, teach with dedication, and are reflective on their teaching practice,
iii. very passionate about teaching and provide meaningful learning experience through good communication, assessment skills, and sound understanding of cultural differences; knowledge about their learners and their learning styles
iv. ability to use a variety of teaching strategies to cater for different learning styles;
v. Have high expectations of their learners and facilitate learning through the use of a range pedagogical approaches, and available resources both inside and outside of the classroom.

2.3. Pedagogy

Livingston et al (2017: 3) define pedagogy "as the dynamic relationship between teaching, learning and culture". According to this definition, pedagogy comprises of teachers' ideas, beliefs, and attitudes which influence their teaching practice and the decisions they take in the classrooms (Saleh, 2016, Westbrook et al., 2013). Similar to Livingston et al definition is that of Murphy (2008: 35) that define pedagogy "as the interactions between teachers, students, the learning environment, and the learning tasks”. According to this definition, pedagogy includes how teachers and learners relate, the context in which teaching and learning takes place and the instructional approach in the classroom.

For Alexander (2009: 540), “whilst teaching is an act; pedagogy is both an act and a discourse”. From a much narrow perspective, Bernstein (2000: 78) define pedagogy “as a sustained process whereby a person acquires new forms or develops existing forms of conduct, knowledge, practice and criteria from another person or something deemed to be an appropriate provider or evaluator”. Bernstein proposed two models which provide the main framework for understanding different pedagogical approaches:

Performance model

Visible pedagogy where the teacher is in control of the teaching - learning process, and dictates to the students what and how they are to learn with a rigid lesson structure, pre-determined ways of behaviour and standardized outcomes.

Competence model

Invisible pedagogy with weaker framing and flexible lesson structure that result in more informal teaching – learning process where the teacher responds to individual learner’s needs with hidden or unfocused learning outcomes (Bernstein, 1990).

From a constructivist perspective, Livingston et al (2017) proposed seven principles for pedagogy:

i. Learner engagement

All teaching and learning process need to be engaging and require that learners play active role; rather than passive recipients of information from the teacher. In essence, meaningful learning takes place when learners are motivated and actively engaged during lessons.

ii. Mutual respect between teachers and learners

A social learning environment with mutual respect between teachers and learners are vital for meaningful learning experience in the classrooms. Learners’ rights must be respected at all times and the learning environment safe, conducive and devoid of exploitations.

iii. Building on prior knowledge

Effective teaching and learning require that teachers take into cognizance and build on learners' existing knowledge; as often time learners use their prior knowledge and new experiences to construct knowledge.

iv. Relevance of curriculum to learners

Learning of science should not be restricted only to the classrooms, rather learners must be able to relate and apply scientific knowledge in different contexts to solve problems encountered in their daily lives.

v. Classroom interactions

Teaching and learning need to be done in ways that provide opportunities for learners to interact amongst themselves and with their teacher. Cooperative learning facilitates such interaction as it allows learners to work in small heterogeneous groups to accomplish a learning task. This conforms to social constructivism that proposes learning through social interaction.

vi. Developing knowledge, skills and attitudes

In addition to acquisition of knowledge, curriculum and pedagogical outcomes should reflect skills and attitudes. This implies that teaching should not focus only on helping learners pass their examinations but also enable them to develop positive attitude, social, and creative skills which are necessary throughout life.

vii. Align assessment with curriculum, pedagogy and learner needs

Assessment should be holistic and encompass knowledge, skills and attitudes. Often time due to content driven and high stakes examinations, teachers are pressured to cover the syllabus on time and in the process compromise on pedagogy that develops creative and critical thinking skills. For this reason, it is important that assessment is not entirely content based but align with pedagogy; and reflect knowledge, understanding and skills of learners.

2.3.1 Pedagogical competencies

The pedagogical competencies for teachers encompass:

Purpose:

Philosophy, attitude, and style that a person brings to the task of teaching,

Content

Static content (what) is the curriculum that teachers are responsible for teaching. It is static because it doesn't change from day to day with the mood of the students or events in the school environment.

Dynamic content (how) is the knowledge and skills about teaching that a teacher uses to do the teaching. This can change at any time based on what is happening in the immediate environment. A teacher must know how to monitor and adjust throughout the day as well as know the procedure for presenting a lesson.

Communication skills

Teachers must be prepared to communicate effectively with four very different audiences: students, colleagues, parents, and the community at large.

Professional development

Teachers are lifelong learners. They do additional coursework in their discipline, take classes in other areas of interest, mentor new teachers, and take part in research activities.

2.3.2 Pedagogy and practice

Teaching and learning of science in schools are influenced by a number of factors, some of which are associated with learners, schools and families (Ngidi & Qwabe, 2006, Harris, 2011); the social and policy context in which teaching and learning occur (Vavrus et al., 2011), subject matter knowledge of teachers, their beliefs about teaching (Esia- Donkoh et al., 2015, Saleh, 2016); and pedagogical content knowledge (PCK) (Ouma, 2012). Other factors that may affect teaching and learning of science in schools include: school climate, teaching and learning support materials (TLSMs), availability of well-equipped science laboratories and qualified science teachers, parental involvement and language of learning and teaching (LOLT).

As one of the factors that impact teaching and learning of science, school climate can been described as the ecology of the school, classroom participation structures, school environment and the culture of the school (Makeba et al., 2008).

Adeogun and Olisaemeka (2011: 552) define school climate as “the aggregate or collective measurement of school’s characteristics, such as relationships between parents, teachers and administrators, as well as the physical facilities on the ground”. In this context, the way in which a school is managed determines the quality of education the learners receive. In South African school system, principals are responsible for creating conducive teaching and learning climate. In this regard, school climate may be considered effective for learning if there is effective leadership and cordial relationship between the principal and the staff (Brown & Medway, 2007). On the other hand, a school climate may be un-conducive for learning if there is poor communication between the management and the teachers (Mupa & Chinooneka, 2015). School climate may also be un-conducive for teaching and learning if there are no facilities and resources such as well-equipped science laboratories, libraries, computers, photocopier machines, internet, textbooks and safe learning school environment.

School climate or culture varies from one school to another and from one region to another. For Instance, in some rural schools in the Limpopo province where this study was conducted; teachers are not only faced with the problem of teaching in overcrowded classrooms but also have to deal with ill-discipline and lack of teaching and learning support materials. Congestion in the classrooms impact negatively on teaching and learning as it creates disciplinary problems and distracts learners during lessons (Makeba et al., 2008).

Meaningful learning entails enacting the teaching of science into forms that can be understood by learners (Suriya, Kongsak & Lula, 2014). However, the extent to which this is achieved depends on teachers’ Pedagogical Content Knowledge (PCK). Science teachers with sound PCK are effective in the classrooms as they are able to utilize a wide range of effective and appropriate teaching methods to develop students understanding of science topics. In addition, they use flexible teaching and learning strategies, create an enabling learning environment, and use interesting learning activities and methods that enhance learner achievement (Westbrook et al., 2013). On the other hand, science teachers with poor or inadequate science PCK tend to adopt ineffective teaching methods, and may find it difficult to explain concepts in ways that learners can understand. In view of this, it becomes necessary that teachers develop sound PCK and conversant with effective teaching strategies that can be used to provide meaningful learning experience in science.

Despite the economic opportunities and the role of science in the society, some learners do harbour negative attitude towards learning of science which impacts negatively on their performance. According to McNall et al, (2009), learners' attitudes in science are influenced by:

i. perception of the teacher
ii. anxiety towards the subject
iii. the value of science
iv. self-esteem
v. enjoyment of the subject
vi. attitudes of peers and friends towards science
vii. attitudes of parents towards science
viii. nature of the classroom
ix. Achievement and fear of failure in science.

Further impacting the teaching and learning of science is motivation. Some learners lack motivation in science which is concerning as unmotivated learners are more likely to lose interest during lessons (Tyler, 2007). In this regard, high level motivation impacts positively on teaching and learning as it fosters a strong sense of self - efficacy which may improve academic performance (Laing, 2011).

Lack of parental support has been identified as impacting negatively on teaching and learning of science in schools (Mmotlane et al. 2009). The problem is more felt in rural areas where learners come from low socio-economic backgrounds. For instance in some rural schools, learners come from homes where parents are working in the farms and children are left to fend for themselves at home. In some cases, parents leave home to work in town while children are left to stay with their grannies who in most cases may not show interest in the studies of the children at home. This could impact severely on the academic progress of learners. Similarly, poor parents from low socio-economic backgrounds may prioritize putting food on the table at the expense of monitoring and supporting their children's educational development, this impacts negatively on the academic performance of the learners (Mokgaetsi, 2009). Therefore, parental involvement and support are essential for effective teaching and learning as they provide information, learning opportunities, behavioural models and other resources.

Further impacting on teaching of science is the language of learning and teaching (LoLT) (Tan & Santhiram, 2010). For a meaningful learning in the classrooms, teachers need to have a certain level of communication competence in the language of instruction; and without which they cannot be able to communicate what is to be learned (Simmons & Cooper, 2011). Effective use of English as a medium of instruction requires cognitive academic language proficiency (CALP) which includes the ability to communicate fluently and engage in abstract thought in a cognitively demanding context (Tan & Santhiram, 2010). In this regard, poor knowledge of English as medium of instruction could compromise effective teaching and learning of science as teachers may be constrained in their ability to explain science concepts in ways that could be understood by learners (Mbarjiorgu et al., 2014, Mokgaetsi, 2009).

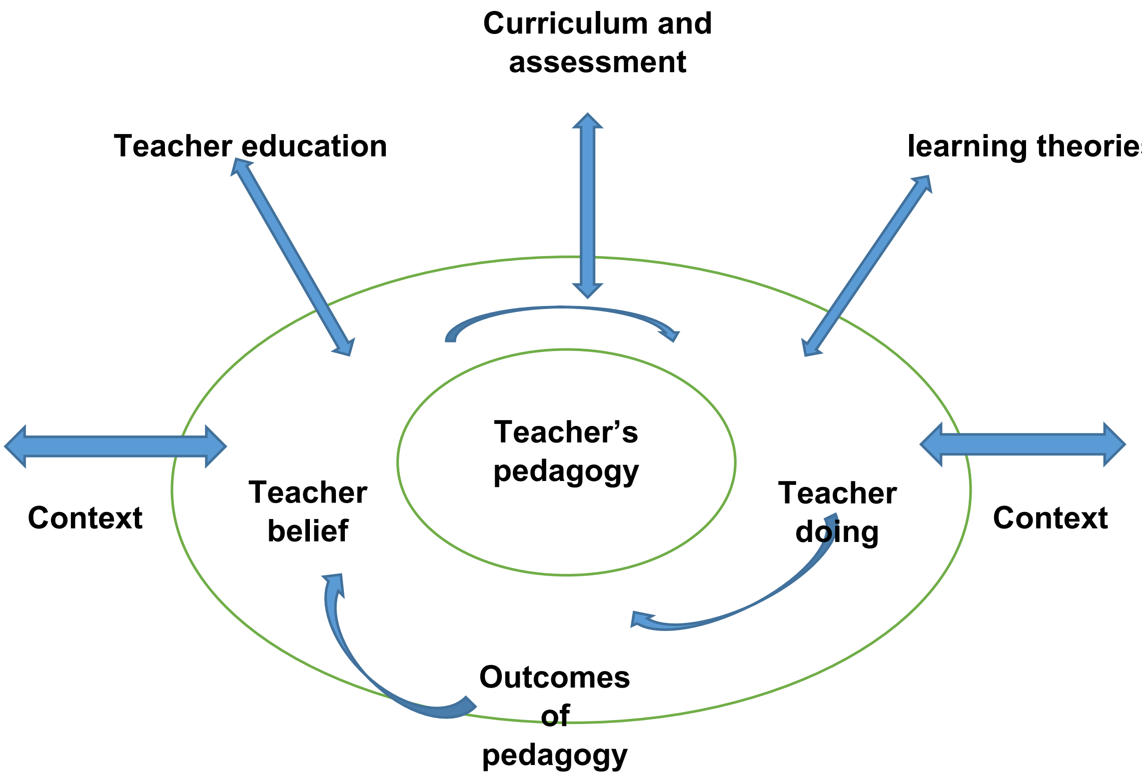
2.4. Conceptual framework

Pedagogy is a complex process that encompasses teachers' belief and practices with the former influencing the latter, thus resulting in the visible, observable and the measurable impact of teachers' classrooms pedagogical practices (Westbrook et al., 2013). In other words, the pedagogical approach of teachers is influenced by their educational belief which translates into observable classroom teaching practices.

Within this framework, the pedagogical practices of teachers are influenced by variety of factors such teacher beliefs, teachers' past schooling experiences, learning theories, and prevalent curriculum and assessment policy. In this regard, teachers' actions in the classroom are perceived as reflection of their pedagogical belief which influences the decisions they make about the methods of teaching. Whilst there are different definitions of teacher beliefs, the current study adopts two broad categories of pedagogical belief: direct transmission beliefs and constructivist beliefs.

Direct transmission beliefs are influenced by behaviouristic theory which emphasizes use of sanctions and reinforcement in learning (Gilleece, 2012). Therefore, teachers with direct transmission beliefs perceive their roles in the classroom as imparting knowledge in a clear and structured way, with the learners listening attentively and absorbing the information (OECD, 2009). In contrast, constructivist approach perceives learners' prior knowledge as an asset that can be explored to link new concepts and learners' misconception. Teachers with constructivist view of learning adopt facilitating inquiry; encourage active participation of learners in the teaching - process, and focus on the development of cognitive and reasoning process more than acquisition of specific knowledge (Gilleece, 2012).

Figure 2.1: Conceptual framework on pedagogical practices in science (Adapted from Westbrook et al, 2013).



2.4.1 Teacher education in South Africa

The policy framework for teacher education and development in South Africa aims at empowering the teaching profession to meet the educational needs of a democratic South Africa. The policy framework comprises of two complementary sub- systems: Initial Professional Education of Teachers (IPET) and Continuing Professional Teacher Development (CPTD). Based on the revised 2015 Minimum Requirements of Teacher Education Qualification Policy (MRTEQP), initial teacher education may follow two training routes:

Completing a four year Bachelor of Education degree or completing an appropriate first degree, followed by a one year Post Graduate Certificate in Education (PGCE); and registering with the South African Council of Educators (SACE). For science teachers, the first route is bachelor’s degree in education comprising an academic component for science content knowledge, and a pedagogical component to learn how to teach science. The second route is an appropriate Bachelor of Science degree with a Post Graduate Certificate in Education (Mashau et al., 2016). Once completed, both routes lead to one being a professionally qualified teacher.

Due to the legacy of apartheid, South Africa has a history of poor teacher education (TIMSS, 2016); and to improve this, various higher learning institutions have developed programmes to upgrade teachers’ skills and provide necessary content knowledge. In this regard, the Continuing Professional Teacher Development (CPTD) assists in upgrading teachers’ skills and providing the necessary content knowledge for teaching of specific subjects. Currently, the Advanced Certificate in Education (ACE) is used as a professional development to address the issue of teachers in the system who do not have teaching qualifications for the subjects they are teaching.

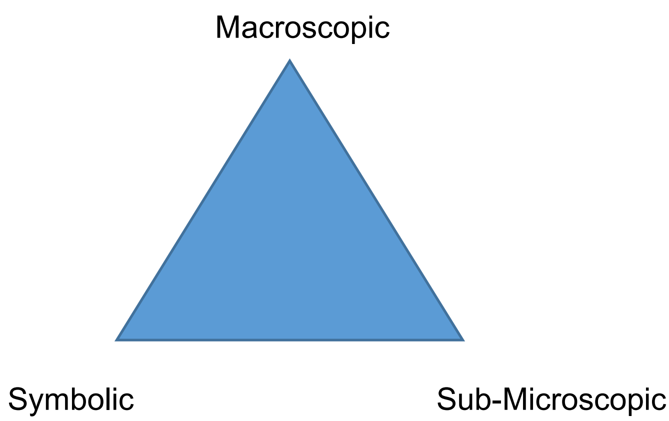
2.4.2 The science of teaching specific domain knowledge: A case of teaching chemical change

Chemistry topics incorporate many abstract concepts, which are central for learning in the subject and other science related areas. Whereas some chemical terms refer to substances learners are familiar with (e.g. water, salts, solution,) or chemical processes that can be easily demonstrated (e.g. combustion, melting, boiling), others refer to ideas that are not easily demonstrated (Taber, 2009). For instance, a chemical change occurs as a result of a reaction during which the atoms within a substance are rearranged into different combinations to form a new chemical substance. At a molecular level, chemical change involves making or breaking bonds to create new chemical substance (Tro, 2011). The challenge in teaching these concepts is that learners cannot easily observe atoms, chemical bonds or molecules which may present a learning difficulty especially if the teacher does not have adequate pedagogical content knowledge. Building on this discussion, Johnstone (2000) proposed a model of thinking in chemistry:

i. a macroscopic level, which describes what can be seen, touched and smelt,
ii. a sub- microscopic level that describes atoms, Ions, and structures of chemical compounds; and a symbolic or representational level, which describes the symbols, equation, molarity (C = n/v where C = concentration, n = number of moles, V = volume of solution), mathematical manipulation and graphs.

This multi-level way of thinking in chemistry can be represented by the corners of a triangle

Figure 2.2: The three representational levels in chemistry (Johnstone, 2000)



The perceived notion of science as a difficult subject stem from the interplay between the macroscopic and microscopic levels of thought which may be challenging for learners to grasp (Johnstone, 2000).

Further exacerbating the teaching and learning difficulty in science is the learners' misconceptions about science phenomena. Often time, learners' pre instructional knowledge of science concepts is inconsistent with that of the scientific community and the intended learning outcomes of science (Taber, 2009). The implication is that when learners come to class with misconceptions of science phenomena, they often try to make sense of the teacher's explanations in terms of their existing understandings which may not be right; and such misconception if not identified and corrected at the beginning of a lesson could impact negatively on teaching and learning outcomes (Taber, 2009). Therefore when teaching in the classroom, teachers need to be aware of learners' misconception in the topic and address them accordingly (Papegeorgious, et al., 2010).

A common misconception in the topic of chemical change is the inability of some learners to differentiate between chemical change and physical change. For instance, some learners assume that when two or more substances are mixed together, a chemical reaction occurs (Sense, 2010). Some learners perceive dissolving and changing of physical state as a chemical change (Lajium 2013). Some learners struggle when explaining chemical reactions as they perceive them as transmutation process rather than reorganization of atoms (Merrino & Sanmarh, 2008).

For some learners, chemical reactions are perceived as a process of mixing of substances or changes in physical characteristics such as change in shape, texture, and colour; whereby no new substances are formed (Lajium, 2013: 90).

Several studies found that learners were unable to recognize the conservation of mass in chemical reactions (Agun & Schwartz, 2007). For instance when predicting mass change in a chemical reaction, learners assume that solid products such as precipitations increase the mass of a chemical system; since a solid is thought to be heavier than a liquid or gas (lajium, 2013). Similarly the study by Ozmen and Ayas (2003) found that 20% of grade 10 learners (ages 15-16) in Turkey predicted that the total mass increases in a precipitation reaction of barium sulphate is because of the formation of the solid precipitate that was thought to weigh more than the original liquid. The aforementioned learning challenges illustrates the conceptual nature of science topics which require a high level teaching skills in order to provide a meaningful learning experience (Taber, 2009).

2.4.3 Learning styles in science

A variety of pedagogical approaches can be implemented in the teaching of science; however, the effectiveness of each method depends on understanding of the diverse learning styles and adapting to the context of the classroom (Livingston et al., 2017). Building on this view point, Gilakjani (2012) and Naqvi (2017), posit that students who learn from an approach that is consistent with their preferred learning style perform better academically and develop a more positive attitude towards learning. In contrast, if the teaching approach is incompatible with the learning styles in the classroom; learners may withdraw from active participation in the lessons which can lead to poor academic performance (Matilde, 2008). Creating awareness of learning styles is vital as it may help students recognize their academic strength, boost their self-confidence and develop effective collaborative skills (Provident et al, 2009).

Learning style has been defined in different ways but the convergence in the definitions point to preferred ways in which individuals make sense of new information.

According to Maria et al. (2015), learning style refers to an individual's habitual and preferred way of absorbing, processing, and retaining new information and skills.

Naqvi (2017) posit that learning styles are characteristic cognitive, affective, and psychological behaviours which are consistent with how individuals learn. For Abante et al (2014), learning style refers to the preferred way an individual makes sense of information and characteristic of a person's mode of thinking, remembering or solving problem. Similarly, Lucas and Corpus (2007) defined learning style as the preferred way an individual processes information and typical of a person's mode of thinking, remembering and solving a problem. Whilst the definitions provide insight on learning style, it must be pointed out that learners do not fit rigidly into a specific learning style and may adopt variety of strategies to learn. In this regard, learning style may be defined as the preferential strategies used by individuals to process, and make sense of new information.

Various learning style models have been proposed to provide framework for understanding the learning styles of people. Such model include the Myers- Briggs type indicator (MBTI) which classified individuals as extroverts or introverts, sensors or intuitors, thinkers or feelers; and judgers or perceivers. Reid’s (2005) model claims that a student could be a sensory/perceptual learner, cognitive and/or affective learner. Other models include the Kolb learning style model, the Herman Brain Dominance Instrument (HBDI) and the Felder- Silverman’s learning style model. This study found VARK, Felder - Silverman learning model and Howard Gardner’s multiple intelligences theory very relevant and applicable in the teaching and learning of science.

2.4.3.1 The VARK model

Originally developed in 1987 by Neil Fleming, the VARK model describes four types of learners: visual, auditory, reading/writing, and kinaesthetic. According to the VARK model, visual learners learn best through seeing visual images such as drawings, pictures, posters and other visual image of educational value. Auditory learners prefer hearing information, listening and engaging in discussions. Reading/writing learners prefer engaging and interacting with textual materials while kinaesthetic learners prefer hands-on learning experience, physical involvement, and manipulation of objects. It must be pointed out that learners do not fit exclusively to one learning style as proposed in the VARK model; rather they utilize a wide range of strategies to learn and accomplish a learning task.

2.4.3.2 Felder- Silverman learning style model

The Felder – Silverman (1998) learning style model provides a frame work for understanding the characteristic pattern and preferences in the way people take in and process information. It incorporates ideas of the major approaches to understanding learning styles and preferences. According to Felder- Silverman’s model, learners could be sensing or intuitive; visual or verbal; sequential or global; and active or reflective.

Sensing versus intuitive learners

Sensing learners are practical, and prefer clear expectations and concrete learning routines. They are oriented towards details, facts and adopt established procedures. In sharp contrast, Intuitive learners are innovative and prefer working with ideas, abstract information and see relationships between different ideas. They explore complexities and comfortable with mathematical formulations.

Visual versus verbal learners

Visual learners prefer lesson presentations enriched with colourful visual images, pictures, diagrams, charts and graphs. On the opposite end, verbal learners prefer learning approach that incorporates oral expressions, writing, explanations and discussions.

Active versus reflective learners

Active learners learn preferentially through hands on approach and being actively engaged in practical investigations, group work, discussion and other opportunities for social interaction. Reflective learners, on the other hand prefer to work alone, and explore opportunities to learn in the absence of social context. Similarities exist between Gardner's frame work and Felder- Silverman's learning style model with regards to active and reflective learners. Active learners may possess high interpersonal intelligence whereas reflective learners could excel in the domain of intrapersonal intelligence (Allen & Tanner, 2005).

Sequential versus global learners

Sequential learners prefer to learn in small increments, and organize information in an orderly manner. They learn in logically sequenced steps and process information in an organized and systematic way. In contrast, global learners organize information more holistically and in a seemingly random manner. They may appear disorganized in their approach but will accomplish the learning task.

In summary, the observant and methodical sensors could make good experimentalists; whilst the insightful and probing intuits make good theoreticians. Active learners are skilled at administration and team oriented project work whilst reflective learners do well at individual research and design. Sequential learners are potential good analyst, and may be skilled at solving problems. Global learners are potential good synthesizers, innovative and able to work out a problem using unconventional approach.

2.4.3.3 Howard Gardner's theory of multiple intelligences

Howard Gardner's theory of multiple intelligences claims that individuals can excel in different ability areas rather than on a single general ability (Slavin, 2009). Gardner (1983) argues that the measure of intelligence focuses on one type of intelligence where as humans can excel in multiple areas of intelligence. To broaden the concept of intelligence, Gardner (1983) proposed eight intelligences:

i. linguistic-verbal
ii. logical-mathematical
iii. visual-spatial
iv. bodily-kinaesthetic
v. musical-rhythmic
vi. interpersonal
vii. intrapersonal and;
viii. Naturalistic intelligence.

Linguistic - verbal intelligence is associated with words, language, reading and writing. Visual - spatial deals with images and graphic information; whilst logical – mathematical is associated with ability in mathematics, calculations, and quantifications.

Bodily - kinaesthetic intelligence is associated with physical manipulation of objects, the body, and other modes of physical interaction; whilst interpersonal intelligence is linked with the ability to interact and work collaboratively in groups. Intrapersonal intelligence is associated with metacognitive ability; and naturalistic intelligence with talent in observation of patterns, identification and classification. Gardner (1983) argues that learners will be better served when teachers use different methodologies and activities to cater for the different intelligence in the classrooms (Gilman, 2012). The multiple intelligence theory is summarized in the table below.

Table 2.1: Howard Gardner's (1983) multiple intelligence

The eight intelligences	
Intelligence	Is characterized by facility with
Linguistic-verbal	Words, language, reading and writing
Logical-mathematical	Mathematics, calculations, and quantifications
Visual-spatial	Three dimensions, imagery and graphic information
Bodily-kinaesthetic	Manipulation of objects, physical interaction with materials
Musical-rhythmic	Rhythm, pitch, melody, and tone
Interpersonal	Understanding of others, ability to work effectively in groups
Intrapersonal	Metacognitive ability to understand oneself, self- awareness
Naturalistic	Observation of patterns, identification and classification

2.5 Theories of learning

2.5.1 Behaviourism

Behaviourism originated from the work of Thorndike (1911), Pavlov (1927) and Skinner (1957). It gained ground in the 1960's and 1970's after being explained with the classical operant conditioning (stimulus- response). Behaviourism emphasizes use of sanctions and rewards in learning. That is, learning achievements are rewarded with positive reinforcement and undesirable behaviour deterred with sanctions. Fundamental to behaviourism is the assumption that learners become active during lessons by reacting to stimuli in the environment. In this regard, the teacher creates conditions (positive reinforcement/rewards) which stimulates the desired behaviour and discourages (negative reinforcements/sanctions) those that are deemed to be undesirable. This role makes the teacher the focus of attention, hence; behaviourism supports teacher – centred pedagogy which is associated with classroom practices such as lecturing, demonstration, rote learning, drill work, and memorisation (Choudhury, 2011). Whilst behaviourism is perceived to be universal and applicable in a wide range of contexts (Westbrook et al, 2013) critics of the learning theory argue that it does not provide learners with higher order cognitive skills and ability to apply knowledge in a variety of context (Vavrus et al, 2011).

