RE-EXAMINING CURRICULUM KNOWLEDGE AND PEDAGOGY OF GRADE 12 PHYSICAL SCIENCE TEACHERS

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DECLARATION OF INDEPENDENT WORK

I Motsienyane Simon Lethena, student number [redacted], do hereby declare that this research project;

RE-EXAMINING CURRICULUM KNOWLEDGE AND PEDAGOGY OF GRADE 12 PHYSICAL SCIENCE TEACHERS;

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ABSTRACT

The purpose of this study was to re-examine theoretical and pedagogical curriculum knowledge of grade 12 physical science teachers in the Xhariep district. Mathematics and physical science have a history of poor performance in South African schools, particularly black schools, largely as a result of inferior education provided to black communities by the apartheid 'Bantu Education'. Even after the 1994 elections, following the introduction of Outcomes-Based Education (OBE) by the new government, little has been achieved in terms of improving performance in these subjects, as international results in the past few years have shown. OBE was intended to correct the imbalances of the past by offering equal education for all, however, implementation challenges saw it being confronted with criticism and resistance that led to its review, culminating in the current CAPS policy that has been implemented