2.5.2 Constructivism

Splitter (2009) describes constructivism as an epistemological and psychological theory about how individuals learn by actively and consciously bringing their past experiences and understanding in order to process, interpret and negotiate the meaning of new information. Constructivism Perceives learning as building on internal cognitive structure (schema) which consists of information and the process of acquiring it.

As experiences happen, the new information is used to alter, add to or change previously existing schemas. The richer the links between prior and new experiences, the deeper the knowledge and the more it can be applied in variety of contexts (Wirth & Perkins, 2008).

According to Sanjna (2015), constructivism is based on four main principles:

i. learning depends on what individuals already know
ii. new ideas occur as old ideas are adapted and/or changed, and
iii. Learning involves the development of ideas rather than mechanically accumulating facts; and
iv. Meaningful learning occurs through previous experiences.

From a historical perspective, constructivism originated from the work of Dewey John (1938) who claimed that knowledge and skills develop in situations where learners have meaningful experiences. That is, learning occurs when an individual builds on internal cognitive structures (Schema) or makes personal interpretation of experience which is subject to change as new situations are encountered. When a new information or experience conforms to the schema, learning occurs through assimilation of the information. Similarly, when a new situation or experience contradicts the schema; accommodation takes place during which existing schema are modified in order to assimilate the new information (Westbrook et al, 2013). Since prior knowledge is central to learning, it becomes necessary that existing misconceptions are established by teachers and corrected at the beginning of a lesson. This is in view of the fact that often times learners come to the classroom with misconceptions about a natural phenomenon which if not identified and corrected at the beginning of a lesson can compromise effective teaching and learning (Wirth & Perkins, 2008). In sharp contrast to behaviourism, constructivism advocates learner – centred pedagogy in which learners play active role in the teaching and learning process, rather than passive recipients of information (Splitter, 2009).

The foundation of personal constructivism can be attributed to Piaget (1972), whilst Vygotsky (1978) is responsible for the ideas pertaining to social constructivism (Nyback, 2013). Based on Piaget's and Vygotsky's ideas, Rutherford (2012) posited that in personal constructivism, learning is constructed within the individual and based on prior knowledge, whereas in social constructivism learning is constructed in a social context and results from individuals dialoguing about problems in a social environment.

2.5.3 Social constructivism

In social constructivism, knowledge is perceived as socially constructed and learning as a social process mediated through cultural tools such as language; and facilitated by drawing on the contexts familiar to the learners (Westbrook et al, 2013). Within this framework, learning is deemed a social process that is facilitated through social interactions and communication which leads to cognitive development (McLeod, 2007). The fundamental concept in social constructivism is the Zone of Proximal Development

(ZPD) which is the area of activity where with the help of a teacher or more capable peers, learners are able to accomplish that which they cannot do working alone (Vygotsky, 1978). In this context, anything that is too complicated for the learner to comprehend that is not in their zone of proximal development cannot be learnt until there is a shift in the zone of proximal development. The shift occurs when the learner attains his/her potential, and can then proceed to learn more challenging materials. When teachers apply the zone of proximal development (ZPD) in their teaching, they can easily identify learners' strengths and weaknesses which enable them to adapt their teaching to provide meaningful learning experience. Furthermore, teaching in the ZPD enables teachers to mediate and provide meaningful instruction and feedback that promotes cognitive development and creates a learning environment in which learners are valued (Lui, 2012).

Similar to zone of proximal development, constructivism incorporates scaffolding or support mechanisms that help a learner to carry out a task which he/she would not be able to do on their own and which supports them until they are able to complete the task independently (Vaughn & Bos, 2012). When applied in the classroom, scaffolding is temporary and as the learners' abilities increase; they are gradually withdrawn by the teacher (Killen, 2013). Social constructivism advocates learner - centred pedagogy and provides a solid basis for modern trends in teaching and learning (Van Dat, 2013).

2.5.4 The Cultural Historical Activity Theory (CHAT)

Cultural historical activity theory (CHAT) perceives learning as culturally and historically situated, and mediated through a social process (Roth, Radford & LaCroix, 2014). CHAT is rooted in the work of Vygotsky (1978) and centres on three core ideas:

i. humans act collectively, learn by doing, and communicate in their actions
ii. humans make, employ and adapt tools of all kinds to learn and communicate;
iii. Community is central to the process of making and interpreting meaning and thus to all forms of learning, communication and action.

Foot (2014) elaborates that cultural in CHAT points to the premise that humans are acculturated, and everything people do is shaped by and draws upon their cultural values and resources. The historical as used in conjunction with cultural indicates that cultures are grounded in history and evolve over time. That is, the analysis of what people do at any point in time including learning must be viewed in light of the historical trajectories in which their actions take place. The term activity refers to what people do jointly, and is influenced culturally to convey its relevance. Theory as used in CHAT denotes a conceptual framework for understanding and explaining human activity. CHAT model offers a paradigm to advance ways of thinking about learning (Roth & Lee, 2007).

2.5.5 The social interdependence theory

The social interdependence theory provides the framework for understanding the role of positive interdependence in cooperative learning. The theory is based on the claim by social scientists that peer interaction play an essential role in socialization and learning (Johnson & Johnson, 2009). The basic premise of social interdependence theory is that the way in which goals are structured determines how individuals interact. In a cooperative learning, social interdependence exists among group members when the accomplishment of each member's goals is affected by the actions of other group members (Deustch, 1949). The core ideas pertaining to social interdependence theory are attributed to Kurt Kafka, who proposed that groups are dynamic wholes in which the interdependence among members could vary. Kurt Lewin elaborated on Kafka's claims, stating that: the essence of a group is interdependence among members (created by common goals), which results in the group being a dynamic whole so that a change in the state of any member or subgroup changes the state of any other member or subgroup. The intrinsic state of tension within group members motivates and mobilizes efforts toward the accomplishment of the desired common goals.

Deutsch (1949) extended Lewin's notions and proposed that state of tension motivates a person's behaviour and as desired goals are envisaged, actions are motivated by this tension to achieve the desired goals. Deutsch (1949) conceptualized two types of social interdependence: positive and negative interdependence. Positive interdependence exists when individuals work cooperatively and assist one another to accomplish shared goals. In contrast, negative interdependence exists when individuals perceive that that they can accomplish their goals only when other individuals with whom they are competitively linked fail to achieve their goals.

Building on the ideas of Deutsch, Johnson David and Johnson Roger (2008) posited that positive interdependence results in constructive interaction as individuals encourage and facilitate each other's effort to accomplish shared goals. Positive interdependence entails that individuals offer mutual help, exhibit mutual trust, exchange needed resources and communicate effectively with one another so as to achieve a common goal. In contrast, negative interdependence leads to competitive interaction where individuals work and sabotage each other's effort. In this context, group members may provide misleading information, display lack of trust, and communicate ineffectively with one another (Johnson & Johnson, 2008).

The social interdependence theory is very relevant and supports the use of cooperative learning in which learners work in small diverse ability groups to accomplish a learning task. Furthermore, it emphasizes positive interdependence or cooperation which encourages and motivates group members to facilitate each other's efforts to learn. This in turn helps the group to accomplish their learning goal. In cooperative learning, positive interdependence can be created by having group members take on complementary roles such as checker, recorder, elaborator, time keeper, reporter and group leader (Woolfolk, 2010). Assigning roles to group members would encourage them to work cooperatively, participate fully in the learning tasks, and accomplish the group's learning goals.

2.6 Pedagogical Content Knowledge (PCK)

The teaching of science in a manner that depends less on transmission requires competence and understanding of the complex relationship between learners' prior knowledge, science content, and PCK (Garbett, 2011). For a meaningful learning experience in science, teachers need to demonstrate competence in the subject matter, develop deep understanding of learners, and address misconceptions. In addition, teachers need to see how science concepts relate across fields and to everyday life; and such understanding lays the foundation for PCK (Adela, 2009).

According to Shulman (1987), effective teaching in the classroom requires that teachers possess the following Knowledge:

i. pedagogical knowledge (PK)
ii. content knowledge (CK)
iii. pedagogical content knowledge (PCK)
iv. Curricular knowledge
v. Knowledge of educational contexts, and
vi. Knowledge of purposes of education.

A question was raised in the literature as to which one of CK and PK is the most important in teaching and learning? Kaya (2009) claimed that both are interlinked and equally important as without sound CK, effective PK will be impossible. Shepherd (n.d.) states that PK is likely to have greater influence on teaching as well as teacher's ability to implement the curriculum. In view of the debate, Shulman (1987) contends that subject matter knowledge and knowledge of how to teach are not mutually exclusive as someone who assumes the role of a teacher must first demonstrate knowledge of their subject matter before being able to help others to learn with understanding. To integrate both the CK and PK, Shulman came up with the term Pedagogical Content Knowledge (PCK).

Shulman (1986) defines PCK as representing the blending of content knowledge and pedagogy into an understanding of how particular aspects of subject matter are organized, adapted, and presented for instruction. It integrates the content knowledge and how to transform this knowledge in ways that provide meaningful learning experience (Marufi et al, 2017).

According to Shulman (1986), a teacher is able to teach effectively if he/she has adequate PCK which includes:

i. knowledge of learning difficulties learners may encounter in the course of learning a particular topic
ii. knowledge of conceptions and/or misconceptions learners may bring to the classrooms about a particular topic, and

iii. Knowledge of teaching strategies appropriate for a teaching situation.

Building on Shulman's (1986) PCK model, Magnuson et al. (1999) conceptualized PCK for science as consisting of five components:

i. orientations towards science teaching
ii. knowledge of curriculum
iii. knowledge of assessment
iv. knowledge of students' understanding of science, and
v. Knowledge of instructional strategies.

PCK is rooted in the belief that teaching transcends delivering the subject content knowledge in the classrooms and that learning is more than absorbing information for later accurate regurgitation by students (Loughran et al., 2012). Building on this, Ingrid (2010) posits that PCK for science includes an understanding of science content and inquiry processes, knowledge of learners and how they learn, and skills for facilitating learning in ways that promote active inquiry and conceptual development.

As a knowledge specific to teaching profession, teachers develop PCK from variety of sources. One of these sources is teaching experience which teachers acquire in the classroom as they interact with learners in a teaching and learning context (Kind, 2009). Another vital source of PCK development is teaching training during which PCK courses aimed at empowering teachers on how to teach are introduced (Haston & Guerrero, 2008). Disciplinary or content knowledge is considered an important source of PCK development as it influences the pedagogical approach the teacher adopts when teaching various topics in the classroom. In this regard, content knowledge impacts positively on teachers' PCK for teaching the subject matter (Evens, Ellen & Depaepe, 2015). Apprenticeship of observation is another potential source of PCK development. In the context of education, apprenticeship of observation refers to the influence of teachers' past experiences as students on their current teaching methods in the classroom (Haston & Guerrero, 2008). The concern though is the kind of teaching and learning experiences teachers were exposed to whilst in school as teachers who were exposed to traditional teaching methods may cling to it in their pedagogical approach (Evens, Ellen & Depaepe, 2015). Teachers may also develop PCK through cooperation and mentoring during which new teachers learn how experienced teachers teach in their classrooms (Pennie, 2019).

2.7 Teaching styles and approaches

This section primarily focuses on literature pertaining to teaching styles in the classrooms. Whilst there are various models of teaching styles, the concern is the kind of learning experience they provide in the classrooms. In view of this, the discussions in this section would explore relevant teaching styles, as well as their strong points and limitations in the classrooms.

2.7.1 Anthony Grasha's teaching styles

Grasha (1996) defines teaching style as a particular pattern of needs, beliefs and behaviours that teachers display in the classroom. According to this definition, teaching style is not simply a repertoire of approach or techniques but encompasses the context and the factors that influence the choice of teaching approach.

Grasha (1996) identified five prevalent teaching styles:

i. expert
ii. formal authority
iii. personal model
iv. facilitator, and
v. Delegator.

2.7.1.1 Expert teaching style

In expert teaching style, the teacher is perceived as a subject specialist and possesses the knowledge and expertise that are fundamental for teaching and learning in the subject. (Grasha, 1996). The teacher strives at all times to maintain his/her status as being more knowledgeable than learners and display qualities such as detailed knowledge of the teaching content and the ability to transmit information to learners. The strong point of this model is that the teacher is competent in terms of content knowledge and the learners are able to acquire the necessary knowledge and skills the teacher possesses. In addition, it is much easier for the teacher to maintain discipline in the classroom as learners are expected to learn from the teacher. The critics of the "sage on the stage" lecture style point to the "empty vessel" theory, which perceives learners' mind as virtually empty and needs to be filled by the "expert" teacher. Critics of this pedagogical approach consider it out-dated for the 21st century classroom. The other concern is that expert teaching style does not take into account the diverse learning styles in the classroom and the display of mastery content and knowledge can be intimidating to learners who may not keep up with the pace of the teacher (Eric, 2013).

2.7.1.2 Formal authority teaching style

Similar to expert teaching style, the formal authority is teacher - centred and is characterized by lengthy lecture sessions or one way presentation during which learners listen and absorb information (Eric, 2013). In this approach, the teacher assumes the position of power and establishes learning goals and expectations, provides feedback and dictates the pace of teaching and learning (Grasha, 1996). A teacher operating within this framework maintains strict discipline and provides limited opportunities for social interaction in the classroom.

The advantage of formal authority teaching style is that it provides clear focus on learning expectations. The major criticism of the teaching style is that it is very rigid in terms of catering for the diverse learning styles and provides little or no room for peer interaction.

2.7.1.3 Personal model teaching style

In personal model teaching style, the teacher is seen as an example and prototype for how to think and behave. The emphasis is on "teaching by personal example" (Grasha, 1996: 154), meaning that learners are encouraged to observe and emulate the teacher's approach. The strong point of this model is that it allows teachers opportunities to incorporate a variety of teaching strategies including lectures, multimedia presentations and demonstrations (Eric, 2013). However, there are concerns that teachers who adopt this teaching style may believe that their way of doing things is the best, and this may lead to frustrations and feeling of inadequacy among some learners who cannot live up to the expectations of the teacher.

2.7.1.4 Facilitator teaching style

The facilitator approach is constructivist in nature. That is, it promotes self-learning, and helps learners develop critical thinking skills and the ability to apply knowledge in different contexts (Eric, 2013). In this approach, the teacher assumes the role of a facilitator and provides multiple opportunities for learners to attain the learning goals (Grasha, 1996). In sharp contrast to expert and formal authority styles, in facilitator style, the teacher works with learners on learning tasks in a consultative fashion and provides the much needed support for active learning.

The advantage of facilitator approach is that it provides personal flexibility and focus on learners' needs and goals, and the willingness to explore options and alternative course of actions to achieve them (Grasha, 1996: 154). The limitations however, is that it can be time consuming and ineffective in situations where more direct approach is needed.

2.7.1.5 Delegator teaching style

Similar to facilitator style, in delegator approach, the emphasis is on capacity building. The teacher strives to develop learners' capacity to learn independently (Grasha, 1996). In this model, learners work independently in small diverse ability groups on projects with the teacher acting in a capacity as a resource person. The delegator style is best suited for science curriculum that requires laboratory activities or subjects that require peer feedback, like debate and creative writing (Eric, 2013). The strong point of delegator teaching style is that it makes learners to perceive and think of themselves as independent learners. However, it may misread or not take into account learners' readiness for independent work.

Whilst Grasha's framework described five teaching styles, it must be pointed out that teachers are not simply confined into one of these five teaching styles; rather they possess each of these styles in varying degrees and use some styles more often than others. Hence, there is no best teaching style or one size fits all pedagogical approach.

Effective teaching requires a variety of strategies and to know how and when to use the most appropriate method for a specific situation (Livingston et al, 2017).

2.7.2 The transmission approach

The transmission approach is a form of expository or traditional teaching methodology where the teacher dominates the learning situation, and the learners required to pay attention, absorb and learn whatever the teacher presents (Choudhury, 2011). The transmission approach to teaching science topics places strong emphases on the idea of science as a body of knowledge that must be taught and learnt, and the learning outcome focused on acquisition of knowledge through rote learning or memorization with the short term goal of scoring high marks in assessment tasks (Eric, 2013). Although generally acknowledged as ineffective teaching method, Fleer and Hardy (2001) posit that transmission mode of teaching may be used in the following situation:

i. Providing explanation and access to unfamiliar concepts; for example, terms such as atoms, elements, molecules, compounds etc. are too abstract and may be challenging for learners to grasp without proper explanations by the teacher.
ii. Providing a knowledge base at the beginning of a lesson on a new topic.
iii. Developing the use of scientific language or terminology
iv. Learners providing explanation to their peers: for instance after science activities and projects, learners may be required to share their findings or conclusions with others.

While transmission approach may be justified in specific context, critics point out that it does not engage students actively in the learning process. Furthermore, it provides little or no opportunities for peer interaction, cooperative learning and does not cater for the diverse learning styles in the classrooms (Loughran et al, 2012). Another concern is that teachers who rely solely on transmission approach may not be able to establish learners' prior knowledge and misconceptions prior to the lessons (Wirth & Perkins, 2008).

Eggen and Kauchak (in Bosman, 2006) listed several other limitations of transmission approach:

i. uncertainty about the level of mental engagement of learners
ii. inability of the lesson to cater for the diverse learning styles
iii. uncertainty about the relevance of the learning material
iv. lack of active participation of learners in the lesson
v. fostering of dependence culture on the teacher as sole source of knowledge
vi. diminishes students' autonomy in the learning process,
vii. Limits learners' ability to develop high order critical cognitive skills.

2.7.3 Cooperative learning

Lin (2006) defines cooperative learning (CL) as instructional method in which learners work in small groups to accomplish a learning goal under the guidance of a teacher. The three primary purposes of using cooperative learning in the classrooms are to develop learners' social and communication skills, increase tolerance, acceptance of diversity, and improve academic achievement (Lin, 2006). Cooperative learning offers learners more active learning experience, equal access to learning and a more supportive social environment (Van Wyk, 2012). Johnson and Johnson (2009) listed five essential features of cooperative learning:

i. positive interdependence
ii. individual accountability
iii. face to face interaction
iv. interpersonal and small group social skills, and
v. Group processing.

As an instructional strategy, cooperative learning shifts the focus of teaching from lecturing to groups of mostly passive learners to instruction that maximizes peer interaction (Shimazoe & Aldrich, 2010). Whilst traditional teaching approach is based on the idea that being in a classroom in the presence of a teacher and listening attentively is enough to ensure that learning takes place, cooperative learning emphasize collaboration in which learners work in small diverse ability groups to accomplish a learning goal (Amelia & Guido, 2010). Cooperative learning is therefore perceived as an alternative teaching method to traditional pedagogy which critics claim creates a competitive learning environment which may alienate some learners from active participation in the lessons (Haman & Nguyen, 2010).

The success of Cooperative learning in the classrooms is largely based on its having a clear theoretical foundation (Johnson & Johnson, 2009), and supported by variety of learning theories such as: cultural historical activity theory (CHAT), social interdependence theory, constructivism and social cognitive theories.

Throughout history, cooperative learning has been used as an instructional strategy. For Instance in ancient Greek, Socrates taught students in small groups engaging them in dialogues in his famous art of discourse (Johnson, Johnson & Smith, 2013). Quintilian (c. 35 – c. 100CE), the first century Roman rhetorician and advocate of child centred education, argued that learners could benefit by teaching one another. In the early 1600s, John Amos Comenius (1592 – 1679), a renowned pedagogical reformer, posited that students could benefit in their own learning by teaching and learning from their peers (Johnson, Johnson and Smith, 2013). For thousands of years, it was claimed that in order to understand the Talmud, one must have a learning partner (Alexenberg, 2004). In the middle ages, cooperative learning was incorporated within the structures of apprenticeship where the master craftsman would teach the most skilled students in small groups. The experienced students in turn would teach others who are less experienced (Goyak, 2009).

As a teaching strategy, cooperative learning had its origins in the work of Dewey John (1859-1952) who argued that "true education emanates from the stimulation of the child's powers through the demands of the social situations in which he finds himself, and through these demands; he is stimulated to act as a member of a unit to emerge from his original narrowness of action and feeling, and to conceive of himself from the standpoint of the welfare of the group to which he belongs" (Dewey, 1897: 77).

When applied in the classroom, cooperative learning comprises of instructional methods in which teachers organize learners into small diverse groups which then work together to learn academic content (Slavin, 2011). Within the groups, learners discuss the learning material, brainstorm and assist one another to accomplish the learning goal. (Johnson et al., 2006).

2.7.3.1 The key elements of cooperative learning

According to Johnson and Johnson (2009), cooperative learning is characterized by: heterogeneous grouping, individual accountability, group processing, face to face interaction, small group social skills and teacher supervision.

Heterogeneous grouping

Heterogeneous grouping entails that learning groups are diverse in terms of gender, academic strength, social background, ethnicity, social class, language proficiency and commitment (Jollife, 2010). The rationale for heterogeneous grouping is that it provides multiple opportunities for peer tutoring, learning assistance and social integration. When grouping learners for cooperative learning, Woolfolk (2010) posited that it is necessary to mix learners who can communicate effectively and solve problems with those who cannot. By so doing, learners who are less competent in communication and problem solving can be assisted by their capable peers. Heterogeneous grouping is also beneficial for gifted or high ability learners as it provides them with the opportunity to explain the learning task to other members of the group, and in so doing learn more.

Teacher supervision

Effective implementation of cooperative learning requires careful planning and supervision by the teacher, as group interactions during lessons if not well managed could yield unintended results. To ensure that group members are participating and contributing to the learning goal, it is suggested that teachers engage the groups with meaningful learning tasks. As the groups work on the tasks, the teacher moves around in the classroom to see how the groups are getting along with the tasks; and possibly mediate or provide explanation to the learners (Johnson et al, 2009).

Adams and Hamm (in Van Wyk, 2007) listed the role of the teacher in cooperative learning situations:

i. Setting clear learning outcomes for the cooperative lessons.
ii. Assigning learners to groups before the lesson commences.
iii. Explaining the learning tasks to the groups.
iv. Monitoring the effectiveness of the cooperative groups and intervening to provide advice and guidance.
v. Assessing the level of learner participation and contribution in the groups.
vi. Creating an enabling learning environment for the cooperative groups to thrive.
vii. Assisting the group members to know their roles and responsibilities.

Positive interdependence

According to Johnson and Johnson (2009), positive interdependence exists when there is a feeling among learners that they can attain their goals only if other learners with whom they are cooperatively linked attain their goals. In a cooperative learning situation, positive interdependence can be created if the group members have common goals, the work is distributed amongst the members, information is shared amongst group members, and the group is rewarded jointly (Van Wyk, 2007). Other methods of achieving positive interdependence in cooperative learning include: division of labour, sharing of resources and assignment of complementary roles to group members.

Promotive interaction

Johnson and Johnson (2009) defined promotive interaction as actions that encourage group members' to accomplish the group's common goals. Face-to-face Interaction is very important for effective cooperative learning as it provides the opportunity for peer engagement and elaborated explanations that promote learning for both academically strong and weak learners (Fushino, 2008).

According to Johnson and Johnson (2009), face to face promotive interaction is characterized by learners:

i. Exchanging materials, information and ideas.

ii. Providing help and support to group members.
iii. Being motivated and strive to accomplish the group's goals.
iv. Exerting positive Influence on one another to achieve the group's goals.
v. Providing group members with feedback in order to improve their performance on subsequent tasks.
vi. Challenging each other's reasoning and conclusions in order to promote high quality learning
vii. Being able to explore different points of view.
viii. Establishing mutual trust amongst the group members.
ix. Exerting effort to achieve mutual goals.
x. Being motivated to strive for mutual benefit.

Individual accountability

For group goals to be achieved in cooperative learning, every member of the group must be held accountable for his or her own learning; and also for the accomplishment of the group's goals. If there is no individual accountability, some members may choose to loaf at the expense of other group member's efforts; which could diminish learners' motivation to learn (Johnson & Johnson, 2009). If however, mechanisms are put in place to ensure individual accountability for learning, and that each group member is contributing his or her own quota towards the accomplishment of the group's goal then the incidence of free riding or social loafing varnishes (Johnson & Johnson, 2009).

According to Johnson et al (2006), individual accountability can be ensured by using the following strategy:

i. Keep the groups' small to ensure greater individual accountability.
ii. Give each learner an individual test at the completion of the learning task.
iii. Randomly call on a learner to orally present the group's work in front of the group or class.
iv. Observe group process to ensure active participation of all members. Have the checker in each group to check his or her member's understanding of the

learning task by asking them to explain what has been learned or the rationale for the group's answer.

v. Have learners teach what they have learned to their group members.

Interpersonal and small group skills

To achieve group goals in cooperative learning, group members need to develop mutual trust, communicate effectively, support one another, and resolve conflicts constructively (Johnson & Johnson, 2009). Equipping learners with social skills for effective cooperative learning requires explicit teaching.

According to Muraya and Kimamo (2011), essential group skills include:

i. Engaging in a group discussion and listening when others are talking.
ii. Being critical yet supportive of alternative views, maintaining current views until convincing contrary evidence is provided.
iii. Ability to communicate and resolve conflicts.

Group processing

In a cooperative learning, group processing entails that members reflect, evaluate and analyse how effective they are learning as a group (Johnson & Johnson, 2009). According to (Woolfolk, 2010), when learners engage in group processing they are able to identify their strengths, as well as their weaknesses and make improvements going forward. In addition, group processing helps learners to improve their social skills, address challenges within the group and strategize on how best to accomplish the group's goal (Muraya & Kimamo, 2011).

2.7.3.2 Benefits of cooperative learning

Empirical evidence indicates that cooperative learning has positive social, academic, affective and psychological outcomes. (Blatchford et al, 2005, Gillies, 2003, Van Dat & Ramon, 2012, Van Wyk, 2007). Proponents of Cooperative learning claim that it creates opportunities for peer interaction and tutoring which do not exist when learners work in a competitive learning environment (Johnson, Johnson & Smith, 2013).

Parr (2007) posit that cooperative learning fosters an environment that utilizes the diversity of learners as a resource to promote learning and social cohesion. Shindler (2004) considers cooperative learning more effective and has the potential to cater more learning styles than individualized direct instruction. In addition to learning from more capable peers, when learners work in cooperative groups; they can observe the most outstanding group members as behavioural models to be emulated (Johnson, Johnson & Smith, 2013).

Shimazoe and Aldrich (2010) listed several benefits of cooperative learning:

i. promotes deep learning of materials
ii. improves academic performance
iii. equips learners with social skills and civic values
iv. learners acquire higher-order, critical thinking skills
v. promotes personal growth
vi. Learners develop positive attitude towards autonomous learning.

Bilesami and Oludipe (2012) affirm that cooperative learning creates a social learning environment in which learners are motivated to learn and are more confident to ask questions from one another leading to a better understanding of the learning tasks.

2.7.3.3 Limitations of cooperative learning

While cooperative learning has been acknowledged as an active pedagogy that fosters high academic achievement (Brady & Tsay, 2010), critics argue that it is too informal to bring about a deep understanding of subject matter. Other opponents claim that it is too time consuming and disruptive due to the informality of the process (Lord, 2001).

Sharan (2010) posit that effective implementation of cooperative learning could be challenging as some teachers lack complete understanding of the method. Furthermore, allowing learners to work in groups does not guarantee that they will arrive at the correct answer (Woolfolk, 2010).

There are concerns that grouping learners into diverse ability group for cooperative learning could give rise to clash of interest as gifted learners who learn faster may feel held back by their slower teammates (Sharan, 2010).

McCaslin and Tom (quoted in Woolfolk, 2010), listed several other limitations of cooperative learning:

i. Socializing and interpersonal relationships may take precedence over learning.
ii. Learners may simply shift dependency from the teacher to the "expert" in the group and in such case learning is still passive and what is learned could be wrong.
iii. Status differences may increase rather than decrease.
iv. Some learners may learn to loaf because the group progresses with or without their contributions.
v. Learners may become more convinced that they are unable to understand without the support of the group.

2.8 Summary

This chapter presented the literature review and the theoretical frame work for this study that explored pedagogical practices in science classrooms. The discussions in the literature review focused on variety of issues that pertain to the study. For a better understanding, the discussions in the literature were subdivided into different sections. The first section explored teaching and learning of science. The second section shed light on pedagogy and practice. The third section discussed the conceptual frame work, teacher education, science of teaching specific domain knowledge, and the learning styles. The fourth section focused on the learning theories. The chapter concludes with discussion on PCK, teaching styles and approaches.

The next chapter will focus on the research methodology.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the design and the methods used in the study. The purpose of this study was to explore pedagogical practices in science classrooms. Teachers' pedagogical practices are all the activities teachers and their learners engage in with the intention to enhance learning of specific topics and/or their concepts (Kozman, 2003). As there are many questions to answer pertaining to teacher practices, specific research questions guide the study. Thus in this study, one research question and two complementing sub- questions were posed to understand teachers' practices in their different contexts of teaching science.

The research problem, research questions and relevant methods to address them are discussed in this section.

3.2 Research problem

Curriculum policy initiatives in South Africa envisage the teaching of science in ways that will empower learners and yield socio - economic, and environmental benefits (Livingston et al, 2017). The Current CAPS advocates the use of learner- centred approach to teaching science in schools; however, this appears not the case as most teachers still teach science as a body of factual knowledge with emphasis on drill work, and memorization with little or no connection to learners' daily lives and experiences. This approach to teaching science is not only ineffective, disempowering, but deprives learners the experience and critical skills they need in order to be successful in life.

3.2.1 Research questions

The primary research question for this study is "What are teachers' pedagogical practices when teaching science?"

I addressed this overriding research question by exploring the following specific research questions:

1. How do the science teachers teach their lessons?

2. What informs science teachers' pedagogical practice when teaching science?

As well, the hypotheses for this study include:

1. There is no significancant difference between teachers' qualification and their pedagogical practice when teaching science.

On the contrary, alternative hypothesis were raised in case the null hypothesis was rejected or not confirmed. The alternative hypothesis is:

1. There is significant difference between teachers' qualification and their pedagogical practice when teaching science.

3.3 Research design

Research design refers to the overall strategy adopted in a research to integrate the different components of the study in a coherent and logical way so as to address the research problem (Yin, 2014). In a research study, the design chosen and its methods must be appropriate and relevant to the research problem so as to yield outcome that is consistent with the purpose of the study. In addition, the data collection and analysis methods should align with the purpose, the research questions and the design of the study.

This is to ensure rigor and the reliability of the research process and its outcomes.

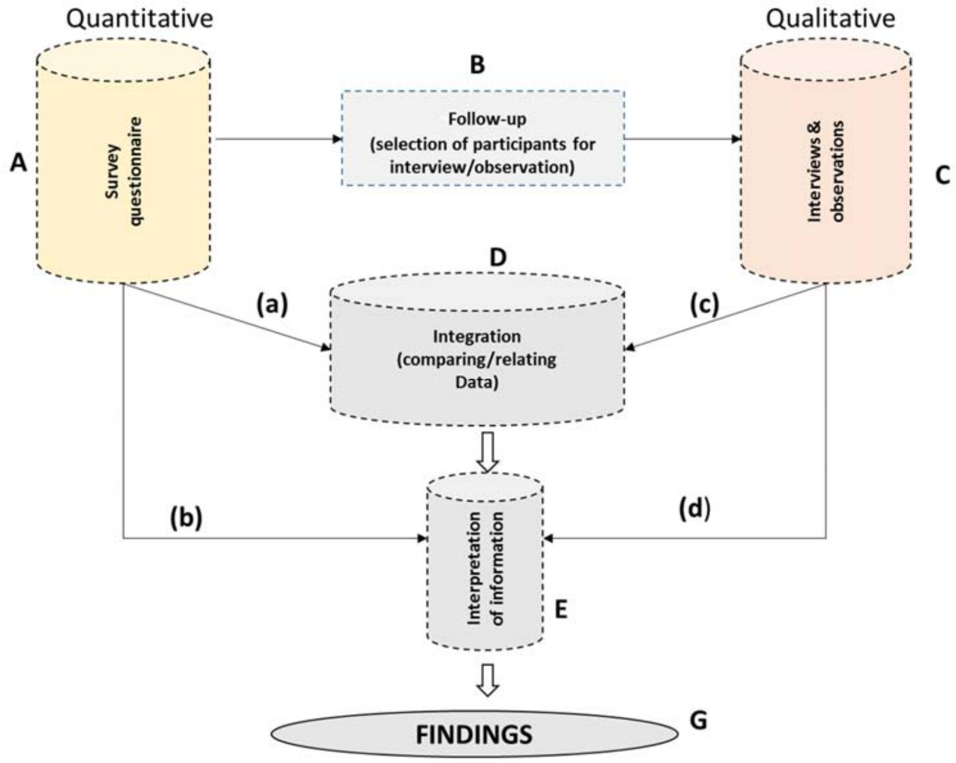
In this study, I used mixed methods design to answer the research questions posed. In this approach, data collected from various methodological sources are analysed and integrated to address questions in a single study (Creswell, 2013). This methodological design provides research strengths from methods that are quantitative and qualitative in nature. Mixed methods approach answers a broader and more complete range of research questions, hence provides stronger evidence for a conclusion through convergence and corroboration of findings (Johnson & Onwuegbuzie, 2004).

In addition, data from different instruments provide a platform that addresses and/or compensate for the weakness of each approach (De Vos et al., 2011). According to Creswell et al. (2006), mixed methods capture the complexity of different research contexts be they educational and/or social. A combination of different data sets in mixed method designs enhances aspects such as transferability, generalizability and practical significance (Onwuegbuzie & Leech, 2004).

In this study, quantitative (A) and qualitative (B) approaches are combined sequentially (from A to B) with a variety of data collection methods (see Fig 3.1). This is to ensure that the study exhibited characteristics described by Onwuegbuzie and Leech, (2004). The quantitative (A) phase of this study involved the use of a survey. Data on teachers' pedagogical practices was collected from senior phase (i.e. grades 7, 8 and 9) natural sciences teachers using a survey questionnaire (see appendix A). The survey sought data that explored teachers' practices in their everyday teaching of specific science topics.

In addition, the questionnaire served as a sampling instrument for the qualitative phase of the study (see Fig 3.1). That is, participants in the qualitative phase of the study were purposively selected through information provided by the survey (i.e. from the quantitative data). The qualitative phase of the study involved the use of focus group interviews, semi-structured interviews and classroom lessons observations for data collection. Focus group interviews also served as a purposive sampling tool for selecting participants for observation and further semi-structured interviews.

Figure 3.1: A sequential multiple methods processing of data



Data collected from the two approaches (A and C) of the mixed designs was integrated further by comparing and/or relating them (D) to draw inferences. The integrated data are then interpreted and outcomes of the interpretation are used to answer research questions and reach the findings of the study (G).

The paragraphs that follow describe the research population and study sample.

3.4 Research population and study sample

In the context of research, population is a group of individuals that is the focus of a research study and to whom the research findings can be generalized (Yin, 2014).

Onwuegbuzie and Collins (2007) contend that in any research study, researchers need to describe and justify the population, the sample and its size, the methods and process of selecting the sample. As well, it is important that researchers identify the target population and the accessible population so as to provide clarity on the actual participants or subjects in the study (McMillan & Schumacher, 2010). In this study, the population were science educators from public schools in Lobethal, Lepelle, Masemola and Mashung Educational Circuits in the Limpopo province. The educators currently teach natural sciences in the senior phase (Grades 7, 8 and 9).

McMillan and Schumacher (2010) contend that a sample for the study is a subset of a population selected to participate in a research. In the quantitative phase of the study, survey questionnaire were distributed to seventy four science teachers selected from four education circuits in the Limpopo province. As the schools were in the same geographical area and in close proximity to one another, it facilitated the hand delivery of the questionnaires to the schools where the respondents are teaching.

3.4.1 Sampling

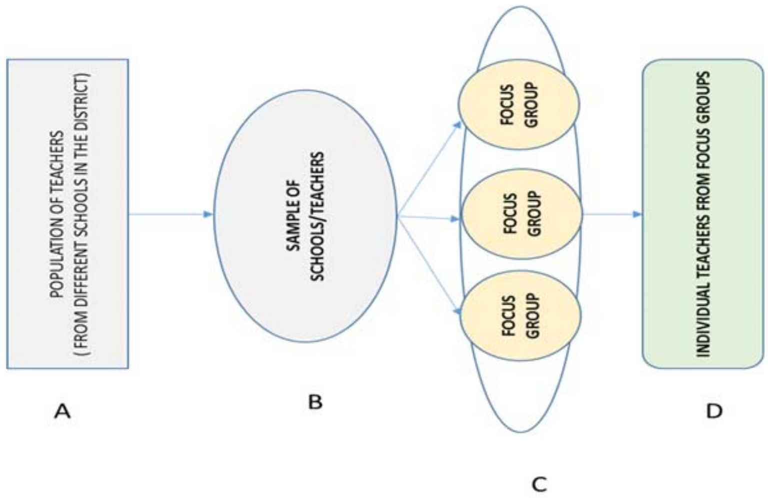
Sampling refers to the process of selecting a group of people with whom to conduct a study (Cohen et al., 2007). This study adopted a non-probability sampling which imply that individuals within the population lacked equal opportunity of being selected in the sample. The rationale for non- probability sampling is that it is less vigorous, feasible and provide easy means of accessing participants for the study (McMillan & Schumacher, 2010). However, the non- probability sampling limits the generalizability of the research findings.

3.4.2 Sampling procedure

Sampling scheme (Onwuegbuzie & Collins, 2007) refers to specific strategies used to select units for the research processes within a particular sampling design.

In this study, the sampling scheme and its processes are presented (Fig. 3.2). The population (A) represents the teachers in the district under investigation. For the purpose of data collection, survey questionnaires were distributed to seventy four science teachers within the district. Convenience sampling was used to select the questionnaires respondents. Convenience sampling is a non-probability type of sampling that select individuals within a population based on criteria such as easy accessibility, geographical proximity, availability at a given time, and willingness to participate in a study (Dornyei, 2007). These criteria were considered in the sampling processes in the study. In addition to the criteria indicated, the selected teachers must have taught natural sciences at any of the grades in the senior phase (Grades 7, 8, and 9).

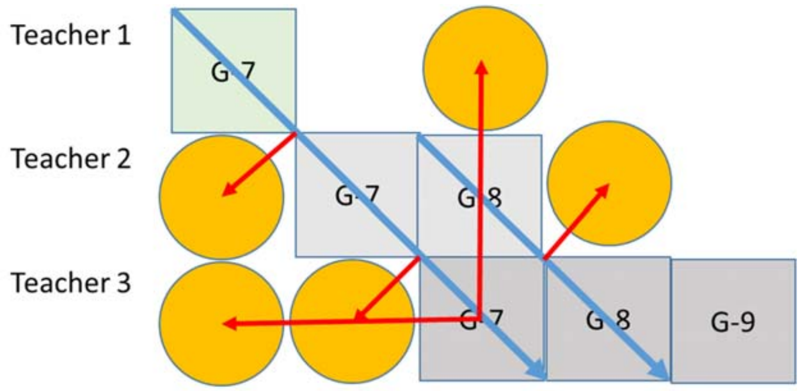
Fig 3.2: Sampling scheme and research methods



From the population (A), a sample (B) of teachers from different teaching contexts was used to select focused groups that represented teachers from all the grades in the senior phase. Each focus group (C) had six teachers from across the three levels of the senior phase (grades 7-9). The rationale for the focus groups comprising of teachers from all the grades in the senior phase is to ensure a better understanding of teachers' pedagogical practices at each level of the senior phase.

The focus groups produced four teachers for lessons observation and semi structured interview stages of data collection (D). The selection for this stage of the process was purposive but not based on preference of a particular focus group. That is, selection only ensured that the study represented teachers at all senior phase levels (see Fig 3.3).

Fig 3.3: Teachers' pedagogical practices at each level of the senior phase



In Fig 3.3, a sample of three teachers and their experiences is illustrated to clarify the representation of all levels in data collection for the study. For example, Teacher 1 has only taught at grade-7 (G-7), Teacher 2 and 3 have taught at grade 7-8 (G-7 to G-8) and (G7 to G-9) respectively. The diagram does not indicate the years of teaching in the levels.

Furthermore, analyses of teacher pedagogical practices (Fig. 3.3) could relate and/or compare teachers' pedagogical practices across levels (yellow circles). That is, commonalities or anomalies between and/or among teachers may be established through cross analyses within and across the levels focusing on particular variable of teaching aspects of teacher practices.

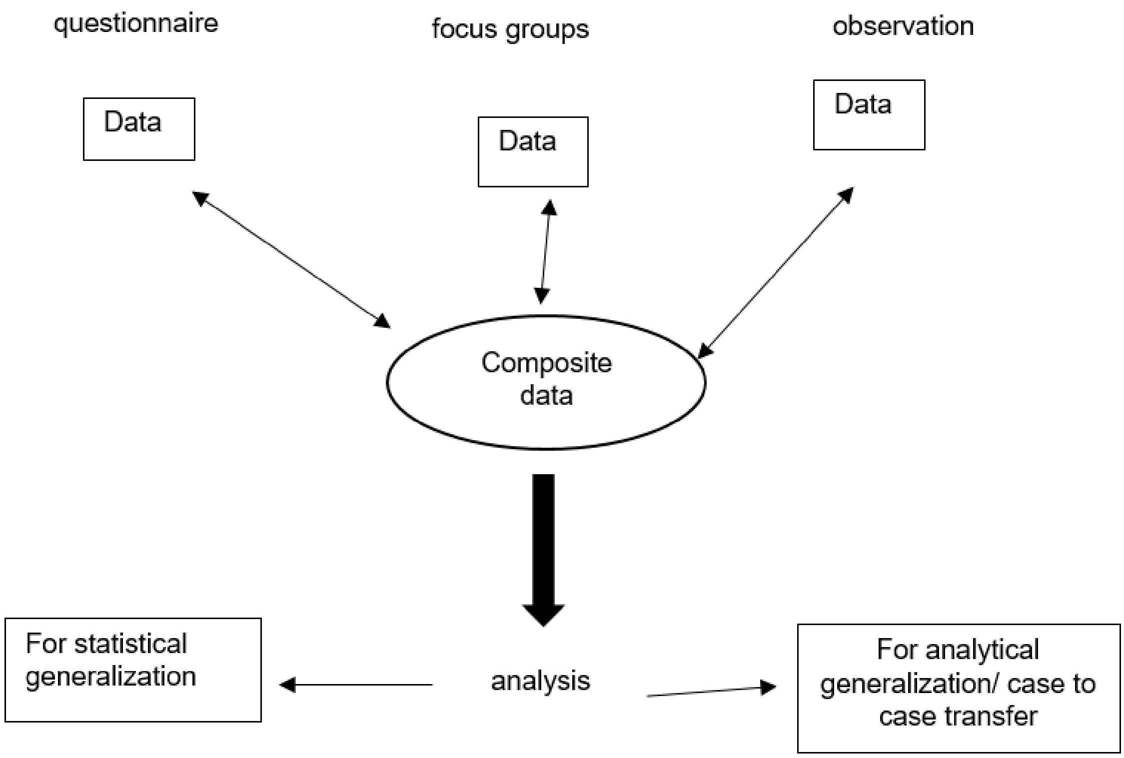
3.5 Data collection

The design of the study had three major sources of data collected by various methods and instruments. The sampling scheme chosen was aimed at maximising perspectives the study investigated. That is, a maximum variation scheme was chosen as it has the capacity to maximise information sought to answer the posed research questions in the different contexts teachers practice their trade (Onwuegbuzie & Collins, 2007). The sample for the teacher survey was sourced from the research population (see Fig 3.2) which consisted of educators who teach science in the senior phase (Grade 7, 8 and 9) within the district under study. The size of the sample was dependent on the returned questionnaires. In a causal comparative study, at least sixty-five (65) participants are the minimum number that is acceptable for statistical analysis (Onwuegbuzie, Jiao & Bostick, 2004).

In this study, seventy four (74) participants responded to the questionnaires. That is, the sample size (74) was dependent on the returned questionnaires. From this sample, a statistical analysis of the relationship between contents (some aspects of teacher practices) of the questionnaire and their numbers was established.

The follow-up stage in the analysis process was the selection of participants for further data collection. The selection was purposive, that is the participants were selected as they were thought to provide valuable information. One focus group of six members represented all senior phase levels. From the focus group, four participants (four cases) were observed during their teaching and were further interviewed on their pedagogical practices. Data collected from all the stages (Fig 3.4) of the study were analysed statistically and thematically.

Fig 3.4: Data sources, purpose and analysis



In the study, each aspect of the design had a particular purpose as far as answering research questions is concerned. The objective of the qualitative aspect is to promote better understanding and increase insight into the human behaviour and experience (Creswell, 2003). On the other hand, the quantitative aspect quantifies and establishes impact to certain characteristics pertaining to the study. The three sources of data collection in Fig 3.4 provided data that may be linked during analysis. The methods and instruments for the data sources are discussed in the paragraphs that follow.

3.5.1 Phase 1: Survey questionnaire

A questionnaire as used in this study may be described as a research instrument that consist of a series of questions for the purpose of gathering information from respondents on variables that are of interest to the researcher (McMillan & Schumacher, 2010). Survey questionnaire was ideal in this study as it enabled the collection of data on teachers' pedagogical practices in science. The questions posed and the responses provided by the teachers were crucial in answering the research questions.

A number of factors were considered in the design of the questionnaire, and this was done so as to realize the objectives of the study. In the design of the questionnaire, I ensured that it was well organized, the questions are clear, response options are well drawn and exhaustive; and there is a natural order of flow (Leedy & Ormrod, 2005). A thorough review of characteristics of a good questionnaire (McMillan & Schumacher, 2010) was done. In compliance with the features, I ensured that the questionnaire was attractive in appearance to elicit interest of the respondents to complete; the questions were short, and only long enough to get the necessary information. In addition, I ensured that the questions are appropriate and relevant to the research questions.

To ensure the questionnaire was fit for the purpose, I reviewed the information requirements necessitating the questionnaire; developed a list of potential questions that will elicit vital information; and assessed each potential question on its merit. Furthermore, I ensured that relevant questions were asked; decided on the wordings of the questions; and evaluated the questionnaire (Brewer, 2009). In developing the questions, I considered the following (Fraenkel & Wallen, 2009):

i. Could this question be asked exactly the way it is written?

ii. Would this question mean the same thing to the respondents?
iii. Could this question be easily answered by the respondents?
iv. Would people be willing to answer this question?

In the design of the questionnaire, I adhered to the list of dos and don’ts for writing good questions (Mertler & Charles, 2008), which requires that questions are:

i. simple, clear, short and un-ambiguous
ii. questions are specific, and precise
iii. questions are easily understood, and technical terms, negative questions and jargons are avoided; biased and loaded questions are avoided
iv. Respondents are knowledgeable and competent to answer the questions.

Like other data collection instruments, there are limitations associated with the use of questionnaire in a research.

In a mailed questionnaire, majority of the people whom questionnaire were administered do not normally complete or return them. That is, there may be a low return rate and the people who do return them are not necessarily representative of the originally selected sample (Leedy & Omrod, 2005). In addition, when people participate in a research survey, their responses are not necessarily a true reflection; rather a reflection of their comprehension and possible misinterpretation of one or more questions (Leedy & Omrod, 2005).

The absence of a researcher in a questionnaire would mean that should the respondents need clarity on some questions, the researcher is not available to offer such clarity. This presents a problem and may question the validity of the responses provided (Molefe, 2013). Furthermore, by specifying in advance all the questions that will be asked, and eliminating other potential questions that could be asked about the issue under investigation; the researcher is bound to gain only limited and possibly distorted information (Downson & McInerney, 2001). There is also a concern that there may be more than one respondent in an institution such that it is possible that they may discuss their responses and influence each other’s views (Molefe, 2013).

3.5.1.1 Classification of items in a questionnaire

As a research instrument, the basic items in a survey questionnaire include: demographic, knowledge, attitudinal, behavioural; and variety of questions (Mertler & Charles, 2008). The types of questions in a survey vary and depend on the specific study and the research questions (Brewer, 2009). Whilst open- ended questions enable the respondents to clarify their answers in details, In the present study, I limited the number of open- ended questions as closed- ended questions are much quicker to respond to, and easier to code for statistical analysis (Gay et al., 2009). The items in the research questionnaire were classified into two, namely: The biographical and the main section (See appendix A).

The biographical section consisted of closed ended questions that explored the academic backgrounds of the respondents, the grades they are teaching and years of science teaching experience in the senior phase (Grades 7, 8 and 9). The main section comprised of both closed and open ended questions that sought information on teachers' pedagogical practices in science. Influencing the choice of the items in the main section are the research questions, which require that ideal questions are used so as to elicit data to answer the research questions. Some of the questions in the survey were sourced from the Organization for Economic Cooperation and Development (OECD) 2009 Teaching and Learning International Survey (TALIS) while others were informed by the effective teaching practices and various learning theories explored in the literature study. The items in the main section are divided into the following:

Subsection 1: (Questions 2.1 – 2. 10) Lesson presentation in the teaching of natural sciences

Questions in this section explored teachers' views on lesson presentation in the teaching of natural sciences in the senior phase. Both open and closed ended questions were used in the section to obtain data on teachers' attitude to lesson plans and approach to lesson presentation in science. The open ended question required teachers to indicate the purpose of lesson plans, while the closed ended questions used a 5 point scale to establish teachers' agreement or disagreement to series of statements that pertain to lesson presentation.

Subsection 2: (Questions 3.1- 3.8) Subject matter knowledge

Questions within this cluster explored teachers' subject matter knowledge in science. Establishing the teachers' science content knowledge was important as pedagogical approaches adopted by teachers and learners' performance in science are influenced by the teachers' subject matter knowledge.

Subsection 3: (Questions 4.1- 4.11) Knowledge of learning difficulties in science

This section aims to establish teachers' awareness of learning difficulties and misconceptions in science topics.

Subsection 4: (Questions 5.1- 5.8) Knowledge of diverse learning styles in science.

The questions in this section explored teachers' knowledge of diverse learning styles and strategies that can be used to accommodate them in the teaching and learning science in the senior phase (Grades 7, 8 and 9).

Subsection 5: (Questions 6.1- 6.11) Teaching practices, beliefs and attitudes.

Within this section, teachers' pedagogical practices, beliefs and attitudes in the teaching of science are explored.

Subsection 6: (Questions 7.1- 7.10) Teachers' assessment strategies in Science

The questions within this section explored teachers' understanding of assessment, and the strategies they use to assess learning achievement in science. The questions explored specifically teachers' understanding of different forms of assessment, and how they apply them in their teaching to assess learning outcome.

3.5.1.2 Administration of the questionnaire

In this study, permission for administering the questionnaire was obtained from the Limpopo Department of Basic Education (LDBE) after which the schools were contacted. Since the schools in the study are located in the same geographical area and in close proximity to one another, it facilitated the hand delivery of the questionnaire to teachers. In this way, the respondents were able to complete the questionnaire at their own pace. Appointments were made with schools for collection of the questionnaire one week after delivery on a date that was convenient for the respondents. A total of eighty five (85) copies of the questionnaire were distributed to the respondents out of which seventy four (74) were duly completed and returned, which translates to 87% return rate.

3.5.2 Phase 2: Focus group interview

A research interview may be defined as open response to questions to elicit participants' meanings and how they make sense of important events in their lives (McMillan & Schumacher, 2010). In this study, focus group interview was used to explore the views, experiences, beliefs and teachers' pedagogical practices in science. Focus group interview was ideal as it provided a setting for the teachers to discuss their pedagogical practices and approach to teaching of science. The focus group interview provided high quality data in a social context which helped to answer the research questions (Muhammad & Rana, 2013).

The focus group in the study consists of a small group of six educators who teach science in the senior phase (Grade 7, 8 and 9) and were brought together to share their views, experiences and strategies they adopt in the teaching of science. To achieve the purpose of the focus group interview, I ensured that that the questions asked are relevant to the research study and able to elicit as much information as possible. Furthermore, I ensured that the interviewees are representative of the science teachers in the senior phase (Grades 7-9) and knowledgeable enough so as to provide information to address the research questions. I adhered to the guidelines for an effective and informative interview (Leedy & Ormrod, 2005) which requires that:

i. The interview is conducted in a suitable location where the interviewees are not distracted or interrupted.
ii. The interviewer establishes and maintains rapport, and avoids putting words into respondents' mouth.
iii. Responses from respondents are treated as perceptions rather than facts.
iv. Responses are recorded verbatim, and
v. All participants have a fair chance of responding to questions.

The guiding questions for the focus group and teacher interviews are included as appendix (Appendix B and C).

3.5.2.1 Administration of focus group interview

The focus group interview was held on 6th of March 2018 at a high school in Masemola educational circuit in the Limpopo province. The venue for the focus group interview was chosen as it was conducive and easily accessible to the participants. To ensure that focus group interview produced rich information, the participants were given the questions prior to the interview so that they can familiarize with the questions and provide relevant information. At the start of the focus group interview, I formally introduced myself and stated the purpose of the focus group discussion. In addition, I explained the ground rules which amongst others require that participants do not interrupt one another and that discussion will be based on one person at a time. The interview questions were posed in the order in which they were arranged (see appendix B) and the participants take turns to respond. The focus group discussion was tape recorded verbatim and lasted for about two hours. At the end of the interview sessions, the recorded tape was played so that participants could make changes or further contributions should they wish to.

3.5.3 Phase 3: Lesson observation

Observation in a research entails collecting data by watching behaviour, or witnessing events as they occur in a natural setting (Centre for Disease Control and Prevention, CDC, 2008). In this study, observation was used to gain first-hand information on teaching and learning of science as it occurs in the senior phase (Grades 7-9). In contrast to other data collection methods that rely on a subject's response to questions or statements (McMillan & Schumacher, 2010), observation in a research provides the opportunity to gather live data from the natural environment. That is, the researcher is not relying on second hand versions described by others, but witnessing the events personally (Jollife, 2010). Observation in this study provided means of checking for non-verbal expressions during lessons; determine how learners interact with one another and with the teacher, gain insight on teaching strategies adopted by teachers, and check for how much time is spent on various activities during lessons.

The lessons observation enabled me to gain a holistic understanding of the phenomena under study, and provided a means of triangulating the data obtained from the questionnaire and the focus group interview. The classroom lessons observation focused specifically on the methods and approaches teachers use to provide learning experience, which include amongst others: lesson presentations, learner participation, strategies for catering diverse learning styles, teacher and learner interactions during lessons, the class milieu, and assessment methods (See appendix D).

As a data collection method, observation can be overt with everyone who is being observed knowing that they are being observed, or covert with none who is being observed knowing that they are being observed. The benefit of covert observations is that those who are being observed are more likely to behave naturally if they do not know that they are being observed (Centre for Disease Control and Prevention, CDC, 2008).

However, there are ethical concerns with regards to one concealing his/her observation in a research; hence overt observation was used in the study as it complies with the ethical requirements of disclosing the purpose of the research to the participants. To minimize Hawthorne effects or reactivity due to the presence of the observer, I informed the learners the purpose of the observation and assured that it would not be used for purposes of assessment. I also made teachers aware that the observation of their science lessons was not meant to assess their teaching ability or mastery of subject content. At the beginning of the lesson, I took a position in the classroom where I could observe the lessons without interference.

The recording of the lessons observation was done with observation schedule (See appendix D). To ensure effective observation (Kawulich, 2005), I adhered to the following strategies:

i. being unobtrusive in dress and actions during the course of the observation
ii. familiarizing with the setting before beginning to collect data
iii. keeping the observation short at first to avoid overwhelming the participants
iv. listening carefully to conversations
v. making sense of verbatim conversations, non-verbal expressions, and gestures

vi. Being observant and actively recording the details.

3.5.3.1 Administration of lesson observation

The teachers whose science lessons were observed had taken part in the focus group interview; hence it was easier to inform them about the lesson observation and the dates. Four teachers in the senior phase were purposively selected for the lesson observation which took place in the schools where they are currently teaching. Prior to the lessons observation, I obtained the time table of the participating schools and familiarize with the science periods. This was done to comply with the condition by Limpopo department of basic education (LDBE) that normal lesson periods are not disrupted by the lessons observation. Therefore, the lesson observations were carried out during the normal science lesson periods.

Before the commencement of the science lessons observation, I was introduced to the class by the teacher after which I took a position in the classroom where I could observe the lessons. To record the lesson proceedings, I used lesson observation schedule (Appendix D) and tick the relevant option as the lessons progress. Each lesson observation lasted for one hour and a total of four lessons observation, one per teacher were carried out.

Table 3.1: Overview of data collection methods

Phase	*Instruments*	*Nature of the empirical material*	*Research question 1*	*Research question 2*
1	Survey questionnaire	Transcriptions	✓	✓
2	Lesson Observation	Researcher's observation using time-map events	✓	
3	Focus group interviews	Audio-recorder and transcriptions	✓	✓

3.6 Data analysis and interpretation

Data analysis refers to the process of evaluating data using analytical and statistical tools to discover useful information (Xia & Gong, 2015). This study adopted a mixed method analysis which involves using quantitative and qualitative analytical techniques within the same study (Onwuegbuzie & Combs, 2010). That is in the study, quantitative data was analysed using quantitative methods and qualitative data analysed using qualitative methods (Creswell & Plano, 2007).

The analysis uses data from various collection instruments namely: questionnaire, focus group interview, science lessons observation, and teacher interview. The mixing of the analysed quantitative and qualitative data increased the understanding of the phenomenon under investigation (Johnson, Onwuegbuzie, & Turner, 2007).

3.7 Research rigor

3.7.1 Piloting

Piloting in a research entails pre-testing the data collection instrument to verify its design and feasibility (Jolliffe, 2010). In this study, the questionnaire was piloted to ten science teachers to ensure that wording is unambiguous and to gain feedback on the ease of completion. During the piloting exercise, ten copies of the questionnaire were given out to teachers to complete. In addition, the interview questions and science lesson observations were also piloted to ascertain the feasibility of the exercise.

The participants in the pilot test were not part of the research sample and the data from the exercise were not included in the research results. Feedback from the pilot test was vital and informed the improvements in the final draft that was used in the study.

3.7.2 Triangulation

Triangulation refers to the use of multiple methods or variety of data sources within the same study to develop a comprehensive understanding of a phenomenon under investigation (Onwuegbuzie & Combs, 2010). This study adopted a mixed methods approach which involves integrating quantitative and qualitative research techniques so as to enhance the findings of the research. The qualitative data from the focus group interview, and lessons observation was triangulated with the quantitative data from the questionnaire to gain insight on science teachers' pedagogical practices in the classrooms.

3.7.3 Member checks

Member checking is defined as a quality control technique by which a researcher seeks to improve the accuracy, credibility and validity of what has been recorded during a research interview (Doyle, 2007). To explore the credibility of interview data in a research, the interviewer may return the interview data to participants to check for accuracy and resonance with their responses. The participants either agree or object that the information reflect their views, experiences or account of events; and if accuracy is affirmed by the participants, then the findings are said to be credible (Creswell, 2007). Member checking may also be carried out toward the end of the study when the analysed interview data are presented to the participants to review for accuracy. In that case, the participants may affirm or disagree that the information is a true reflection of their responses (Harper & Cole, 2012).

In this study, the interview proceedings were tape recorded, and at the end of the exercise, the recorded interview responses were played individually to the interview participants to validate; and possibly add more information if they wished to. Member checks were conducted in the study as it provided the opportunity to verify the accuracy of the interview data which enhanced the validity of the study (Cohen & Crabtree, 2006).

3.7.4 Reporting style

In this study, painstaking effort was made to ensure accurate data analysis and reporting of the results. The analysed questionnaire and interview data reflected the authentic responses by the participants. The lesson observation report was a true reflection of the data collected during the science lessons observation. Piloting, triangulation, member checks and painstaking reporting were accomplished in the study to ensure research rigor.

3.8 Ethical considerations

In a research context, ethics focuses on what is morally proper and improper when engaging participants or when collecting data for a research purpose (McMillan & Schumacher, 2010).

According to Neuman (2011), research ethics deals with the concerns, choices and conflicts that arise on proper ways to conduct research. In this regard, ethics provides guidelines when engaging research participants and establish enforcement mechanisms to ensure compliance (Rogelberg, 2008).

This study, complied with the ethical requirements (McMillian & Schumacher, 2010) that in a research, subjects must consent to take part, and this consent must be based on full disclosure of the purpose of the study and the procedure. In addition, the identity of the participants must be protected at all times and the information they provided must not be traced to them (Cohen et al. 2007).

In this study, I applied for ethical clearance and got approval from UNISA College of education ethics review committee (See Appendix F). In addition, I requested and granted permission to embark on the research by the Limpopo department of basic education (See Appendix E). Participants in the study were fully informed of the purpose of the study and the research procedure. The teachers were made aware that participation in the study is voluntary and they can withdraw from the study at any time without consequences.

3.8.1 Confidentiality

Confidentiality in a research entails that no one has access to individual data or the names of the participants except the researcher and that the subjects know before they participate who will see the data (Creswell, 2007). According to McMillan and Schumacher (2010), confidentiality can be accomplished through the following ways:

i. collecting the data anonymously
ii. using a system to link names to data that can be destroyed
iii. using a third party to link names to data and then giving the results to the researcher without the names
iv. asking subjects to use aliases and

v. Reporting only group instead of individual results.

In this study, I assured the participants that their identity and the information they provided will be treated with strict confidentiality and that no information about them and their school will be disclosed. To accomplish this, I used alphabets instead of the participants’ real names when reporting the results.

3.8.2 Informed consent

Informed consent means that prospective research participants are fully informed about the procedures and risks involved in research and must agree to participate (William, 2008). According to McMillan and Schumacher (2010), informed consent can be achieved by explaining to the participants what the research is all about, and providing subjects with an opportunity to terminate their participation at any time with no penalty. In addition, there must full disclosure of any risks associated with the study. When embarking on a research that involves learners, it is advised that the researcher obtain consent by asking subjects or the parents of minor subjects to sign a form that indicates understanding of the research and consent to participate. In this study, the ethical rights of participants to make their own decisions about participation were observed.

3.9 Summary

This chapter focused primarily on the research design and methodology. The chapter discussed the research population, sampling procedure, and data collection methods. The discussions also include analysis and interpretation methods, pilot studies, research rigor and ethical considerations pertaining to the study. The next chapter will focus on data analysis.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 Introduction

The purpose of this study was to explore science teachers' pedagogical practices in the classroom. This chapter presents the data analysis so as to answer the research questions and accomplish the aims of the study. The analysed data in this section were sourced from the survey questionnaire.

4.2 Results and analysis of the teacher survey questionnaire

The survey explored wide range of issues that relate to teaching and learning of natural sciences in the senior phase (Grades 7, 8 and 9), and specifically provided data on teaching conceptions and beliefs; and how teachers create opportunities for learners to participate in learning of science. The questionnaires comprised of two sections; the biographical and the main sections. The discussions that follow are based on the biographical data.

4.2.1 Biographical profile of respondents

The respondents in the survey consisted of senior phase natural science teachers, in other words teachers who teach natural sciences in grades 7, 8 and 9. All the respondents teach in public schools (primary and secondary) at Lobethal, Lepelle, Masemola, and Mashung Educational Circuits in the Limpopo Province. The data collected in this section focused on the age, gender, highest teaching and/or academic qualifications, the grade the teacher is currently teaching, and years of teaching experience (See appendix A). The results obtained are presented as follows:

Table 4.1: The age distribution of the respondents in the survey

Age (years)	number	%
20 and below	0	0
21 – 30	8	10.8
31 – 40	18	24.3

41 - 50	24	32.4
51 and above	24	32.4

It may be seen from the table that majority of the senior phase science teachers who took part in the survey were within the age range of 41- 50, and 51 and above. This corresponds to 64.8% of the respondents, while 24.3% and 10.8% of the respondents fall within the age range of 31 – 40 and 21 – 30 respectively. None of the respondents in the survey aged 20 and below (0%).

Table 4.2: The gender of the questionnaires respondents

Gender	**number**	**%**
Male	46	62
Female	28	38

The information in table 4.2 shows that 62% of the teachers who took part in the survey were male while 38% were female. Based on the data, it may be deduced that more male teachers took part in the survey than female teachers.

Table 4.3: The academic/teaching qualification of the survey respondents

Qualifications	**number**	**%**
Teachers' Diploma	10	13.5
HDE	4	5.4
ACE	8	10.8
BA	2	2.7
B.Sc.	4	5.4
B.Ed.	2	2.7
PGDE	4	5.4
PGCE	10	13.5
B.Sc. (Hons.)	6	8.1
B.Ed. (Hons.)	20	27

MA	2	2.7
MED	2	2.7

Table 4.3 above shows that all the respondents in the survey were academically qualified and majority have different teaching qualifications. Some of the teaching qualifications indicated by the respondents include: HDE (5.4%), Teachers' diploma (13.5%), ACE (10.8%), PGCE (13.5%), PGDE (5.4%), B.Ed. (2.7%), B.Ed. (Hons.), 27% and M.Ed. (2.7%). From the table, it emerges that 5.4% of the respondents have master's degree; MA (2.7%) and M.Ed. (2.7%). Statistical test was performed to establish the significance of the teachers' qualifications to their pedagogical practices when teaching science.

Table 4.4: Chi-Square Tests for the Significant Association between teachers' qualification and their pedagogical practice when teaching science at $p < .05$

		Educational Qualification
I understand different learning styles in my science classroom	Chi-square	6.228
	df	12
	Sig.	.904[a,b]

From the table, it emerges that the calculated value of 6.228 is greater than the critical value of 5.226; the interpretation is that there is a significant association between the educational qualification of the teachers and their pedagogical practice when teaching science in the visited schools. Therefore, the alternative hypothesis is accepted and the null hypothesis is rejected.

Table 4.5: The grades in the senior phase where the respondents are currently teaching

Grade currently teaching	**number**	**%**
Grade 7	22	30
Grade 8	22	30
Grade 9	14	19
Grade 8 and 9	16	21

From table 4.5 above, it emerges that out of the seventy four (74) teachers that took part in the survey, twenty two (30%) teach natural sciences in grade 7, twenty two (30%) teach the subject in grade 8, fourteen (19%) teach in grade 9; and sixteen (21%) teach in both grade 8 and 9. The schools in the study that had one science educator for both grade 8 and 9 were small schools with low learner enrolment whilst the schools with different science educators for grade 8and 9 were big schools with high learner enrolment.

Table 4.6: The number of years of teaching experience of the respondents

Years of teaching experience	Number	%
0 – 5	20	27
6 - 10	16	22
11 –15	14	19
16 - 20	6	08
21 and above	18	24

Evidence from table 4.6 above shows that majority of the respondents in the survey had sufficient number of years of teaching experience in natural sciences at the senior phase. Out of the seventy four (74) respondents that took part in the survey, eighteen (24%) had teaching experience in natural sciences that span over 21 years, six (8%)

had teaching experience that range between sixteen and twenty years; sixteen (22%) had teaching experience between 6 and 10 years, and fourteen (19%) with teaching experience between 11 and 15 years. The respondents with the lowest number of years of teaching experience in science in the senior phase (0 - 5years) account for 27% of the of the survey sample.

4.2.2 Results for main section

Section two of the questionnaire comprised of open and closed ended questions. The open ended questions were meant for respondents to elaborate on their responses while the closed ended questions required the respondents to indicate their level of agreement or disagreement to series of statements that relate to teachers' classroom practices in the teaching and learning of natural sciences in the senior phase. The respondents were to choose one of the following options:

1: Strongly disagree 2: Disagree 3: Neutral/Undecided 4: Agree 5: Strongly agree.

For ease of analysis, the strongly disagree and disagree options have been merged into negative scores (-), whilst agree and strongly agree options are integrated to form the positive scores (+). The neutral or undecided option is represented in the table as n/u. Therefore in the tables that present the questionnaires results, the following keys are used:

_ : Negative scores expressed in percentage (%)

+ : Positive scores expressed in percentage (%)

N/u : Neutral/undecided

G-7 : Grade 7 teachers

G-8 : Grade 8 teachers

G8-9 : Grades 8 and 9 teachers

G-9 : Grade 9 teachers

Lesson presentation in the teaching and learning of natural sciences

Teachers' conceptions and beliefs play a significant role in the way teaching and learning are organized, and to a large extent influence the teaching methods and pedagogical practices in the classrooms (Saleh, 2016). In other words, the teaching methods and pedagogical practices of teachers in the classrooms are influenced by their perceptions and beliefs on how teaching and learning should be organized. In this study, teachers' conceptions and beliefs are thought to influence their pedagogical practices in the classrooms.

The discussed results in this subsection encompass a wide range of pedagogical issues such as lesson presentations, subject content knowledge and competence, awareness of learning difficulties in science, knowledge of diverse learning styles, teaching practices, beliefs and attitudes; and assessment strategies in science.

The following questions (Q2.1- Q2.10) were used to collect data on teachers' approach to lesson presentation in the teaching of natural sciences:

2.1 What do you see as the main purpose of lesson plan in the teaching of natural sciences?

2.2 When I plan for a science lesson, I include the goals or what the learners are supposed to learn, how the goals will be achieved and ways of measuring how well the goals were reached.

2.3 During lesson plan, I refer to the CAPS policy document for natural sciences (Grades 7, 8 and 9) to know the details of the learning contents.

2.4 At the beginning of a science lesson, I state clearly the objectives of the lesson and guide learners towards achieving the objective.

2.5 When I present lesson on a new topic, I link it with the previous topic or knowledge of the learner.

2.6 To ensure effective teaching and learning of science, teachers should design activities or ask questions when new topics are presented to assess learners' pre-conceived notion about it.

2.7 In order for learners to see the practical applications of the learning content, I make provision for expanded opportunity for learners to explore further on the lesson topic.

2.8 When I introduce a new topic, I try to establish some misconceptions about the topic that learners might be having.

2.9 My role as a science teacher in the senior phase is to guide and facilitate learners' inquiry.

2.10 At the end of each science lesson, I make out time to reflect on what worked well and why; and what could have been done differently.

In response to the first question on the main purpose of lesson plan in the teaching of natural sciences, the respondents demonstrated a clear understanding of the purpose of lesson plans as reflected in the extracts below:

Teacher A (Grade 7) "lesson plan is important to the teacher as it clearly outlines the aims and objectives of the lesson, and also helps in planning the strategies the teacher could use to achieve the learning goals"

Teacher B (Grade 8) "It helps the educator to be confident and certain about what must be done in class and how to go about it"

Teacher C (Grades 8 and 9) "lesson plan enables the teacher to comply with the policy requirements for natural sciences in the senior phase, and also help the teacher to plan for intervention strategies. In addition, teachers who go to the class without having planned for the lesson end up doing irrelevant things that are not related to the topic, and learners benefit nothing resulting in poor teaching and learning"

Teacher D (Grade 9) "lesson plan serves as a guide for the teacher throughout the lesson, and helps the teacher to be better prepared before going to the class so as to avoid embarrassment or inability to answer questions which may come from more knowledgeable learners. Furthermore, having a lesson plan before going to class is good as it helps the teacher to manage time and to cover all the topics that is expected to be covered for the year; and in case the teacher is absent or on leave, it will help the new teacher to continue from where the subject teacher has stopped"

Other questions in this subsection were closed ended; the responses are displayed in the table below.

Table 4.7: Teachers' views on lesson presentation in the teaching and learning of natural sciences

	— (%)				N/u (%)				+ (%)			
	G-7	G-8	G8&9	G-9	G-7	G-8	G8&9	G-9	G-7	G-8	G8&9	G-9
Q2.2	2	2	5	2	8	14	25	15	90	84	70	83
Q2.3	12	4	9	2	10	8	7	8	78	88	84	90
Q2.4	0	0	0	0	20	15	18	10	80	85	82	90
Q2.5	12	15	3	2	3	10	4	3	85	75	93	95
Q2.6	0	0	0	0	20	4	15	10	80	96	85	90
Q2.7	19	3	13	3	16	13	12	14	65	84	75	83
Q2.8	10	8	8	8	15	7	22	11	75	85	70	81
Q2.9	0	0	0	0	8	15	10	5	92	85	90	95
Q2.10	17	3	10	14	18	17	15	16	65	80	75	70

As evident from table 4.7 above, when planning for a science lesson (Q2.2), majority of the teachers: Grade 7 (90%), Grade 8 (84%), Grades 8 and 9 (70%); and Grade 9 (83%) indicated that they include the learning goals, how the goals will be achieved and ways of measuring how well the goals were reached. During lesson plan (Q2.3), large majority of the respondents: Grade 7 (78%), Grade 8 (88%), Grades 8 and 9 (84%); and Grade 9 (90%) indicated that they refer to the CAPS policy document for natural sciences (Grades 7, 8 and 9) to know the details of the learning content.

At the beginning of a natural sciences lesson (Q2.4), a large number of teachers: Grade 7 (80%), Grade 8 (85%), Grades 8 and 9 (82%); and Grade 9 (90%) state clearly the objectives of the lesson and guide learners towards achieving the learning goals. When presenting lesson on a new topic (Q2.5), large majority of the teachers: Grade7 (85%), Grade 8 (75%), Grades 8 and 9 (93%); and Grade 9 (95%) link it with the previous topic or the knowledge of the learner.

To ensure effective teaching and learning of natural sciences in the senior phase (Q2.6), overwhelming majority of the teachers: Grade 7 (80%), Grade 8 (96%), Grades 8 and 9 (85%); and Grade 9 (90%), indicated that they design activities or pose questions when new topics are presented to assess learners' preconceived notion about the topic. Pedagogical practice, such as pre-instructional assessment is supported by literature (See subsection 2.4.2) to improve learning as it exposes the misconceptions learners could be having regarding the topic and enables the teacher to address them appropriately before proceeding with the lesson. Therefore, when new topics are introduced during science lessons (Q2.8), large number of the teachers: Grade 7 (75%), Grade 8 (85%), Grades 8 and 9 (70%); and Grade 9 (81%) devise means to establish the misconceptions about the topic learners might be having. In addition, majority of the teachers: Grade 7 (65%), Grade 8 (84%), Grades 8 and 9 (75%); and Grade 9 (83%) make provisions for expanded opportunity so that learners can see the practical applications of the learning content.

With regards to the role of a science teacher in the classroom (Q2.9), an overwhelming majority of the teachers: Grade 7 (92%), Grade 8 (85%), Grades 8 and 9 (90%); and Grade 9 (95%) perceived their roles as facilitators of learners' inquiry. At the end of each science lesson (Q2.10), large number of the teachers: Grade 7 (65%), Grade 8 (80%), Grades 8 and 9 (75%); and Grade 9 (70%) make out time to reflect on what worked well and why; and what could have been done differently.

Subject content Knowledge and competence in the teaching of natural sciences

The results discussed in this subsection were based on teachers' subject content knowledge and competence in the teaching of natural sciences. The results are in response to the following questions (Q3.1 – Q3.8)

3.1 I have adequate subject content knowledge for effective teaching of natural sciences in the senior phase.

3.2 Some of my courses during teaching training were science related.

3.3 I feel more confident teaching life science topics than physics and chemistry topics in the natural sciences.

3.4 I find it difficult to teach the topic chemical change in the senior phase.

3.5 For me, the teaching of balancing of chemical equation is very challenging.

3.6 I consider myself a good science teacher.

3.7 When I present lessons, I make sure that I carry all learners along.

3.8 All learners in the senior phase are capable of excelling in science.

3.9 Which topic(s) in natural sciences do you find challenging to teach?

3.10 In what ways do you think the teaching and learning of natural science can be improved?

The responses to the questions are shown in the table below.

Table 4.8: Results of subject content knowledge and competence in the teaching of natural sciences

	– (%)				N/u (%)				+ (%)			
	G-7	G-8	G8&9	G-9	G-7	G-8	G8&9	G-9	G-7	G-8	G8&9	G-9
Q3.1	24	27	11	19	11	13	14	11	65	60	75	70
Q3.2	25	17	21	12	5	3	4	3	70	80	75	85
Q3.3	24	37	42	41	16	13	18	16	60	50	45	43
Q3.4	51	45	53	60	19	16	18	10	30	37	29	30
Q3.5	37	58	50	54	19	17	20	19	44	25	30	27
Q3.6	8	5	7	5	18	15	18	25	74	80	75	70
Q3.7	0	0	0	0	7	5	12	8	93	95	88	92
Q3.8	40	35	48	32	25	45	36	46	35	20	16	22

When analysed per grade (Q3.1), majority of Grade 7 teachers (65%) indicated that they have adequate subject content knowledge for teaching of natural sciences, 11%

were uncertain about their subject content knowledge, whilst 24% expressed lack of adequate subject content knowledge for effective teaching of natural sciences.

For Grade 8, 60% of the teachers indicated that they have adequate subject content knowledge, 13% expressed uncertainty in this regard whilst 27% indicated that they lack adequate subject content knowledge for effective teaching of natural sciences. A large majority (75%) of educators who teach in both Grade 8 and 9 indicated that they have adequate subject content knowledge; 14% expressed uncertainty about their subject content knowledge, whilst 11% indicated lack of adequate subject content knowledge for effective teaching of natural sciences. Similarly, 70% of Grade 9 teachers indicated that they have adequate subject content knowledge for teaching of science, 11% expressed uncertainty about their subject content knowledge whilst 19% expressed lack adequate subject content knowledge for effective teaching of natural sciences.

Of concern is the fact that cross all the grades, a significant number of teachers: Grade 7 (24%), Grade 8 (27%), Grades 8 and 9 (11%); and Grade 9 (19%) expressed lack of adequate subject content knowledge for effective teaching of science teaching. As found in the literature study (See subsection 2.4.2) lack of subject content knowledge by teachers compromises effective teaching in the classrooms which may lead to poor academic performance .

Large majority of the teachers indicated that some of their courses during teaching training were science related (Q3.2), which when analysed per grade corresponds to 70% of Grade 7 teachers, 80% of Grades 8 teachers, 75% of Grades 8 and 9 teachers; and 85% of Grade 9 teachers.

With regard to teacher confidence in the teaching of natural sciences topics (Q3.3), 60% of Grade 7 teachers indicated that they feel more confident teaching life science than physical science topics (Chemistry and physics); 50% of Grade 8 teachers expressed more confidence in teaching life science than physical science topics; 45% of Grades 8 and 9 teachers indicated more confidence teaching life science than physical science topics; whilst 43% of Grade 9 teachers expressed preference in teaching life science than physical science topics.

When compared across the grades: 24% of Grade 7 teachers indicated more confidence in teaching physical science than life science topics, which is the same for Grade 8 (37%), Grades 8 and 9 (42%); and Grade 9 (41%) teachers respectively. Of concern though is the fact that across all the grades, a sizeable number of teachers: Grade 7 (16%), Grade 8 (13%), Grades 8 and 9 (18%); and Grade 9 (16%) were uncertain about their confidence in the teaching of physical and life science topics. Therefore, one may not know if these teachers lack confidence in the teaching of physical and/or life science topics.

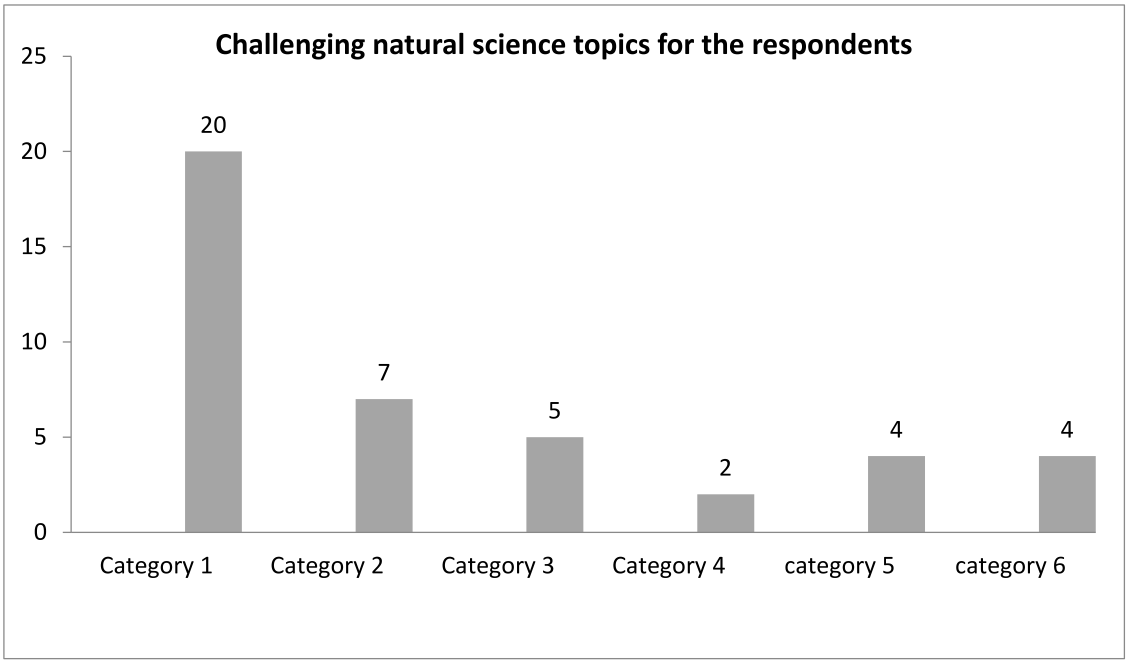
The problem that arises when natural sciences teachers are not evenly confident in their ability to teach both life science and physical science topics is that they tend to be selective in topics to teach which could compromise content coverage and effective teaching and learning. Based on these results, it may be infered that in the subject of natural sciences (Grade 7- 9); majority of the teachers in the study prefer to teach life science than physical science topics. This result corroborates that of Bosman (2006) that explored the value, place and method of teaching natural sciences in the foundation phase (Grades R- 3); which found that most natural sciences teachers in the foundation phase prefer the teaching of life science to physical science topics.

Across all the grades, a large number of teachers expressed difficulty in teaching some of the chemistry topics (Q3.4). This corresponds to 30% of Grade 7 teachers, 37% of Grade 8, 29% of Grades 8 and 9; and 30% of Grade 9 teachers. Similarly, 44% of Grade 7, 25% of Grade 8, 30% of Grades 8 and grade 9; and 27% of Grade 9 teachers indicated challenges when teaching balancing of chemical equations (Q3.5).

Whilst overwhelming majority of the teachers: Grade 7 (74%), Grade 8 (80%), Grades 8 and 9 (75%); and Grade 9 (70%) considered themselves as good science teachers (Q3.6); and carry their learners along during natural sciences lessons (Q3.7), quite a significant number: Grade 7 (25%), Grade 8 (45%), Grades 8 and 9 (36%); and Grade 9 (46%) were uncertain if all learners in the senior phase are capable of excelling in science (Q3.8). Across all the grades, smaller number of teachers: Grade 7 (35%), Grade 8 (20%), Grades 8 and 9 (16%); and Grade 9 (22%) expressed belief that all learners in the senior phase are capable of excelling in science. This contrasts to the higher number of teachers: Grade 7 (40%), Grade 8 (35%), Grades 8 and 9 (48%) and Grade 9 (32%) that expressed lack of belief that all learners in the senior phase are capable of excelling in science.

With regard to the topics in natural sciences that respondents consider challenging to teach (Q3.9), Some of the teachers indicated topics such as: earth and beyond, acids and bases, chemical change, elements and compounds, periodic table, and electric circuits. The graph below illustrates the various natural sciences topics that respondents found challenging to teach.

Figure 4.1: The challenging topics for the respondents in natural sciences



Category 1: Earth and beyond; Category 2: Chemical change; Category 3: Elements and compound; Category 4: Periodic table; Category 5: Electric circuit; Category 6: Acids and bases.

As evident from figure 4.1 above, the topics related to earth and beyond (category 1), chemical change (category 2), and elements and compounds (category 3) appear to be challenging for a greater number of the respondents; than electric circuits (category 5), acids and bases (category 6), and periodic table (category 4).

On ways that can be used to improve the teaching and learning of natural sciences in the senior phase (Q3.10), the teachers suggested different strategies. The responses are summarized in the extracts below.

Teacher E (Grade 7); “The teaching and learning of natural sciences in the senior phase may be improved through content training of science teachers at least on a yearly basis and also by delivering enough textbooks to schools as learners in most rural schools do not have textbooks which makes teaching and learning very difficult”.

Respondent F (Grade 8); “To improve the teaching and learning of naturals sciences in schools, the government must equip schools with resources because teachers are just teaching theory and without the relevant teaching aids, it will be difficult for learners to understand the concepts. Let every school in the country be supplied with science equipment to enable teachers present their lessons effectively”.

Respondent G (Grades 8 and 9); “There is a very little room for catering different learning styles in the classrooms due to resource limitations. If more teaching aids for example, textbooks, videos, colourful charts and posters etc., could be supplied; it would bring a significant improvement in the teaching and learning of natural sciences”

Respondent H (Grade 9); “The department of education must supply teaching and learning support materials on time, and provide schools with equipped science laboratories to enable teachers conduct science experiments with their learners”

Knowledge of learning difficulties in natural sciences

The results discussed in this subsection were based on the following questions (Q4.1-Q4.11) that explored teachers’ knowledge of learning difficulties in natural sciences

4.1 I am aware of the sources of learning difficulties in natural sciences in the senior phase.

4.2 Often times, learners mistook science terms for everyday use meaning.

4.3 Learning difficulties in chemistry/science stem from the inability of learners to grasp the microscopic level and macroscopic level simultaneously.

4.4 When I provide learning experiences, I organize learning tasks in an increasing order of complexity for optimal learning.

4.5 During science lessons, If I want to teach learners a more complex concept, I begin by providing learners with the most basic version of the concept, and then gradually present lessons that will ultimately lead to the realization of the learning goals.

4.6 When I present lesson on a new topic, I provide learners with a summary of the previous lessons, so that they can fully grasp the concept in the new topic.

4.7 In my lessons, when I introduce a new topic, I first establish the depth and level of learners' knowledge base in the topic.

4.8 Learners' prior knowledge is an asset that can be tapped into to link new concepts and learners' misconception.

4.9 To ensure effective learning, when I present lessons; I explicitly explain the meaning of science terms and differentiate them from every day use.

4.10 As a natural sciences teacher in the senior phase, I am aware that what learners already know is a key factor in learning.

4.11 I have a high expectation of my learners in science.

The responses to the questions are displayed in the table below:

Table 4.9: The results of teachers' knowledge of learning difficulties in natural sciences

	– (%)				N/u (%)				+ (%)			
	G-7	G-8	G8&9	G-9	G-7	G-8	G8&9	G-9	G-7	G-8	G8&9	G-9
Q4.1	12	16	7	12	13	14	13	10	75	70	80	78
Q4.2	9	13	11	11	35	37	29	32	56	50	60	57

Q4.3	15	14	15	20	40	38	25	30	45	48	60	50
Q4.4	5	5	9	5	25	17	21	19	70	78	70	76
Q4.5	11	5	7	10	14	5	8	12	75	90	85	78
Q4.6	7	12	10	6	8	18	12	14	85	70	78	80
Q4.7	10	6	12	7	15	12	10	6	75	82	78	87
Q4.8	11	15	5	6	9	10	5	9	80	75	90	85
Q4.9	17	22	13	12	13	10	12	8	70	68	75	80
Q4.10	10	15	10	7	22	10	5	5	68	75	85	88
Q4.11	8	10	5	6	12	17	10	6	80	73	85	88

As evident from the table above, large majority of the teachers: Grade 7 (75%), Grade 8 (70%), Grades 8 and 9 (80%); and Grade 9 (78%) indicated being aware of the sources of learning difficulties in natural sciences (Q4.1). However, a significant number: Grade 7 (35%), Grade 8 (37%), Grades 8 and 9 (29%); and Grade 9 (32%) were uncertain if learners sometimes mistook science terms for everyday use meaning (Q4.2). As found in the literature (See subsection 2.4.2) science topics incorporate many abstract terms and concepts that are different from everyday use meaning, hence meaningful learning may not take place if these concepts are not fully grasped and/or if learners are unable to differentiate science terms from everyday use meaning.

In a much similar result, a significant number of the teachers: Grade 7 (40%), Grade 8 (38%), Grades 8 and 9 (25%), and Grade 9 (30%) were uncertain if learning difficulties in chemistry stem from the inability of learners to grasp the microscopic level and macroscopic level simultaneously (Q4.3). With regard to organizing learning contents during science lessons (Q4.4), large majority of the respondents: Grade 7 (70%), Grade 8 (78%), Grades 8 and 9 (70%), and Grade 9 (76%) indicated that when they provide learning experience, they organize learning tasks in an increasing order of complexity for optimal learning. Across all the grades, the teachers: Grade 7 (75%), Grade 8 (90%), Grades 8 and 9 (85%), and grade 9 (78%) indicated that during lessons if they want to teach a more complex topic, they begin by providing learners with the most basic version of the topic and then gradually present lessons that will ultimately lead to the realization of the learning goals (Q4.5). As indicated by the teachers, the pedagogical practice such as organizing learning content in an increasing order of complexity enhances effective teaching and learning in the classroom.

Similarly, overwhelming majority of the teachers: Grade 7 (85%), Grade 8 (70%), Grades 8 and 9 (78%), and Grade 9 (80%) indicated that when they present lesson on a new topic (Q4.6), they provide learners with a summary of the previous lesson so that they can fully grasp the concepts in the new topic.

Large majority of the teachers: Grade 7 (80%), Grade 9 (75%), Grades 8 and 9 (90%), and Grade 9 (85%), considered learners' prior knowledge as an asset that can be tapped into to link new concepts and learners' misconception (Q4.8). Hence when new topics are introduced in class (Q4.7), the teachers: Grade 7 (75%), Grade 8 (82%), Grades 8 and 9 (78%), and grade 9 (78%) first establish the depth and level of learners' knowledge base in the topic.

To ensure effective teaching and learning in the classroom, when lessons are presented (Q4.9), large number of the teachers: Grade 7 (70%), Grade 8 (68%), Grades 8 and 9 (75%), and Grade 9 (80%) indicated that they explain the meaning of science terms and differentiate them from every day use.

Large majority of the respondents: Grade 7 (68%), Grade 8 (75%), Grades 8 and 9 (85%) and Grade 9 (88%) expressed the belief that what learners already know is a key factor in learning. Across all the grades, overwhelming majority of the teachers: Grade 7 (80%), Grade 8 (73%), Grades 8 and 9 (85%), and Grade 9 (88%) indicated high expectation of learners in science.

Knowledge of diverse learning styles in science

The discussions in this subsection were based on the results from the following questions (Q5.1- Q5.8)

5.1 I understand different learning styles in my science classroom.

5.2 I use array of teaching strategies to accommodate diverse learning styles in my lessons.

5.3 I have adequate knowledge and understanding of learners, their individual differences and learning styles.

5.4 I use variety of instructional materials and teaching aids to promote learning.

5.5 To cater for visual learners in my science class, I provide learning experience that is enriched with visual images such as colourful posters, charts, drawings and other images of educational value.

5.6 To cater for kinaesthetic learners in my science lessons, I provide hands on learning approach and engage learners in science practical activities, building models and designs.

5.7 To cater for interpersonal intelligence in my science lessons, I engage learners in group work, projects and cooperative learning tasks.

5.8 Science teachers in the senior phase should adapt their teaching and use approaches that best suit the needs or context of their classrooms.

The responses to the questions are displayed in the table below:

Table 4.10: The results of teachers' knowledge of diverse learning styles in science

	– (%)				N/u (%)				+ (%)			
	G-7	G-8	G8&9	G-9	G-7	G-8	G8&9	G-9	G-7	G-8	G8&9	G-9
Q5.1	14	6	9	7	16	6	11	7	70	88	80	86
Q5.2	17	14	15	11	8	5	7	3	75	81	78	86
Q5.3	13	15	8	11	9	14	7	9	78	71	85	80
Q5.4	14	8	8	11	16	12	10	14	70	80	72	75
Q5.5	21	22	17	16	15	18	18	14	64	60	65	70
Q5.6	16	8	10	11	15	12	15	11	69	80	75	78
Q5.7	8	5	10	6	7	5	7	3	85	90	83	91
Q5.8	4	10	7	3	8	12	8	3	80	78	85	94

As evident from table 4.10, large majority of the respondents indicated that they understand the different learning styles in science (Q5.1). When compared across the grades, this corresponds to: 70% of Grade 7 teachers, 88% of Grade 8 teachers, 80% of Grades 8 and 9 teachers, and 86% of Grade 9 teachers. In contrast, a small number of the respondents indicated that they do not understand the different learning styles in science which when compared across the grades corresponds to 14% of Grade 7 teachers, 6% of Grade 8 teachers, 9% of Grades 8 and 9, and 7% of Grade 9 teachers.

Similarly, a large number of the teachers: Grade 7 (78%), Grade 8 (71%), Grades 8 and 9 (85%), and Grade 9 (80%) indicated that they have adequate knowledge and understanding of learners, their individual differences and learning styles (Q5.3).

To cater for the diverse learning styles of learners (Q5.2), overwhelming majority of the teachers: Grade 7 (75%), Grade 8 (81%), Grades 8 and 9 (78%), and Grade 9 (86%) indicated that they use array of teaching strategies in their classrooms. Similarly to promote learning (Q5.4), large number of the teachers: Grade 7 (70%), Grade 8 (80%), Grades 8 and 9 (72%), and Grade 9 (75%) indicated that they use variety of instructional materials and teaching aids.

As found in the literature (See subsection 2.4.3), being aware and matching teaching methods to learning styles impact positively on learners' academic achievement. In this study, majority of the teachers: Grade 7 (64%), Grade 8 (60%), Grades 8 and 9 (65%) and Grade 9 (70%) indicated that to cater for visual learners; they provide learning experience that is enriched with visual images such as colourful posters, charts, drawings and other images of educational value (Q5.5).

To cater for kinaesthetic learners (Q5.6), large number of the teachers: Grade 7 (69%), Grade 8 (80%), Grades 8 and 9 (75%), and Grade 9 (78%), indicated that they provide a hands on learning approach and engage learners in science practical activities, building models and designs. For interpersonal intelligence (Q5.7), the teachers: Grade 7 (85%), Grade 8 (90%), Grades 8 and 9 (83%), and Grade 9 (91%), revealed that they engage learners in group work, projects and cooperative learning tasks. Across all the grades, overwhelming majority of teachers: Grade 7 (80%), Grade 8 (78%), Grades 8 and 9 (85%), and Grade 9 (94%) expressed the view that science teachers should adapt their teaching and use approaches that best suit the needs or context of their classrooms.

Teaching practices, beliefs and attitudes

The results discussed in this subsection pertain to teaching practices, beliefs and attitudes. They were based on the following statements: (Q6.1- Q6.11),

6.1 A quiet classroom is generally needed for effective teaching and learning of science in the classrooms.

6.2 Learners should be allowed to think of solutions to a learning task themselves before the teacher shows them how they are solved.

6.3 My role as a science teacher in the senior phase is to facilitate learners' own inquiry

6.4 Teachers know a lot more than learners and should therefore transmit information to them.

6.5 Students learn best by finding solutions to problems on their own.

6.6 It is better when the teacher and not the learners decide what activities are to be done in the classroom.

6.7 Rote learning and memorization of facts are ineffective approach to learning science

6.8 Science teachers in the senior phase should improvise when conducting experiment with learners.

6.9 How much students learn depend on how much background knowledge they have, and that is why teaching facts is so necessary.

6.10 Science instructions should be built around problems with clear correct answers and ideas that most learners can grasp quickly.

6.11 In my classroom, to maintain order and discipline; I explicitly state the rules and regulations which I display in the classroom for learners to read.

The responses to the questions are described below:

Table 4.11: Results of teaching practices, beliefs and attitudes

	– (%)				N/u (%)				+ (%)			
	G-7	G-8	G-8&9	G-9	G-7	G-8	G8&9	G-9	G-7	G-8	G8&9	G-9
Q6.1	14	22	14	18	18	18	16	14	68	60	70	68
Q6.2	12	8	5	4	16	12	10	6	72	80	85	90
Q6.3	0	0	0	0	10	15	10	5	90	85	90	95
Q6.4	16	18	12	20	14	16	16	11	70	66	72	69
Q6.5	12	10	10	6	23	18	14	11	65	72	76	83
Q6.6	12	25	21	21	18	15	14	11	70	60	65	68
Q6.7	20	17	21	18	15	13	16	14	65	70	63	68
Q6.8	4	5	2	3	2	5	1	2	94	90	97	95
Q6.9	10	8	8	8	22	20	17	19	68	72	75	73
Q6.10	10	11	10	11	12	7	5	8	78	82	85	81
Q6.11	4	5	6	3	6	10	15	10	90	85	79	87

As evident from table 4.11, a large number of teachers: Grade 7 (68%), Grade 8 (60%), Grades 8 and 9 (70%), and Grade 9 (68%) indicated that a quiet classroom is generally needed for effective teaching and learning of natural sciences (Q6.1). Similarly, large majority: Grade 7 (70%), Grade 8 (66%), Grades 8 and 9 (72%), and Grade 9 (69%) indicated that teachers know a lot more than learners and should therefore transmit information to them (Q6.4). The data from Q6.1 and Q6.4 reflects behaviouristic view of learning which suggests that majority of the teachers in the study may be predisposed to teacher- centred approach when teaching natural sciences. As found in the literature (See subsections 2.5.2, 2.7.2), teacher centred pedagogy requires that learners pay attention, and absorb whatever the teacher presents in class. However, other responses by the teachers reflect constructivist approach. For instance an overwhelming majority of the teachers: Grade 7 (90%), Grade 8 (85%), Grades 8 and 9 (90%), and Grade 9 (95%) perceived their roles in the classrooms as facilitators of learners' own inquiry (Q6.3). A large majority: Grade 7 (72%), Grade 8 (80%), Grades 8 and 9 (85%), and

Grade 9 (90%) indicated that learners should be allowed to think of solutions to a learning task themselves before the teacher shows them how they are solved (Q6.2).

In a similar trend, majority of the teachers: Grade 7 (65%), Grade 8 (70%), Grades 8 and 9 (63%), and Grade 9 (68%) considered rote learning and memorization of facts as ineffective approach to learning science (Q6.7). Large number of the teachers: Grade 7 (65%), Grade 8 (72%), Grades 8 and 9 (76%), and Grade 9 (83%) expressed belief that students learn best by finding solutions to problems on their own (Q6.5).

In other results, overwhelming majority of the respondents: Grade 7 (68%), Grade 8 (72%), Grades 8 and 9 (75%) and Grade 9 (73%) indicated that how much students learn depend on how much background knowledge they have; which makes teaching of facts very necessary (Q6.9). Across all the grades, large majority of the teachers: Grade 7 (78%), Grade 8 (82%), Grades 8 and 9 (85%), and Grade 9 (81%) indicated that science instructions should be built around problems with clear correct answers and ideas that most learners can grasp quickly (Q6.10).

When conducting science experiments (Q6.8), large majority of the respondents: Grade 7 (94%), Grade 8 (90%), Grades 8 and 9 (97%) and Grade 9 (95%) indicated that teachers should improvise. To maintain order and discipline in the classroom (Q6.11), a large number of the teachers: Grade 7 (90%), Grade 8: (85%), Grades 8 and 9, (79%), and Grade 9: (87%) indicated that they explicitly state rules and regulations which they display in the classroom for learners to read.

Teaching and assessment strategies

This section explored teaching and assessment strategies in science. Unlike in the previous sections, within this section the respondents were required to indicate how often they carry out specific teaching practices that are described in the statements below (Q7.1- Q7.10).

7.1 I present new topics to the class lecture style.

7.2 I explicitly state learning goals at the beginning of every lesson.

7.3 At the beginning of a lesson, I present a short summary of the previous lesson.

7.4 I use variety of assessment strategies to evaluate attainment of learning outcome.

7.5 I give feedback to learners on every assessment task.

7.6 I check my learners' notebooks and classwork books.

7.7 Learners work in small diverse ability groups to complete a learning task.

7.8 Learners work individually to complete a learning task.

7.9 Practical work is carried out to illustrate concepts that have been introduced.

7.10 I administer test to assess student learning.

The responses to the questions are shown in the table below.

Table 4.12: Results of teaching and assessment strategies

	Never (%)				Rarely (%)				*Sometimes/ Most of the time (%)			
	G-7	G-8	G8&9	G-9	G-7	G-8	G8&9	G-9	G-7	G-8	G8&9	G-9
Q7.1	3	5	6	4	7	10	12	8	90	85	82	78
Q7.2	0	0	0	0	12	5	10	15	88	95	90	85
Q7.3	12	15	10	14	13	10	12	11	95	90	94	75
Q7.4	0	0	0	0	18	10	11	8	82	90	89	92
Q7.5	2	4	5	0	12	9	13	10	86	87	82	90
Q7.6	0	0	0	0	0	0	0	0	100	100	100	100
Q7.7	0	0	0	0	8	15	11	3	92*	85*	89*	97*
Q7.8	6	4	3	5	4	8	7	3	90*	88*	90*	92*
Q7.9	0	0	0	0	8	4	10	5	92*	96*	90*	95*
Q7.10	0	0	0	0	10	5	2	4	90	95	98	96

As evident from table 4.12, overwhelming number of teachers: Grade 7 (90%), Grade 8 (85%), Grades 8 and 9 (82%), and Grade 9 (79%) indicated that most of the time they present new topics to the class lecture style (Q7.1). In a similar trend, the teachers:

Grade 7 (88%), Grade 8 (95%), Grades 8 and 9 (90%), and Grade 9 (85%) indicated that most of the time they state the learning goals at the beginning of a new lesson (Q7.2). The trend persisted across all the grades where large majority of the teachers: Grade 7 (95%), Grade 8 (90%), Grades 8 and 9 (94%), and Grade 9 (75%) expressed that most of the time they provide a short summary of the previous lesson before they proceed with the new one (Q7.3).

Across all the grades, overwhelming majority of the teachers: Grade 7 (82%), Grade 8 (90%), Grades 8 and 9 (89%), and Grade 9 (92%) indicated that they use variety of assessment strategies to evaluate attainment of learning outcome in natural sciences (Q7.4). Similarly, large majority of the teachers: Grade 7 (86%), Grade 8 (87%), Grades 8 and 9 (82%), and Grade 9 (90%) indicated that they give feedback to learners on every assessment task (Q7.5).

Large number of the teachers: Grade 7 (77%), Grade 8 (92%), Grades 8 and 9 (89%), and Grade 9 (97%) indicated that sometimes they allow learners to work in small diverse ability groups to complete a learning task (Q7.7); whilst other times the teachers: Grade 7 (90%), Grade 8 (88%), Grades 8 and 9 (90%), and grade 9 (92%) let learners work individually to complete a learning task (Q7.8). As indicated by the teachers, pedagogical practice such as collaborative work is supported by social constructivism (See subsection 2.5.3) as when learners work in diverse ability groups, the less capable ones are able to learn from the more capable peers. Overwhelming majority of the teachers: Grade 7 (92%), Grade 8 (96%), Grades 8 and 9 (90%) and grade 9 (95%) indicated that sometimes they organize practical work to illustrate concepts that have been introduced (Q7.9); and most of the time they: Grade7 (90%), Grade 8 (95%), Grades 8 and 9 (98%), and Grade 9 (96%) administer test to assess student learning (Q7.10). All the teachers in the study indicated that they check learners' notebooks and classwork books (Q7.6).

4.3 The reliability statistics and Cronbach's alpha coefficient

The previous section focused on the analysis of the questionnaire results so as to gain insight on science teachers' pedagogical practices in the classroom. The analysed data on various aspects that relate to teaching and learning of natural sciences were instrumental in answering the research questions. This section discusses the reliability statistics of the items in the questionnaire. The Cronbach's alpha measures internal consistency or how ideal and closely related a set of items are in measuring a construct under investigation (Institute for Digital Research and Education, IDRE, 2018). In this study, the Cronbach's alpha coefficient was calculated using the SPSS software and as a rule of thumb, alpha values greater than 0.7 indicate reliability.

4.3.1 Reliability statistics for items on lesson presentation

Subsection 1 of the questionnaire comprised of nine items that explored science teachers' approach to lesson presentation in the teaching and learning of natural sciences. The responses to the questions used a 5-point Likert scale, and the Cronbach's alpha calculated to determine the reliability of the items. The results are shown in the table below.

Table 4.13: Reliability statistics for items on lesson presentation

Cronbach's alpha	Cronbach's alpha based on standardized items	No. of items
0.954	0.952	9

The reliability statistics table presented above shows a Cronbach's alpha value of 0.954 for the questions that explored science teachers' approach to lesson presentation. The interpretation is that the questions within this section were highly reliable in exploring science teachers' approach to lesson presentation. In addition to the reliability statistics, item- total statistics was analysed to establish whether the reliability or alpha value (α = 0.954) would increase or decrease if some of the questions in the section were removed.

Table 4.14: Item – total statistics for lesson presentation in the teaching of natural sciences

Items	Scale mean if Item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's alpha if item deleted
Q2.2	33.76	27.365	0.946	0.942
Q2.3	33.76	26.077	0.955	0.941
Q2.4	33.72	29.384	0.896	0.947
Q2.5	33.59	28.738	0.894	0.945
Q2.6	33.36	30.345	0.896	0.948
Q2.7	34.62	35.471	0.750	0.976*
Q2.8	33.89	25.385	0.962	0.942
Q2.9	33.36	30.345	0.896	0.948
Q2.10	33.82	26.804	0.947	0.942

The last column of table 4.14 above (Cronbach's alpha if items deleted) shows the alpha value that would be obtained if any question in this section were removed. For instance, if Q2.2 was deleted, the alpha value would decrease from 0.954 to 0.942; hence it was retained as it increased the reliability of the questions in exploring science teachers' approach to lesson presentation in natural sciences. The same applies to all the other questions which if removed from the section would decrease the alpha value ($\alpha = 0.954$), hence they were all retained in the questionnaires. Removing Q2.7 from this section would slightly increase the alpha value from 0.954 to 0.976, an increase of 0.02 (rounded off to 2 decimal places) which is insignificant; hence it was retained as it contributed to the reliability of the questions in exploring the construct under investigation.

4.3.2 Reliability statistics for items on content knowledge and competence in the teaching of natural sciences

This subsection comprised of eight questions that explored teachers' content knowledge and competence in the teaching of natural sciences. The responses to the questions used a 5-point Likert scale and Cronbach's alpha calculated to determine the reliability of the questions. The SPSS output for the reliability of the questions is shown in the table below.

Table 4.15: Reliability statistics for items on subject content knowledge and competence in the teaching of natural sciences

Cronbach's alpha	Cronbach's alpha based on standardized items	No. of items
0.967	0.976	8

The table above shows a Cronbach's alpha value of 0.967 for the items that explored teachers' subject content knowledge and competence in the teaching of natural sciences. The interpretation is that the questions within the section were highly reliable in exploring teachers' subject content knowledge and competence in the teaching of natural sciences. In addition, item- total statistics was performed to determine the questions that could be removed to further enhance the reliability. The table below summarizes the result.

Table 4.16: Item – total statistics for subject content knowledge and competence in the teaching of natural sciences

Items	Scale mean if item deleted	Scale variance if item deleted	Corrected item- total correlation	Squared multiple correlation	Cronbach's alpha if item deleted
Q3.1	24.26	54.851	0.887	0.882	0.963
Q3.2	24.14	55.269	0.803	0.929	0.966
Q3.3	25.35	45.190	0.952	0.951	0.961
Q3.4	25.65	48.478	0.934	0.949	0.959
Q3.5	28.85	47.279	0.923	0.955	0.961
Q3.6	24.39	53.310	0.938	0.937	0.960

Q3.7	24.04	57.985	0.898	0.936	0.967
Q3.8	25.64	51.084	0.891	0.836	0.961

From table 4.16 above, it emerges that all the alpha values in the column of "Cronbach's alpha if item is deleted" were less than the alpha value for this cluster (α = 0.967), which meant that if any question were removed from this section the reliability or the alpha value would decrease. For instance if item Q3.1 was deleted, the alpha value would decrease from 0.967 to 0.963; hence it was retained as doing so increased the reliability of the questions in collecting data on the construct being investigated.

The same applies to all the other questions which if removed from the cluster would decrease the reliability or the alpha value, hence they were retained. If item Q3.7 were removed, the alpha value would remain the same (α = 0.967), hence it was retained as it contributed to providing insight on teachers' subject content knowledge and competence in the teaching of natural sciences.

4.3.3 Reliability statistics for items on knowledge of learning difficulties in science

This section consists of eleven questions that explored the teachers' knowledge of learning difficulties in science. The responses to the questions used a 5- point Likert scale, and the Cronbach's alpha calculated to determine the reliability of the questions. The table below presents the result.

Table 4.17: Reliability statistics for items on knowledge of learning difficulties in natural sciences

Cronbach's alpha	Cronbach's alpha based on standardized items	No. of items
0.983	0.987	11

As the table above shows, the Cronbach's alpha value for the items in this section was 0.983 which indicated high reliability of the questions in the cluster. Similarly, item– total statistics was analysed to determine whether the alpha value would increase or decrease if any item in the cluster was removed. The result of the item- total statistics is presented in the table below

Table 4.18: Item- total statistics for items on knowledge of learning difficulties in science

Items	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Cronbach's alpha if item deleted
Q4.1	43.08	58.459	0.954	0.980
Q4.2	43.59	57.696	0.918	0.982
Q4.3	43.07	58.995	0.957	0.980
Q4.4	43.19	58.019	0.960	0.980
Q4.5	43.07	58.995	0.957	0.980
Q4.6	42.95	62.244	0.969	0.980
Q4.7	42.96	64.313	0.885	0.983
Q4.8	42.92	61.363	0.945	0.981
Q4.9	42.81	65.388	0.901	0.983
Q4.10	42.82	66.804	0.816	0.985*
Q4.11	43.05	59.449	0.970	0.980

The column of "Cronbach's alpha if item deleted" in table 4.18 above indicates what the alpha would be if an item or question is removed from the section. For instance if Q4.2 and Q4.3 were removed, the alpha value for the cluster would decrease from 0.983 to 0.982 and 0.980 respectively, hence the questions were retained as doing so increased the reliability of the questions that explored teachers' knowledge of learning difficulties in science. The table also show that all the alpha values (except Q4.7, Q4.9, and Q4.10) in the last column, were all smaller than the alpha value for the cluster which implies that if any of these questions was deleted, the reliability of the scale would decrease; hence the questions were retained. It must be pointed out that if Q4.10 was deleted, the alpha value would increase from 0.983 to 0.985 (an increase of 0.002) which is insignificant, therefore the question was retained as it contributed to a better understanding of the science teachers' knowledge of learning difficulties in science. Similarly if Q4.7 and Q4.9 were removed, alpha value would remain the same (α = 0.983), hence they were retained in the cluster as they provided diverse perspective in exploring the construct under investigation.

4.3.4 Reliability statistics for knowledge of learning styles in science

This section comprised of seven questions that explored teachers' knowledge of diverse learning styles in science. The responses to the questions used a 5-point Likert scale, and Cronbach's alpha calculated to determine the reliability of the items.

Table 4.19: Reliability statistics for items on knowledge of diverse learning styles in science

Cronbach's alpha	Cronbach's alpha based on standardized items	No. of items
0.981	0.987	7

As shown in table 4.19 above, the Cronbach's alpha for the items in this cluster was 0.981 which indicated reliability for the questions that explored science teachers' knowledge of diverse learning styles in science. Similarly, item- total statistics was analysed to determine how the reliability of the items would change if any question was removed from the cluster. The item- total statistics result is presented in the table below.

Table 4.20: Item- total statistics for knowledge of diverse learning styles in science

Items	Scale mean if item is deleted	Scale variance if item deleted	Corrected item total correlation	Squared multiple correlation	Cronbach's alpha if item deleted
Q5.1	23.35	35.957	0.948	0.949	0.976
Q5.2	25.32	36.880	0.964	0.961	0.975

Q5.3	25.57	36.057	0.966	0.970	0.974
Q5.4	25.77	33.440	0.954	0.946	0.978
Q5.5	25.62	36.101	0.960	0.964	0.975
Q5.6	25.14	39.735	0.930	0.946	0.979
Q5.7	25.04	41.875	0.915	0.920	0.983*

The column of "Cronbach's alpha if item deleted" in table 4.20 above shows that all the alpha values, with the exception of Q5.7 were less than 0.981, which meant that if any of this set of questions were removed from the cluster, the alpha value would decrease; hence the questions were retained as they were instrumental in gaining insight on teachers' knowledge of diverse learning styles in science.

On the other hand if Q5.7 was removed, the alpha value would increase from 0.981 to 0.983; an increase of 0.002 which is insignificant, hence the question was retained as it provided broader perspective on teachers' knowledge of diverse learning styles in science.

4.3.5 Reliability statistics for items on teaching practices, beliefs and attitudes

This subsection comprised of eleven questions that explored teaching practices, beliefs and attitudes of science teachers. The responses to the questions used a 5- point Likert scale and Cronbach's alpha calculated to determine the reliability of the questions. The table below shows the result.

Table 4.21: Reliability statistics for items on teaching practices, beliefs and attitude

Cronbach's alpha	Cronbach's alpha based on standardized items	No. of items
0.985	0.990	11

The table above shows that this cluster had a Cronbach's alpha of 0.99 (rounded off to a two decimal place) which indicated reliability for the questions that explored teaching practices, beliefs and attitudes of science teachers with regard to teaching and learning of natural sciences. To determine whether the reliability would increase or decrease if any question in this cluster was removed, item- total statistics was analysed. The table below shows the result.

Table 4.22: Item- total statistics for teaching practices, beliefs and attitude

Items	Scale mean if item deleted	Scale variance if item deleted	Corrected item total correlation	Squared multiple correlation	Cronbach's alpha if item deleted
Q 6.1	41.14	106.118	0.970	0.985	0.983
Q6.2	40.74	113.454	0.935	0.982	0.984
Q6.3	40.86	112.529	0.965	0.965	0.983
Q6.4	41.39	102.077	0.947	0.972	0.985
Q6.5	40.84	116.247	0.917	0.942	0.984
Q6.6	41.58	104.466	0.940	0.948	0.984
Q6.7	41.24	108.680	0.961	0.985	0.983
Q6.8	40.53	119.212	0.887	0.920	0.986*
Q6.9	41.01	110.863	0.963	0.963	0.983
Q6.10	41.04	111.902	0.963	0.966	0.983
Q6.11	40.70	115.335	0.940	0.977	0.984

From the column of "Cronbach's alpha if item deleted" in table 4.22, it emerges that the alpha value for this cluster would increase from 0.985 to 0.986 (an increase of 0.001) if Q6.8 was removed. However the item was retained as the increase was insignificant, and the question contributed to gaining insight on teaching practices, beliefs and attitude. The remainder of the items have alpha values less than 0.985 which meant that the reliability of the questions in the cluster would decrease if any of the items was removed.

4.3.6 Reliability statistics for items on teaching and assessment strategies

The items in this cluster comprised of ten questions that explored teaching and assessment strategies in science. The responses used a 5- point Likert scale, and Cronbach's alpha calculated to determine the reliability of the questions in exploring the construct under investigation. The result is summarized in the table below.

Table 4.23: Reliability statistics for items on teaching and assessment strategies

Cronbach's alpha	Cronbach's alpha based on standardized items	No. of items
0.965	0.982	10

The table above shows that the Cronbach's alpha for the items in this cluster was 0.965 which indicated reliability of the questions in exploring teaching and assessment strategies of the teachers in the study. Item- total statistics was analysed to determine if the Cronbach's alpha would increase or decrease if any question was removed from the cluster.

Table 4.24: Item- total statistics for teaching and assessment strategies

Items	Scale mean if item deleted	Scale variance if item deleted	Corrected item total correlation	Cronbach's alpha if item deleted
Q7.1	39.04	45.985	0.882	0.960
Q7.2	40.32	39.948	0.874	0.970*
Q7.3	39.50	42.116	0.954	0.958
Q7.4	38.99	49.383	0.942	0.960
Q7.5	39.09	46.635	0.927	0.958
Q7.6	38.96	52.094	0.836	0.965
Q7.7	39.01	51.000	0.885	0.963
Q7.8	39.20	46.657	0.901	0.959
Q7.9	38.93	50.146	0.935	0.961
Q7.10	38.93	50.146	0.935	0.961

From table 4.24 above, it emerges from the last column that all the alpha values with the exception of Q7.2 were lesser than 0.965 which meant that if any question or item was deleted from this cluster; the alpha value for the scale would decrease, hence the questions were retained. Removing Q7.2 would increase the alpha value from 0.965 to 0.970, an increase of 0.005 which is not significant hence the question was retained as it contributed to gaining insight on teaching and assessment strategies in the natural sciences. The summary of the reliability statistics for the questionnaire is presented in the table below.

Table 4.25: The Cronbach's alpha values for the various scales in the questionnaires that explored science teachers' pedagogical practices in the classrooms.

Subsections	N	Items included	Cronbach's alpha coefficient
Lesson presentation in the teaching and learning of natural sciences	74	9	0.95
Subject content knowledge and competence in the teaching of natural sciences in the senior phase	74	8	0.96
Knowledge of learning difficulties in natural sciences	74	11	0.98
Knowledge of diverse learning styles in science	74	8	0.98
Teaching practices, beliefs and attitudes	74	11	0.99
Teaching and assessment strategies	74	10	0.97

Table 4.25 above shows that the Cronbach's alpha for the various subsections of the questionnaire were greater than 0.7, the interpretation thereof is that the questions within the various subsections were reliable in exploring the science teachers' pedagogical practices in the classroom.

4.4 Summary

This chapter provided analysis of the survey data that explored science teachers' pedagogical practices in the classroom. The survey data was analysed to gain insight on the activities of the teachers when engaged with learners in teaching and learning of natural sciences. The outcome of the analysis informs the discussion in the next chapter which seeks to address the research questions.

CHAPTER 5
DISCUSSION OF THE RESULTS

5.1 Introduction

This chapter discusses the results of the study on science teachers' pedagogical practices in the classroom. The previous chapter focused on the analysis of the questionnaire data. In this chapter, I discuss the results that emanated from the data on how science teachers teach their lessons and what informs their pedagogical practices in the classroom.

The discussions in this chapter incorporate the data from the questionnaire, focus group and lessons observation with a view to answering the research questions and accomplishing the objectives of the study.

5.2 Addressing the research questions

The primary research question for this study is "What are teachers' pedagogical practices when teaching science?"

I addressed this overriding research question by exploring the following specific research questions:

1. How do the science teachers teach their lessons?
2. What informs teachers' pedagogical practice when teaching science?

5.2.1 Results pertaining to research question 1

- How do science teachers teach their lessons?

In answer to the first research sub question on how science teach their lessons, the analysed study data established the following:

Prior to formal teaching and learning of science in the classroom, majority of the participating teachers first design lesson plan which guides and informs what happens during the lessons. When the teachers plan for science lessons, large majority (Grade 7: 78%, Grade 8: 88%, Grades 8 and 9: 84%, and Grade 9: 90%) refer to the CAPS policy document for natural sciences (Grades 7- 9) to know the details of the learning content.

In the lesson plan, majority of the teachers (Grade 7: 90%, Grade 8: 84%, Grades 8 and 9: 70%, Grade 9: 83%) include the learning goals, how the goals will be achieved and ways of measuring how well the goals were reached. At the beginning of a science lesson, majority of the teachers (Grade 7: 80%, Grade 8: 85%, Grades 8 and 9: 82%, Grade 9: 90%) state the objectives of the lesson and guide learners towards achieving the objectives. When the teachers present lesson on a new topic, large majority of the teachers (Grade 7: 90%, Grade 8: 85%, Grades 8 and 9: 82%, Grade 9: 78%) perform diagnostic assessment to establish the knowledge base of the learners and misconceptions they might be having in the topic. As the focused group interview data revealed, the teachers use different strategies to identify learners' misconceptions at the beginning of a lesson. Teacher A (Grade 9) indicated that at the beginning of a lesson on a new topic, they direct questions at individual learners to ascertain their understanding of the basic concept in the topic. Teacher B (Grade 7) explained that they give individual attention to learners and check their class work books to see where they could be having a problem with the topic. Teacher C (Grades 7) indicated that at the beginning of a lesson, they give learners a short activity on the topic to establish their knowledge base and possible misconceptions in the topic.
Majority of the teachers (Grade 7: 56%, Grade 8: 50%, Grades 8 and 9: 60%, Grade 9: 57%) claimed to be aware of learning difficulties in science and their sources, and to address the challenges in their science lessons; the teachers (Grade 7: 70%, Grade 8: 68%, Grades 8 and 9: 75%, Grade 9: 80%) explicitly explain the meaning of science terms and differentiate them from everyday use. Furthermore, when the teachers give learning tasks, large majority (Grade 7: 70%, Grade 8: 78%, Grades 8 and 9: 70%, Grade 9: 76%) organize them in an increasing order of complexity for optimal learning.

During lessons, if the teachers want to teach a complex topic; large majority (Grade 7: 75%, Grade 8: 90%, Grades 8 and 9: 85%, Grade 9: 78%) begin by providing learners with the basic version of the topic and then gradually present lessons that will ultimately lead to the realization of the learning goals. When the teachers present lessons on a new topic, overwhelming majority (Grade7: 85%, Grade 8: 70%, Grades 8 and 9: 78%, Grade 9: 87%) use whole class lecture method during which they provide a summary of the previous lessons so that learners can fully grasp the concepts in the new topic.

Majority of the teachers (Grade7: 78%, Grade 8: 71%, Grades 8 and 9: 85%, Grade 9: 80%) claimed to have adequate knowledge and understanding of learners, their individual differences and learning styles. Hence during lessons, the teachers (Grade 7: 75%, Grade 8: 81%, Grades 8 and 9: 78%, Grade 9: 86%) use array of teaching strategies to accommodate the diverse learning styles in their classrooms.
To cater for visual learners in their lessons, large number of the teachers (Grade 7: 64%, Grade 8: 60%, Grades 8 and 9: 65%, Grade 9: 70%) provide learning experience that is enriched with visual images such as colourful posters, charts, drawings and other images of educational value. To accommodate the kinaesthetic learners in the lessons, majority of the teachers (Grade 7: 69%, Grade 8: 80%, Grades 8 and 9: 75%, Grade 9: 78%) provide a hands on learning approach and engage learners in science practical activities, building models and designs. For interpersonal intelligence, a sizeable number of the teachers (Grade 7: 85%, Grade 8: 90%, Grades 8 and 9: 83% and Grade 9: 91%) engage learners in group work, projects and cooperative learning. As indicated by the teachers, pedagogical practice such as matching teaching methods to learning styles improve the academic performance of learners (See subsection 2.4.3).

Large majority of the teachers use both collaborative and individual work during lessons. When using collaborative work, the teachers (Grade 7: 92%, Grade 8: 85%, Grades 8 and 9: 89%, Grade 9: 97%) allow learners to work in small diverse ability groups to complete a learning task; and when using individual work, the teachers (Grade 7: 90%, Grade 8: 88%, Grades 8 and 9: 90%, Grade 9: 92%) allow learners to work individually to complete a learning task. As indicated by the teachers, the use of collaborative work in science lessons is supported by social constructivism (See subsection 2.5.3) to improve learning. Similarly, allowing learners to work individually to complete a learning task is supported by literature (See subsection 2.4.3.3) as it caters for intrapersonal intelligence or learners who prefer to work alone to accomplish a learning task. Assessment and feedback are some of the opportunities teachers provide for learning natural sciences. Large majority of the teachers (Grade7: 92%, Grade 8: 85%, Grades 8 and 9: 89%, Grade 9: 97%) use variety of assessment strategies to evaluate attainment of learning outcome in natural sciences. In addition, the teachers give feedback to learners on every assessment task.

The focused group interview (See Appendix B) data established that teachers make use of different assessment strategies such as classwork, homework, practical work, assignments, projects, test and examinations in natural sciences. Some of the teachers give individual activities, pose questions randomly to learners and administer short tests after the completion of a topic. On when teachers assess learning achievement in natural sciences, teacher A (Grade 9) indicated that they assess learning achievement in natural sciences after each and every lesson or any time when there is a chance to give learners work. For teacher B (Grade 7), “assessment of learning achievement in my science class is done by means of monthly tests and by examinations after I have completed many topics. I also give class works, home works and assignments to know how well learners understood the topics. ”

Teacher C (Grade 7) explained that assessment of learning achievement in natural sciences is continuous and involves the use of classwork, assignments, projects, practical work and home work. In addition, summative assessments in the form of quarterly test and end of year examinations are used to assess learning achievement in natural sciences.

The teachers use feedback to communicate to learners on their achievement. On when the teachers give feedback to learners, the respondents indicated that they give feedback after the marking of every assessment task. The feedback comes in the form of corrections which is provided in the classroom after learners shall have written and the teachers marked the work.

In the exact words of Teacher D (Grade 8), “I let learners write corrections after marking their work on a given assessment task, and also provide explanations for learners to see how the various answers were obtained”.

Teacher E (Grade 8) explained that when marking learners’ written work on a given assessment task, they note the common mistakes and the hazy areas and address them accordingly in class with learners before the commencement of another lesson.

The teachers conduct science experiments with learners on some of the topics that were taught in class. However, the teachers indicated that due to lack of resources for science experiments; they improvise in various ways so as to carry out the experiments.

In the exact words of teacher F (Grade 9), “due to lack of resources for science experiments I try to use available local materials and relate the experiments to the learners’ everyday experiences” For teacher A (Grade 9), “Due to lack of resources for science experiments in my school, I don’t conduct hands on experiments; rather I rely on demonstration after which learners complete a work sheet on tasks related to the experiment.” Similarly teacher B (Grade 7) indicated that “due to lack of science laboratory and resources for experiments, I make copies from the textbooks on the experiment and orally explain to learners the procedures to be followed if the experiment were to be conducted in the laboratory after which learners answer questions related to the experiment.”

The teachers use variety of strategies to identify learners’ misconceptions in their science lessons. A common strategy is diagnostic assessment which the teachers carry out at the beginning of a lesson to identify misconceptions that learners might be having in the topic.

To establish learners’ misconceptions in their science lessons, teacher A (Grade 9) indicated that at the beginning of a lesson, questions are directed at individual learners to ascertain their understanding of the basic concepts in the topic.

Teacher B (Grade 7) explained that they give individual attention to learners and check their workbooks to see where they could be experiencing challenges in the topic.

Teacher C (Grade 7) indicated that at the beginning of a lesson on a new topic, they give learners a short activity to identify and possibly address their misconceptions on the topic.

The teachers use variety of teaching strategies to cater for the diverse learning styles in their science lessons. In this regard, teacher C (Grade7) indicated that sometimes they use cooperative learning during which learners work in small diverse ability groups to complete a learning task.

In the exact words of teacher D (Grade 8) “I use different teaching aids in class to cater for different learning styles in my lessons. For visual learners, I use highly colourful posters and charts to help them grasp the concepts better. I also group learners to complete projects and assignments”. Teacher E (Grade 8) indicated that when they give a task, they allow learners to work individually and sometimes mix gifted learners with slow learners so that they can complete the task.

To further answer the first research sub-question on how science teachers teach their lessons, I conducted science lessons observation in selected public schools. The teachers whose science lessons were observed had earlier taken part in the survey questionnaires, and focus group interview; and currently teach natural sciences in the senior phase (Grades 7, 8 and 9). The objectives of the lessons observation were two folds: firstly to gain first- hand information on how teachers engage learners in the teaching of natural sciences topics, and secondly to triangulate the data gained from the survey questionnaires and focused group interviews. A total of four lessons observation, one per teacher were conducted with each lesson lasting a period of one hour. The observation was based on pre-determined criteria (See Appendix C of the lesson observation schedule) and made use of lesson observation schedule. At the end of the science lessons observation, I conducted interview with the individual teachers to understand the rationale for the pedagogical approach and strategies they adopted during the lessons.
Therefore, the discussions that follow would focus on the outcome of the lesson observations. For purpose of clarity, the discussions are categorized into case 1, case 2, case 3 and case 4 with each case detailing what transpired in the classroom during the lessons observation.

Case 1

The first lesson observation was conducted on 8th of March 2018 and took place in a grade 9 natural science class at a high school in Masemola educational circuit. The topic of the lesson was human digestive system. The teacher started the lesson by asking learners the importance of food. Learner A responded that “food helps to keep us alive”, learner B responded that “food gives us energy” and learner C indicated that “food helps us to grow”. The teacher acknowledged the various responses from the learners and added that food provides humans with energy which enables them to carry out their day to day activities. The teacher indicated that in order for the nutrients in the food to be absorbed, digestion must take place. A question was posed to the learners on why food materials example fish/meat, and chips are chewed before they are swallowed, learners responded that food materials are chewed so that they can be digested and absorbed in the body. The teacher acknowledged the response and described digestion as the breaking down of food into smaller nutritional components which can be absorbed by the body. Continuing with the lesson, the teacher asked learners what happens when they eat certain food substances such as meat, bread, fish etc.; the learners responded that they first chew the food material before they can swallow it. The teacher acknowledged the response and explained that chewing of food is done so as to break it into tiny pieces that can be easily swallowed and digested in the stomach.

The teacher differentiated between mechanical and chemical digestion, and explained that mechanical digestion involves the chewing of food by the teeth, and churning by the walls of the digestive system as the ingested food substance passes from the oesophagus to the stomach.

On the other hand, chemical digestion involves the breaking down of complex food materials into simpler forms by the enzymes. The teacher explained that mechanical digestion does not require enzymes, and occur when the ingested food substances pass through the digestive system during which the muscular walls of the system breaks down the food materials into tiny forms. To ensure that learners understand the concept of mechanical and chemical digestion, the teacher displayed a poster of the human digestive system on the board and explained the processes that take place from the moment food is ingested in the mouth to the point when unabsorbed substances are egested. During the course of the lesson, the teacher posed questions to learners. For instance learners were asked at random to identify the various parts of the human digestive system and their functions which they did with the help of the colourful poster that was displayed on the board.

During the course of the lesson, the teacher code switched and often time used sepedi home language to provide explanations on the topic. The teaching method adopted during the lesson could be described as comprising of both teacher - centred and learner-centred. The lesson was very engaging and learners played active role as they asked questions and responded to the questions posed by the teacher. The lesson catered for the diverse learning needs of learners as the teacher displayed a colourful poster of the human digestive system on the chalk board which promoted learning especially for visual learners. To ensure active participation of learners during the lesson, the teacher would pose questions randomly at learners. For instance the teacher would ask learners to read aloud a paragraph on the topic of the lesson from their natural sciences textbooks. Similarly, the teacher would call out learners to identify from the poster the various parts of the human digestive system and their functions. At the end of the lesson, learners were given class activity which focused on digestion and human digestive system.

Case 2

The second lesson observation was conducted on 11th of March 2018 at a primary school in Lepelle educational circuit. The focus of the observation was a grade 7 natural sciences class and the topic of the lesson was human reproductive system. The teacher started the lesson by stating the learning outcomes which require amongst others learning of the human reproductive systems, processes that occur in the male and female reproductive organs, puberty, and signs of puberty in males and females. The teacher linked the lesson with the previous one on pollination and asked learners to explain pollination. Learner 'A' explained pollination as the transfer of pollen grains from the anthers to the stigma of a flower. The teacher acknowledged the response by the learner and posed another question why pollination is important. Learner 'B' responded that without pollination, there will be no fruits for human beings and other animals. The teacher acknowledged the response and added that pollination is very important as it brings about fertilization in flowering plants and trees which leads to the formation fruits that serve as food for humans and other animals. In addition learners were asked to list the agents of pollination which they randomly answered as rain, wind, insects, and animals. Having established that learners are conversant with the content of the previous lesson on reproduction in plants, the teacher proceeded with the lesson.

The teacher defined human reproduction as the process by which females give birth to young ones. Building on the definition, the teacher explained that reproduction starts with fertilization which is the fusion of sperm cell and egg cell to form the zygote. To facilitate the learning of human reproductive system, the teacher displayed a colourful poster of the male and female reproductive systems and explained the various organs that constitute them and their functions. For instance, the teacher pointed to the testes and the ovaries as the main sex organs in males and females that produce sperm and egg cells respectively. Pointing to the ovaries and the fallopian tubes on the poster, the teacher explained that the ovary releases the egg cell/ovum in the fallopian tube through a process known as ovulation, and fertilization occurs when the sperm cell fuses with the egg cell to form zygote. In anticipation of fertilization and possible pregnancy, the teacher indicated that the wall of the uterus thickens and is enriched with blood vessels. In the event that no fertilization takes place, the lining of the uterus degenerates and with the shrunk egg cell are discharged through the female body in a process known as menstruation.

The teacher explained that menstruation signals sexual maturity or puberty in females. In addition to menstruation, the teacher indicated other noticeable changes at puberty in females which include development of breasts, broad waists, and pubic hairs. Similarly in males, the teacher indicated that puberty is characterized by development of the testes, deep voice, “wet dreams” pubic hair and muscles.

The learning environment was very engaging and to ensure that all learners are participating in the lesson, the teacher would write a definition of a term related to human reproduction on the chalkboard and ask learners to read aloud the definition which they did. This was observed from time to time throughout the lesson period. At the end of the lesson, learners were given a classwork which required them to refer to their natural sciences textbooks to explain the following terms: reproduction, puberty, fertilization, zygote, foetus, implantation, and menstruation.

Case 3

The third natural sciences lesson observation was conducted on 13th of March 2018 in a grade 7 classroom at a primary school in Lepelle educational circuit. The topic of the lesson was plant diversity. The teacher started the lesson by stating the learning outcomes which amongst others require that pupils learn about the classification and diversity of plants in the plant kingdom. Proceeding with the lesson, the teacher linked the topic with the previous one on photosynthesis by asking learners what plants need in order to survive in the environment. Learners took turns and in no definite order identify factors such as sunlight, water, carbon dioxide, nutrients, and soil. The teacher acknowledged the responses and linked some of the identified factors as essential for the process of photosynthesis. Furthermore, the learners were asked to define photosynthesis which they defined in unison by reading from their natural sciences textbooks as “the process by which plants make their own food by using sunlight, water and carbon dioxide”.

The teacher acknowledged the responses and explained that photosynthesis is important as it enables plants to produce food which are consumed by human beings and other animals. In addition, it reduces the level of carbon dioxide in the atmosphere and releases oxygen which is used for respiration by other living organisms. Continuing with the lesson, the teacher asked learners to give examples of different types of plants. The plant crops listed by the learners include: maize, beans, grass, peanut, sugarcane, rice, wheat and sunflower. The teacher acknowledged the responses and explained that there are variety of plants in the plant kingdom, and that some plants produce seeds while others produce spore

The learners were referred to a page in their natural sciences textbooks that shows the diversity of plants in the plant kingdom and their classification. The teacher indicated that plants are broadly grouped into Gymnosperms and Angiosperms. Proceeding further, the teacher explained the difference between the Gymnosperm and Angiosperm. The Gymnosperms produce seeds that are not contained within an ovary or fruit and include plants such as, conifers (pine trees), cycads and gingko. In contrast, Angiosperms produce seeds that are enclosed within an ovary or fruit; and include plant crops such as maize, beans, sunflower, millet, sorghum, ground nut and fruit bearing trees. To facilitate the learning of plant diversity, the teacher referred learners to a page in their natural sciences textbook that contained colourful diagrams of different plants that belong to Gymnosperms and Angiosperms. As learners were going through the diagrams, the teacher moved around from one learner’s seat to another so as to provide explanation to individual learners.

Continuing with the lesson, the teacher explained that Angiosperms are subdivided into two groups namely: the dicotyledons and monocotyledons. To differentiate between the angiosperms, the teacher explained that dicotyledons produce two seed leaves when they germinate; for example bean, groundnut whilst monocotyledons produce one seed leaf when they germinate; example maize, sorghum, and millet. The lesson was very engaging and interactive as learners asked questions and responded to the questions asked by the teacher. At the end of the lesson, learners were given a classwork from their natural sciences textbook in which they were provided with a list of plants and asked to classify them into dicotyledons and monocotyledons.

Case 4

The fourth and last natural sciences lesson observation took place on 26th March 2018 in a grade 8 classroom at a high school in Masemola educational circuit. The topic of the lesson was reproduction in Angiosperms (flower producing plants). The teacher started the lesson by stating the learning outcomes which require that pupils learn about pollination, agents of pollination and adaptations of flowers for pollination. Proceeding with the lesson, learners were asked to define pollination which they read out from their natural sciences textbooks as the transfer of pollen grains from the anthers to the stigma of a flower. The teacher acknowledged learners' response and explained that angiosperms produce flowers which contain both the male and female reproductive parts.

The teacher explained that as adaptation for pollination, flowers are brightly coloured, scented and the nectar secretes sugary substance which attracts the bees. In search of the nectar, the bees transfer pollen grains from the anthers to the stigma of a flower in a process known as pollination. Apart from the bees, learners were asked to state other agents of pollination which they listed as birds, wind, and animals. The teacher referred learners to a page in their natural science textbooks that illustrates the series of events that take place in the flower after pollination. Whilst going through the diagrams with the learners, the teacher indicated that after pollination has taken place, the pollen grain grows down the gynoecium or the female part of the flower until it reaches the ovary where it fertilizes the egg cells located in the ovules; and after fertilization, the ovule forms the seed while the ovary forms the fruit. The learners played active role during the lessons and were very eager to answer the questions posed by the teacher. At the end of the lesson, learners were given a classwork from their natural science textbook which required them to draw a labelled diagram of a flower.

Sequel to the natural sciences lessons observation; interview was conducted (See

appendix C) with the individual teachers whose science lessons were observed.
The interview data provided further insights on the pedagogical practices of the teachers.
On how the teachers ensure active participation of all learners during science lessons; Teacher A (case 1) indicated that during lessons, they don't limit questions to selected learners; rather they ask as many learners as possible and at random.
Teacher B (Case 2) explained that in their science lessons, they strive to make the lessons as interactive as possible and encourage learners to ask questions. They sometimes group learners into small diverse ability groups so that they can complete a learning task.
Teacher C (Case 3) indicated that they pose questions randomly at learners and sometimes when learners are given a project, they allow them to work in small diverse ability groups; and on completion, they give them the opportunity to make presentations in class.
Teacher D (Case 4) explained that during lessons, they interchange between learner centred and teacher dominated methods, and encourage active learner participation by posing questions and responding to questions from learners. In addition, when they give learning tasks, they provide opportunities for learners to discuss and explore the answers on their own before they discuss the answers with them.

With regard to teachers' expectation of learners in science; Teacher A (Case 1) expressed that they have high expectation of learners and expect them to excel in science. In addition, learners must be able to apply scientific knowledge at home to solve problems.
In the exact words of Teacher B (Case 2) "I expect all my learners to work hard and pass natural sciences as that would set them on a good path for science in the FET band."
Similarly, Teacher C (Case 3) indicated that they expect learners to apply the scientific knowledge in real life situations to solve problems encountered and live a successful life. In addition, learners are expected to show understanding of what they are learning in class and always do the work given to them.
Teacher D (Case 4) explained that they expect learners to be dedicated and committed to learning of science and be able to do the work given to them in class.

To maintain discipline in their science lessons, the teachers adopt different strategies to

ensure that teaching and learning are not disrupted in the classrooms.
In the exact words of teacher A (Case 1) “I always remind learners of the ground rules drawn at the beginning of the year, and always give them learning activities so as to keep them busy in class. In addition, I ensure that learners are given homework to encourage them to study at home.” Teacher B (Case 2) indicated that during lessons, learners are discouraged from moving about aimlessly in class and are reminded of the classroom rules which forbid disruptive behaviour in class. Teacher C (Case 3) explained that they enforce class management rules very strictly which may require identifying potential trouble makers in the class for close attention. Teacher D (Case 4) elaborated that they provide clear instructions and prepare well for lessons so that learners are actively engaged and there is less chance of disturbance in class. In addition, provisions are made for expanded opportunity especially for fast learners who may finish the learning task much faster than others, so that they don’t resort to disruptive behaviour. Another strategy is that they give enough work to hyperactive learners so as to keep them busy and minimize disruptive behaviour. On why the learning of natural sciences is important in the senior phase, the respondents echoed that learning of natural sciences is very important as it forms the foundation for learning and understanding of pure sciences in the FET band.

The teachers do motivate learners in their science lessons. On how the teachers accomplish it, teacher A (Case 1) indicated that they recognize learners’ efforts and contributions in class and sometimes let outstanding learners stand in front of the class and be acknowledged by the teacher which encourage other learners to work hard so that they can be acknowledged in future. In the exact words of teacher B (Case 2), “I motivate my learners in science by giving them examples of people who have done science and are now working and successful in their careers”. Teacher C (Case 3) indicated that they motivate learners in science by taking them to trips on science Expos’ and career exhibitions where they learn about prospective careers in science. Teacher D (Case 4) stated that they try to be exemplary to learners and model behaviours they would like them to emulate.

5.2.2 Results pertaining to research question 2

- What informs teachers' pedagogical practice when teaching science?

Teachers' pedagogical beliefs and schooling experiences influence their teaching in the classroom (Saleh, 2016).

In answer to the second research sub- question on what informs the science teachers' pedagogical practice in the classroom, the analysed research data established the following:

Large majority of the teachers: Grade 7: 68%, Grade 8: 60%, Grades 8 and 9: 70% and Grade 9: 68%; expressed a belief that a quiet classroom is generally needed for effective teaching and learning of science in the classroom. A prevailing belief amongst the majority: Grade 7: 70%, Grade 8: 66%, Grades 8 and 9: 72%, and Grade 9: 69%; is that teachers know a lot more than learners and should therefore transmit information to them.

In a similar trend, large number of the teachers: Grade 7: 70%, Grade 8: 60%, Grades 8 and 9: 65%, and Grade 9: 68%; indicated that it is better when the teacher and not the learners decide what activities are to be done in the classroom. Based on these results, it may be infered that majority of the teachers in the study hold behaviouristic view of learning and may be predisposed to transmission approach.

As found in the literature (Subsection 2.7.2), transmission approach to teaching of science is considered ineffective as it does not encourage active participation of learners during lessons and fosters the culture of overdependence on the teacher as the sole source of knowledge. The approach perceives science as a body of knowledge that must be taught and learnt, and the learning outcomes focused on acquisition of scientific knowledge with a short term goal of scoring high marks in assessment tasks (Eric, 2013). Effective teaching of science in the classroom transcends transmission and entails developing learners' enquiry skills, problem solving, critical thinking, and ability to apply knowledge in a wide range of contexts (Livingston et al, 2017).

Whilst majority of the teachers in the study expressed behaviouristic view of learning, greater part of their views and responses reflected constructivist approach. As the research data revealed, overwhelming majority of the teachers: Grade 7: 90%, Grade 8: 85%, Grades 8 and 9: 90%, and Grade 9: 95%; perceived their roles in the classroom as facilitators of learners' own inquiry. The teachers' perception of their role in the science classroom as facilitators of learners' own inquiry is consistent with constructivist approach which emphasize learner centred pedagogy and active participation of learners in the teaching and learning process (See subsection 2.5.2).

When teaching in the classroom, a large majority of the teachers: Grade 7 (72%), Grade 8 (80%), Grades 8 and 9 (85%), and Grade 9 (90%) indicated that learners should be allowed to think of solutions to a learning task themselves before the teacher shows them how they are solved. As expressed by the teachers, pedagogical practice such as allowing learners autonomy to work on a learning task before teacher intervention reflects constructivist approach which encourages active participation of learners in the lesson as they are engaged in class activities designed to assist them in constructing their own knowledge (See subsection 2.5.2).

Across all the grades, large number of the teachers: Grade 7 (65%), Grade 8 (70%), Grades 8 and 9 (63%), and Grade 9 (68%) indicated that rote learning and memorization of facts are ineffective approach to learning science. The teachers' views on rote learning is particularly true based on the fact that learners who memorize facts without understanding often find it difficult to apply knowledge in different contexts, which renders such learning ineffective (Livingston et al, 2017).

Large majority of the teachers: Grade 7 (65%), Grade 8 (72%), Grades 8 and 9 (76%), and Grade 9 (83%) expressed belief that students learn best by finding solutions to problems on their own. In other results, a large majority of the respondents: Grade 7 (68%), Grade 8 (72%), Grades 8 and 9 (75%) and Grade 9 (73%) indicated that how much students learn depend on how much background knowledge they have; which makes teaching of facts very necessary. Overwhelming majority of the teachers: Grade 7 (78%), Grade 8 (82%), Grades 8 and 9 (85%), and Grade 9 (81%) expressed the view that science instructions should be built around problems with clear correct answers and ideas that most learners can grasp quickly. Large number of the teachers: Grade 7: 80%, Grade 8: 75%, Grades 8 and 9: 90%, and Grade 9: 85%; expressed the belief that learners' prior knowledge is an asset that can be tapped into to link new concepts and learners' misconception. Therefore, when the teachers introduce a new topic in their lessons; large number of them (Grade 7:75%, Grade 8: 82%, Grades 8 and 9: 78% and Grade 9:87%) first establish the depth and level of learners' knowledge base in the topic. As indicated by the teachers, tapping into learners' prior knowledge and establishing the depth of their knowledge base in a topic improves learning as it enables the teacher to identify learners' misconception in the topic and address it before the lesson can commence.

Based on the data described in this section, it may be infered that majority of the teachers in the study may rely more on transmission approach than learner – centred pedagogy. This study finding is inconsistent with one of the findings of the OECD's 2009 Teaching and Learning International Survey (TALIS) that explored aspects of teacher developments; teachers' beliefs, attitudes and practices; teacher appraisal and feedback; school evaluation; and school leadership styles in the 24 participating countries as being the factors responsible for differences in learning outcomes. The TALIS finding as it pertain to teacher beliefs and practices, was that majority of the teachers expressed constructivist beliefs more than direct transmission beliefs.

As the subject content knowledge influences the teaching methods in the classroom, majority of the teachers in the study: Grade 7: 65%, Grade 8: 60%, Grades 8 and 9: 75% and Grade 9: 70%; indicated that they have adequate subject content knowledge for effective teaching and learning of natural sciences in the senior phase (Grades 7- 9).

This was based on the claim by large number of the teachers: Grade 7: 70%, Grade 8: 80%, Grades 8 and 9: 75%, and Grade 9: 85%, that some of their courses during teacher training were science related. As natural sciences in the senior phase comprised of physics, chemistry, and life sciences, a sizeable number of the teachers: Grade 7: 60%, Grade 8: 50%, Grades 8 and 9: 45% and Grade 9: 43%; expressed more confidence in teaching teach life science than physics, and chemistry topics. Similarly, a significant number of the teachers: Grade 7: 30%, Grade 8: 37%, Grades 8 and 9: 29% and Grade 9: 30%; expressed difficulty when teaching chemical change and balancing of chemical equation. The lack of confidence expressed by a significant number of the teachers to teach some of the topics in natural sciences have serious implications in the classroom as it could compromise content coverage since the teachers would be selective of the topics to teach. In addition, it can lead to ineffective teaching and learning, and consequently poor academic performance of learners in science. In a similar trend, a significant number of the teachers: Grade 7: 25%, Grade 8: 45%, Grades 8 and 9: 36%, and Grade 9: 46%; were uncertain if all learners in the senior phase are capable of excelling in science. This contrasts with the low number: Grade 7: 35%, Grade 8: 20%, Grades 8 and 9: 16%, and Grade 9: 22%; that expressed belief that all learners in the senior phase are capable of excelling in science. Low expectation of learners in science as expressed by some of the teachers is very concerning as teachers who have low expectations of learners are less likely to adopt an effective teaching strategy that will provide a meaningful learning experience for learners. In contrast, teachers who have high expectations of learners perceive them as capable of excelling in the subject; and may strive to create a positive learning environment that would lead to higher academic achievement (Papageorge & Gershenson, 2016). At the end of each science lesson, large majority of the teachers: Grade 7: 65%, Grade 8: 80%, Grades 8 and 9: 755%, and Grade 9: 70%; make out time to reflect on what worked well and why, and what could have been done differently.

5.3 Summary

This chapter presented discussion of the study results with the aim of answering the research questions. The discussed results pertain to the questionnaire, focus group, lessons observation and teacher interview data which seek to answer the research questions formulated in the study. The next chapter focuses on the summary, model for effective pedagogical practice in science classrooms, recommendations and limitations of the study.

CHAPTER 6

SUMMARY, RECOMMENDATIONS AND CONCLUSIONS

6.1 Introduction

This study explored the pedagogical practices of teachers in science classroom. The study adopted multiple data collection strategies, namely: survey questionnaire, focus group interviews, lessons observation and teacher interview to explore the construct under investigation. The study also incorporated extensive literature study that laid the ground work for data collection and analysis of results. The previous chapter provided the results and the discussions, and in this chapter; I presents the summary, findings of the study and recommendations.

6.2 An overview of the study

This study sought to gain insights on pedagogical practices in science classroom. The population consisted of educators who teach natural sciences in the senior phase at public schools in four educational circuits in the Limpopo province. From the study population, a sample of seventy four (74) science teachers were selected and completed a questionnaire that explored a wide range of issues that pertain to pedagogical practices in the science classroom. In furtherance to seeking answers to the research questions, a focus group interview was conducted amongst six (6) educators who had earlier taken part in the survey questionnaire. From the focus group participants, four educators were purposefully selected for science lessons observations. The lessons observation sought to gain first-hand information on how teachers enact the teaching of natural sciences topics in the senior phase (Grades 7-9). In addition, it provided valuable means of triangulating the data from the questionnaire, and focus group interview. Sequel to the lessons observation, teacher interview was conducted. In this case, the interviewees were the four teachers whose science lessons were observed. Amongst others, the interview sought to gain insights on the rationale for the pedagogical practices observed during the lessons.

The main research question for the study is “what are teachers’ pedagogical practices when teaching science?”

The overriding research question was addressed by exploring the specific research questions:

1. How do science teachers teach their lessons?
2. What informs teachers’ pedagogical practice when teaching science?

Addressing the research questions required a holistic approach which entailed extensive literature review of relevant teaching and learning theories, effective teaching practices, and the use of multi method data collection strategy namely; survey questionnaire, focus group interview, lessons observation and teacher interview. The data generated in the study were presented, analysed and discussed.

6.3 Developing model for effective pedagogical practice in science classrooms

6.3.1 Observation-Theory-Planning (OTP) model for effective pedagogical practice in science classrooms

Based on the research findings, the **Observation-Theory-Planning (OTP)** model for effective pedagogical practice in science classrooms was developed.

The model has three components namely; planning of teaching, observation and theory that form part of the teachers’ pedagogical practice. These are shown on figure 6.1 below.

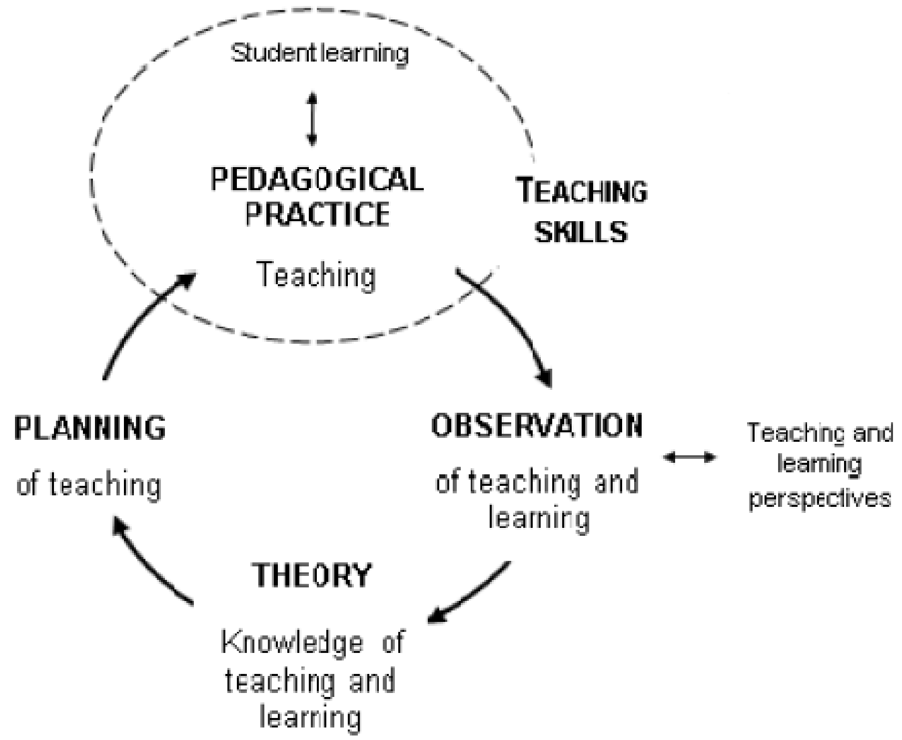


Figure 6.1: Observation-Theory-Planning (OTP) model

Whilst majority of the teachers in the study expressed a behaviouristic view of learning which may indicate a predisposition to teacher – centred pedagogy in the classroom. However, other pedagogical practices indicated by the teachers and observed in the science lessons are consistent with constructivist or learner – centred pedagogy which suggests strategies that may be used to provide a meaningful learning experience in science. The strategies include amongst others:

Planning of teaching

Use of lesson plan in science lessons

As indicated by the teachers, preparation and use of lesson plans enhances teaching as it provides a road map on how teaching and learning should be organized in the classroom. When thoroughly planned, lesson plans enable the teacher to know the details of the learning content and device strategies on how to accomplish the lesson objectives. In addition, it informs what teachers and learners do during the lessons, the learning tasks that are given and ways of assessing the learning outcome.

Observation of teaching and learning

(i) Linking lessons on a new topic to the previous one

Linking new lessons on a new topic to the previous one as observed during the lessons, improves teaching and learning as it enables learners to grasp the new topic by building on their knowledge of the previous topic. It also helps the teacher to offer revision on the previous topic which facilitates the teaching of the new topic.

(ii) Diagnostic assessment

As indicated by the teachers, pedagogical practice such as diagnostic assessment at the beginning of a lesson on a new topic improves teaching and learning as it enables the teacher to establish the knowledge base of the learners and the possible misconceptions they might be having in the topic and address them accordingly before proceeding with the lesson.

(iii) Code switching during lesson

The teachers in the lesson observations code switched, that is interchange between English and Sepedi home language during the lessons. Code switching may improve teaching and learning as it enables the teacher to explain abstract concepts in the home language of learners which may lead to better understanding by learners.

(iv) Use of resources other than textbooks

In addition to textbooks, the teachers in the study indicated use of posters, charts, and pictures of educational value to enrich their lessons. The use of posters and charts as observed during the lessons improves teaching and learning as it caters for learning diversity, especially the visual learners who learn better by seeing visual images.

(vi) Use of collaborative work

The teachers in the study indicated use of collaborative work in their lessons during which they group learners into small diverse ability groups so that they can work and accomplish a learning task. The use of collaborative work improves learning as it enables learners to work cooperatively on a learning task during which they discuss, share ideas, and develop essential social skills.

. **Theory**

Knowledge of teaching and learning

Teaching can be defined as engagement with learners to enable their understanding and application of knowledge, concepts and processes. To teach is to engage learners in learning; thus teaching consists of getting students involved in the active construction of knowledge.

Teachers' knowledge of teaching and learning may include the following steps:

Step 1: Analysing needs for implementing an active learning strategy.

Step 2: Identify topic and questions.

Step 3: Identify learning objectives & outcomes.

Step 4: Plan and design the activity.

Step 5: Identify sequence of learning events.

Step 6: Evaluate and assess.

Giving of feedback on assessment tasks

As indicated by the teachers in the study, pedagogical practice such as giving of feedback on assessment tasks improves teaching and learning as it provides opportunity for teachers to correct learners work and help learners to see where they erred and avoid such errors in future

Organizing learning tasks in an increasing order of complexity

Pedagogical practice such as organizing learning activities in an increasing order of complexity may improve learning as it enables learners to grasp basic version of the task which facilitates learning of more complex tasks.

6.4 Recommendations

The current study explored science teachers' pedagogical practices in the classroom; and in so doing provided results which may help teachers make informed decision on ways that can be used to provide meaningful learning experience in science. With the emphasis on improving the teaching and learning of science in South Africa, it is envisaged that the findings of this study will contribute to research effort aimed at improving the teaching and learning of science in schools. The findings of the study suggests that majority of the teachers in the study may rely more on transmission approach than learner centred pedagogy in the teaching and learning of science in the classroom. Based on the findings of the study, the following recommendations are made:

i. In service training on subject content knowledge for natural science teachers, especially those without relevant science qualifications so that they can grapple with the subject content knowledge.
ii. Science workshops to be organized from time to time to train teachers on effective teaching practices in the classroom.
iii. Outsourcing or involving more than one teacher in the teaching of natural sciences in schools.
iv. Equipping of schools with science laboratories so that teachers can carry out science experiments with learners.
v. The schools must ensure that only teachers with relevant science qualifications are assigned to teach natural sciences in the senior phase.

6.5 Limitations of the study

The use of non-probability sampling in the selection of the seventy four (74) teachers that took part in the study, limits the generalizability of the findings of the research. In compliance with the conditions by the Limpopo Department of Basic Education (LDBE) that the study does not disrupt normal teaching and learning in schools, the topics taught during the lessons observation were mainly life sciences as the observation was carried out in the first quarter of the school year; hence it was not possible to observe the teaching and learning of physical science topics which are taught in the second and third quarters. Therefore, the findings of the lessons observation are limited to the teachers involved in the study and do not reflect how teachers in the seniors phase (Grades 7- 9) teach natural sciences topics.

6.6 Recommendations for further research

The need to improve the teaching and learning of science in schools can never be overemphasized, and requires a continuous research on innovative pedagogical approach that will transform the classroom into that where the teachers' role transcend transmission of knowledge to facilitators of learning. Meaningful and effective teaching of science in the classrooms requires that learners play active role during lessons and construct their own knowledge during the process. The current study explored the teachers' pedagogical practices in the teaching and learning of natural sciences in the senior phase (Grades 7 - 9). It is recommended that further studies be carried out to explore:

i. The pedagogical practices of teachers in the teaching and learning of science in the intermediate phase (Grades 4 - 6).
ii. The impact of matching teaching methods in natural sciences to learning styles in the senior phase (Grades 7 – 9).
iii. Teachers' perception and notion of constructivist approach in the teaching and learning of science in the senior phase (Grades 7 – 9).
iv. The impact of teaching methodology on the performance of learners in science.
v. The impact of assessment on the academic performance of learners in science.

vi. Science teachers’ perception and views on effective teaching practices in science

6.7 Summary

This section provided the summary of the current study that explored the pedagogical practices in the teaching and learning of science in the classroom. The discussion in the section focused on the findings of the study, strategies to improve the teaching and learning of science, limitations of the study, and recommendations for further studies.

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APPENDICES

APPENDIX A: TEACHERS' SURVEY QUESTIONNAIRES

TEACHERS' SURVEY QUESTIONNAIRES

Dear teacher,

May you complete this anonymous questionnaire that aims to explore science teachers' perceptions and views regarding effective teaching practices in the senior phase (Grades 7 -9)). The completion of the questionnaire is voluntary and your honest response to the questions is needed so as to realize the objectives of the survey. Do not write your name and any comment you made on the questionnaires will not be traced to you or your school.

Thank you for taking part in the study.

SECTION 1: Biographic and demographic information.

Please indicate your response by placing X in the appropriate box.

1.1 Age

20 years and below	21- 30 years	31 – 40 years	41- 50 years	51 years and above

1.2 Gender

Male	Female

1.3 Highest academic

Teacher's diploma	ACE	PGDE	PGCE	B.Sc.	B.Sc. (Hons)

B.Ed. (Hons)	M.Ed.	M.Sc.	PhD

Others specify……………………………………………………………………………………

1.4 Grade currently teaching Natural Science in the senior phase

Grade 7	Grade 8	Grade 9

1.5 Years of teaching experience in the senior phase

0 – 5 years	6 – 10 years	11 – 15 years	16 – 20 years	21 years and above

SECTION 2: Lesson presentation in the teaching and learning of natural science

2.1 What do you see as the main purpose of lesson plan in the teaching of natural science in the senior phase?

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For the following statements, please indicate your level of agreement or disagreement by marking X on the appropriate box. Use the following scale:

1: Strongly disagree	2: Disagree	3: Neutral/Undecided	4: Agree	5: Strongly agree

2.2 When I plan for a lesson, I include the goals or what the learners are supposed to learn, how the goals will be achieved and ways of measuring how well the goals were achieve	1	2	3	4	5
2.3 During lesson plan, I refer to CAPS policy document for natural science (Grades 7, 8 and 9) to know the details of the learning contents	1	2	3	4	5
2.4 At the beginning of a science lesson, I state clearly the objectives of the lesson and guide learners towards achieving the objective	1	2	3	4	5
2.5 When I present lesson on a new topic, I link it	1	2	3	4	5

with the previous topic or knowledge of the learner					
2.6 To ensure effective teaching and learning of science, teachers should design activities or ask questions when new topics are presented to assess learners' preconceived notion about it	1	2	3	4	5
2.7 In order for learners to see the practical applications of the learning content, I make provisions for expanded opportunity for learners to explore further on the lesson topic	1	2	3	4	5
2.8 When I introduce a new topic, I try to establish some misconceptions about the topic that learners might be having	1	2	3	4	5
2.9 My role as a science teacher in the senior phase is to guide and facilitate learners' inquiry	1	2	3	4	5
2.10 At the end of each science lesson, I make out time to reflect on what worked well, and why; and what could have been done differently	1	2	3	4	5

SECTION 3: subject content knowledge and competence in the teaching of natural science in the senior phase.

May you read the following statements carefully and indicate the level to which you agree/disagree with them by putting X on the appropriate box. Use the following scale:

1: Strongly disagree	2: Disagree	3: Neutral/Undecided	4: Agree	5: Strongly agree

3.1 I have adequate subject content knowledge for effective teaching of natural science in the senior phase	1	2	3	4	5
3.2 Some of my courses during teaching	1	2	3	4	5

training were science related					
3.3 I feel more confident teaching life science topics than physics and chemistry topics in the natural science	1	2	3	4	5
3.4 I find it difficult to teach the topic chemical change in the senior phase	1	2	3	4	5
3.5 To me, the teaching of balancing of chemical equation is very challenging	1	2	3	4	5
3.6 I consider myself a good science teacher	1	2	3	4	5
3.7 When I present lessons, I make sure that I carry all learners along	1	2	3	4	5
3.8 All learners in the senior phase are capable of excelling in science	1	2	3	4	5

3.9 May you indicate the topics in the natural science that you consider challenging to teach.

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3.10 In your own views how would the teaching and learning of natural science in the senior phase can be improved?

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SECTION 4: Knowledge of learning difficulties in natural science

Read the following statements and indicate the level to which to which you agree/disagree with them by marking X on the appropriate box. Use the following scale:

1: Strongly disagree	2: Disagree	3: Neutral/Undecided	4: Agree	5: Strongly agree

4.1 I am aware of the sources of learning difficulties in natural science in the senior phase	1	2	3	4	5
4.2 Often times, learners mistook science terms for everyday use meaning	1	2	3	4	5
4.3 Learning difficulties in chemistry/science stem from the inability of learners to grasp the microscopic level and macroscopic level simultaneously	1	2	3	4	5

4.4 When I provide learning experiences, I organize learning tasks in an increasing order of complexity for optimal learning	1	2	3	4	5
4.5 During science lessons, If I want to teach learners a more complex concept, I begin by providing learners with the basic version of the concept and then gradually present lessons that will ultimately lead to the realization of the learning goals	1	2	3	4	5
4.6 When I present lesson on a new topic, I provide learners with a summary of the previous lessons so that they can fully grasp the concepts in the new topic	1	2	3	4	5
4.7 In my lessons, when I introduce a new topic, I first establish the depth and level of learners' knowledge base in the topic	1	2	3	4	5
4.8 Learners' prior knowledge is an asset that can be tapped into to link new concepts and learners' misconception	1	2	3	4	5
4.9 To ensure effective learning, when I present lessons, I explicitly explain the meaning of science terms and differentiate them from everyday use	1	2	3	4	5
4.10 As a natural science teacher in the senior phase, I am aware that what learners already know is a key factor in learning	1	2	3	4	5
4.11 I have a high expectation of my learners in science	1	2	3	4	5

SECTION 5: Knowledge of diverse learning styles in science

May you indicate your knowledge of diverse learning styles in science. Read the following statements and indicate your level of agreement/disagreement by marking X on the applicable box. Use the following scale:

1: Strongly disagree	2: Disagree	3: Neutral/Undecided	4: Agree	5: Strongly agree

5.1 I understand different learning styles in my science classroom	1	2	3	4	5
5.2 I use array of teaching strategies to accommodate diverse learning styles of learners	1	2	3	4	5
5.3 I have adequate knowledge and understanding of learners, their individual differences and learning styles	1	2	3	4	5
5.4 I use variety of instructional and teaching aids to promote learning	1	2	3	4	5
5.5 To cater for visual learners in my science class, I provide learning experience that is enriched with visual images such as colourful posters, charts, drawings and other images of educational value	1	2	3	4	5
5.6 To cater for kinaesthetic learners in my science lessons, I provide a hands on learning approach and engage learners in science practical activities, building models and designs	1	2	3	4	5
5.7 To cater for interpersonal intelligence in my science lessons, I engage learners in group work, projects and cooperative learning tasks	1	2	3	4	5
5.8 Science teachers in the senior phase should adapt their teaching and use approaches that	1	2	3	4	5

best suit the needs or context of their classrooms					

SECTION 6: Teaching practices, beliefs and attitudes.

May you indcate your views and personal beliefs on teaching practices and learning. Carefully read the following statements and indicate how much you agree/disagree with each of them by marking X on the appropriate box. Use the following scale:

1: Strongly disagree	2: Disagree	3: Neutral/Undecided	4: Agree	5: Strongly agree

6.1 A quiet classroom is generally needed for effective teaching and learning of science in the senior phase	1	2	3	4	5
6.2 Learner should be allowed to think of solutions to a learning task themselves before the teacher shows them how they are solved	1	2	3	4	5
6.3 My role as a science teacher in the senior phase is to facilitate learners' own inquiry	1	2	3	4	5
6.4 Teachers know a lot more than learners and should therefore transmit information to them	1	2	3	4	5
6.5 Students learn best by finding solutions to problems on their own	1	2	3	4	5
6.6 It is better when the teacher and not the learners decide what activities are to be done in the classroom	1	2	3	4	5
6.7 Rote learning and memorization of facts are ineffective approach to learning science	1	2	3	4	5
6.8 Science teachers in the senior phase should improvise when conducting experiments with	1	2	3	4	5

learners					
6.9 How much students learn depend on how much background knowledge they have, and that is why teaching facts is so necessary	1	2	3	4	5
6.10 Science instructions should be built around problems with clear, correct answers and ideas that most learners can grasp quickly	1	2	3	4	5
6.11 In my classroom, to maintain order and discipline, I explicitly state the rules and regulations which I display in the classroom for learners to read	1	2	3	4	5

SECTION 7: Teaching and assessment strategies

How often does each of the following activities happen in your teaching in the classroom? May you indicate your response by marking X on the appropriate box. Use the following scale:

1: Never	2: Rarely	3: Neutral/Undecided	4: Sometimes	5: Most of the time

7.1 I present new topics to the class lecture style	1	2	3	4	5
7.2 I explicitly state the learning goals at the beginning of every lesson	1	2	3	4	5
7.3 At the beginning of a lesson, I present a short summary of the previous lesson	1	2	3	4	5
7.4 I use variety of assessment strategies to evaluate attainment of learning outcome	1	2	3	4	5
7.5 I give feedback to learners on every	1	2	3	4	5

assessment task					
7.6 I check my learners notebooks and classwork books	1	2	3	4	5
7.7 Learners work in small diverse ability groups to complete a learning task	1	2	3	4	5
7.8 Learners work individually to complete a learning task	1	2	3	4	5
7.9 Practical work is carried out to illustrate concepts that have been introduced	1	2	3	4	5
7.10 I administer test to assess student learning	1	2	3	4	5

This is the end of the questionnaires, thank you for your participation.

Appendix B: FOCUS GROUP TRANSCRIPTS

Researcher: How do you assess learning outcomes in natural sciences?

Participant 1: To find out if my learners have achieved the learning outcomes in natural sciences; I administer tests, and examinations which I normally do per quarter. In addition, I do sometimes give learners projects, practical work, assignments and homework. Their performance in the tasks indicates whether they have mastered the learning outcome.

Participant 2: In my class, to know if the learning outcomes have been achieved; I pose questions at random to learners after completing a topic. I also administer short tests; give classwork, homework and assignments.

Participant 3: To know if the learning outcomes have been achieved, I give learners short tests every month to assess them. In addition, I give long test per quarter and examination during the mid-year and end of year. I also administer informal assessments such as classwork, homework, assignments and projects.

Participant 4: I give classwork, homework, and perform formal assessment by administering tests and examinations.

Participant 5: I use both formal and informal tasks to assess learning achievements in natural sciences. I administer tests and examinations as formal assessment. I also give classwork, homework, projects and assignments to learners which I mark and give corrections in class.

Participant 6: I give classwork, homework, assignments and administer tests to determine whether learners understood the learning content or topics that were taught in the class.

Researcher: When do you assess learning achievements in natural sciences?

Participant 1: Assessment of learning achievement in my class is continuous and involves the use of classwork, assignments, projects, practical work and homework. In addition, summative assessments in the form of monthly and quarterly tests; and end of year examinations are used to assess learning achievements in natural sciences.

Participant 2: Assessment of learning achievements in my science class is done by means of tests on monthly basis, and by examination after I have completed many topics. I also give class work, homework and assignments to know how well learners understood the lesson topic.

Participant 3: I assess learning achievements in natural sciences after each every lesson or any time when there is a chance to give learners work.

Researcher: How and when do you give feedback to learners on their achievement?

Participant 3: I give feedback to learners after each and every assessment. I let them write corrections after marking their work on a given assessment task, and also provide explanations so that learners can see and understand how the various answers were obtained.

Participant 4: When I mark learners written work, I note common mistakes and hazy areas and address them accordingly in class with learners before the commencement of a new topic.

Researcher: How do you conduct experiments in natural sciences?

Participant 1: There is no science laboratory and materials for experiments in my school; hence I don't conduct hands on experiments. I rely on demonstration after which learners complete a worksheet on a task related to the experiment.

Participant 2: Due to lack of resources for science experiments, I try to use available local materials and relate the experiments to learners' everyday experiences.

Participant 4: I do not have resources for experiments due to lack of functional laboratory in my school. When I want to conduct experiments in natural sciences, I make copies from the textbooks on the experiment and orally explain to the learners the procedures to be followed if the experiment were to be conducted in the laboratory after which the learners answer questions related to the experiment.

Participant 5: I simply improvise since we do not the apparatus and reagents to carry out the experiments hands on.

Researcher: What strategies do you use in your lessons to identify learners' misconceptions in science?

Participant 1: At the beginning of a lesson on a new topic, I pose questions at individual learners to establish their understanding of the basic concepts in the topic. Learners' responses to the questions will help me to establish their misconceptions in the topic if any and rectify them before proceeding with the topic.

Participant 2: Before I start a lesson, I make sure that I first identify if learners are having misconceptions in the topic. This I do by posing questions at random to the learners and getting a feedback from them. Based on their response, I will see if there are misconceptions and correct them before I continue with the lesson.

Participant 4: When I mark learners' tasks, I check to see if their answers are wrong and give corrections in the next lesson before proceeding with a new topic. When I start a new topic in class, I ask questions to the learners to find out their depth of knowledge in the topic and possible misconceptions they are having and correct them before continuing to tech the topic.

Participant 5: I give individual attention to learners and check their classwork books to see where they could be having problems in the topic.

Researcher: How do you cater for the diverse learning styles in your science class?

Participant 3: I use different teaching aids in class to cater for different learning styles in my lessons. For visual learners, I use highly colourful posters and charts to help them grasp the concepts better. I also group learners to complete projects and assignments in natural sciences.

Participant 4: Sometimes when I give learners task in the classroom, I group them into small diverse ability groups to complete the task. I also use charts and posters to help learners understand the learning task or concepts in the lesson.

Participant 5: I try to make my lesson very engaging by using different teaching strategies that will ensure that all learning styles in my class are carried along during the lesson. Sometimes when I give projects and assignments, I allow learners to work in small groups and make presentations in class on their projects.

Participant 6: When I give tasks during natural sciences lesson, I allow learners to work individually and sometimes I mix gifted learners with slow learners so that they can complete the task.

APPENDIX C: INTERVIEW TRANSCRIPTS

Researcher: How do you ensure active participation of all learners in your science class?

Teacher A (Case 1): When teaching science in the classroom, I don't limit questions to selected learners, rather I pose questions to as many learners as possible and at random.

Teacher B (Case 2): I try to make the lessons as interactive as possible and encourage learners to ask questions. I sometimes group learners into small diverse ability groups so that they can complete a learning task.

Teacher C (Case 3): In my science lessons, I pose questions randomly to learners and sometimes when I give projects to learners, on completion of the task; I give learners the opportunity to make presentations in class.

Teacher D (Case 4): In my science lessons, I do interchange between learner centred and teacher -dominated approach, and encourage active learner participation by posing questions and responding to questions from the learners. In addition, when I give learning tasks; I provide opportunities for learners to discuss and explore the answers on their own before I discuss the answers with them.

Researcher: What kind of expectations do you have for your learners in science?

Teacher A (case 1): I have high expectations of my learners and expect them to excel in science. I expect my learners to apply scientific knowledge at home to solve problems.

Teacher B (Case 2): I expect all my learners to work hard and pass natural sciences as that would set them on a good path for science in the FET band.

Teacher (case 3): I expect learners to apply the scientific knowledge in real life situations to solve problems encountered and live a successful life. I expect them to show understanding of what they are learning in the classroom and always do the work given to them.

Teacher D (case 4): I expect my learners to be dedicated and committed to learning of science and be able to do the work given to them in class.

Researcher: How do you maintain discipline in your science class?

Teacher A (case 1): I always remind learners of the ground rules drawn at the beginning of the year, and always give learning tasks to learners so as to keep them busy in class. In addition, I ensure that learners are given home work to encourage them to study at home.

Teacher B (Case 2): During lessons, learners are discouraged from moving about aimlessly and are reminded of the classroom rules which forbid disruptive behaviour in class.

Teacher C (Case 3): I enforce classroom management rules very strictly which may require identifying potential trouble makers in the class for close attention.

Teacher D (Case 4): I provide clear instructions and prepare well for lessons so that learners are actively engaged and there is less chance of disturbance in class. In addition, I make provisions for expanded opportunity for fast learners who may finish the learning task much faster than others, so that they don't resort to disruptive behaviour. Another strategy is that I give enough work to hyper active learners so as to keep them busy and minimize disruptive behaviour.

Researcher: Why is the learning of natural sciences important in the senior phase (Grades 7- 9)?

Teacher A (Case 1): learning of natural sciences is important in the senior phase as it lays the foundation for science in the FET band. Learners who pass natural sciences in the senior phase are more likely to be in the science stream in the FET band.

Teacher B (Case 2): Natural sciences in the senior phase generally promote scientific literacy amongst the learners which makes them aware and informed on scientific issues.

Teacher C (case 3): I consider the learning of natural sciences in the senior phase important it sets learners on a good path for learning of science in the FET band.

Teacher D (case 4): The learning of natural sciences in the senior phase gives the learners the **basic foundation in science which they can build on in the FET phase.**

Researcher: How do you motivate learners in your science class?

Teacher A (Case 1): I recognize learners' efforts and contributions in class and sometimes let outstanding learners stand in front of the class and be acknowledged as a way to encourage other learners to work hard so that they can be acknowledged in future.

Teacher B (Case 2): I motivate my learners in science by giving them examples of people who have done science and are now working and successful in their careers.

Teacher C (case 3): I motivate my learners in science by taking them to trips on science Expos' and career exhibitions where they learn about prospective careers in science.

Teacher D (Case 4): I try to be exemplary to learners and model the behaviours that I want them to emulate.

APPENDIX D: LESSON OBSERVATION SCHEDULE 1

NATURAL SCIENCES LESSON OBSERVATION SCHEDULE GRADE: 9 DATE: 08. 03. 2018 Mark (√) if the teacher demonstrated as described, or (X) if the teacher did not demonstrate as described	
LESSON PRESENTATION	
Learning goals and objectives stated	√
Lesson linked to the previous topic	√
Learning content in line with the requirements of the CAPS policy document for natural sciences (Grade 7- 9)	√
Questions posed to elicit learners' preconception	√
Lesson linked to practical application	√
Lesson is teacher dominated	X
Learners participated actively in the lesson	√
Lesson adapted to cater for the diverse learning needs of learners	√
Learners given classwork	√

Teacher reflection I tried to make the lesson very engaging so as to sustain learners' interest in the	Observer reflection Teaching and learning occurred in a very conducive classroom and the learners

lesson	participated actively

LESSON OBSERVATION SCHEDULE 2

NATURAL SCIENCES LESSON OBSERVATION SCHEDULE GRADE: 7 DATE: 11. 03. 2018 Mark (√) if the teacher demonstrated as described, or (X) if the teacher did not demonstrate as described	
LESSON PRESENTATION	
Learning goals and objectives stated	√
Lesson linked to the previous topic	√
Learning content in line with the requirements of the CAPS policy document for natural sciences (Grade 7- 9)	√
Questions posed to elicit learners' preconception	√
Lesson linked to practical application	√
Lesson is teacher dominated	X
Learners participated actively in the lesson	√
Lesson adapted to cater for the diverse learning needs of learners	√
Learners given classwork	√

Teacher reflection Giving learners work at the end of the lesson will help me to know if the learning outcomes for the lesson were achieved.	Observer reflection The learners were actively engaged during the lesson. The learning tasks that were given to the learners after the lesson were

	of high quality.

LESSON OBSERVATION SCHEDULE 3

NATURAL SCIENCES LESSON OBSERVATION SCHEDULE GRADE: 7 DATE: 13. 03. 2018 Mark (√) if the teacher demonstrated as described, or (X) if the teacher did not demonstrate as described	
LESSON PRESENTATION	
Learning goals and objectives stated	√
Lesson linked to the previous topic	√
Learning content in line with the requirements of the CAPS policy document for natural sciences (Grade 7- 9)	√
Questions posed to elicit learners' preconception	√
Lesson linked to practical application	√
Lesson is teacher dominated	X
Learners participated actively in the lesson	√
Lesson adapted to cater for the diverse learning needs of learners	√
Learners given classwork	√

Teacher reflection	Observer reflection
Stating the learning goals at the beginning of the lesson helped me to	The teacher carried all the learners along throughout the lesson. Learners played

work towards achieving the set goals.	active role during the lesson.

LESSON OBSERVATION SCHEDULE 4

NATURAL SCIENCES LESSON OBSERVATION SCHEDULE GRADE: 8 DATE: 26. 03. 2018 Mark (√) if the teacher demonstrated as described, or (X) if the teacher did not demonstrate as described	
LESSON PRESENTATION	
Learning goals and objectives stated	√
Lesson linked to the previous topic	√
Learning content in line with the requirements of the CAPS policy document for natural sciences (Grade 7- 9)	√
Questions posed to elicit learners' preconception	√
Lesson linked to practical application	√
Lesson is teacher dominated	X
Learners participated actively in the lesson	√
Lesson adapted to cater for the diverse learning needs of learners	√
Learners given classwork	√

Teacher reflection	Observer reflection
I planned well for the lesson and was encouraged by the active participation of	The lesson was very interactive as the teacher posed questions and got feedback

the learners.	from the learners and vice versa.

APPENDIX D: PERMISSION LETTER TO THE DEPARTMENT OF BASIC EDUCATION LIMPOPO PROVINCE

PERMISSION LETTER

Request for permission to conduct research at _Masemola High School, Diphale High School, Fred Ledwaba High Shool and Kgolodi High School in the Limpopo Province

Title of the research: Science Teachers' Classroom Pedagogical Practices: A Case of Natural Sciences Teaching

12. 12. 2017

LIMPOPO PROVINCE
HEAD OF DEPARTMENT'S OFFICE
RECEIVED
2018 -03- 02
PRIVATE BAG X9489 POLOKWANE 0700
DEPARTMENT OF EDUCATION

The HOD
Department of Education
Limpopo Province

Dear Sir/Madam

I, Nwosu Chidiebere Marcelam doing research under supervision of Dr. T.D.T Sedumedisenior lecturerin the Department of science and technology towards a PHDat the University of South.

The aim of the study is to understand teachers' classroom pedagogic practices when teaching natural sciences at the senior phase (Grades 7, 8 and 9)

Schools in the Limpopo Province are selected as they form the focus of the study and are offering natural sciences in the senior phase

The study will entail a distribution of questionnaires to teachers. The questionnaires will be followed with interviews and observations of classroom teaching at all levels of the senior phase. The benefits of this study are that teachers' challenges in teaching this subject may be accurately understood and intervention measures implemented to improve learner performance and achievement. The study poses no risks to both teachers and learners. The feedback procedure will entail arranging a feedback meeting or a workshop where the final results of the study will be discussed with the research participants.

Yours sincerely

Signature__________ (Researcher/Student)

NWOSU C. M. (Name of the above signatory

APPENDIX E: APPROVAL LETTER FROM THE DEPARTMENT OF BASIC EDUCATION LIMPOPO

LIMPOPO

PROVINCIAL GOVERNMENT

REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF

EDUCATION

Ref: 2/2/2 Enq: MC Makola PhD Tel No: 015 290 9448 E-mail:MakolaMC@edu.limpopo.gov.za

Nwosu C.M
University of South Africa
P O Box 392
Unisa
0003

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH

1. The above bears reference.
2. The Department wishes to inform you that your request to conduct research has been approved. Topic of the research proposal: **"SCIENCE TEACHERS CLASSROOM PEDAGOGICAL PRACTICES: A CASE OF NATURAL SCIENCES TEACHING".**
3. The following conditions should be considered:

3.1 The research should not have any financial implications for Limpopo Department of Education.

3.2 Arrangements should be made with the Circuit Office and the schools concerned.

3.3 The conduct of research should not in anyhow disrupt the academic programs at the schools.

3.4 The research should not be conducted during the time of Examinations especially the fourth term.

3.5 During the study, applicable research ethics should be adhered to; in particular the principle of voluntary participation (the people involved should be respected).

3.6 Upon completion of research study, the researcher shall share the final product of the research with the Department.

4 Furthermore, you are expected to produce this letter at Schools/ Offices where you intend conducting your research as an evidence that you are permitted to conduct the research.

5 The department appreciates the contribution that you wish to make and wishes you success in your investigation.

Best wishes.

2018/08/16

Ms NB Mutheiwana
Head of Department

Date

APPENDIX F: ETHICS APPROVAL LETTER FROM UNISA ETHICS REVIEW COMMITTEE

UNISA university of south africa

UNISA COLLEGE OF EDUCATION ETHICS REVIEW COMMITTEE

Date: 2018/02/14

Ref: 2018/02/14/46618317/35/MC
Name: Mr CM Nwosu
Student: 46618317

Dear Mr Nwosu

Decision: Ethics Approval from 2018/21/14 to 2023/02/14

Researcher(s): Name: Mr CM Nwosu
E-mail address: Chidieberenwosu@rocketmail.com
Telephone: +27 83 768 9844

Supervisor(s): Name: Dr TDT Sedumedi
E-mail address: sedumeditdt@tut.ac.za
Telephone: +27 84 206 2159

Title of research:

Science Teacher' classroom pedagogical practices: A case of Natural Science teaching

Qualification: PhD in Science and Technology Educational

Thank you for the application for research ethics clearance by the UNISA College of Education Ethics Review Committee for the above mentioned research. Ethics approval is granted for the period 2018/02/14 to 2023/02/14.

*The **Low risk** application was reviewed by the Ethics Review Committee on 2018/02/14 in compliance with the UNISA Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa

2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the UNISA College of Education Ethics Review Committee.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.
7. No field work activities may continue after the expiry date **2023/02/14.** Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

The reference number **2018/02/14/46618317/35/MC** *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Kind regards,

M Claassens

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LIST OF FIGURES AND TABLES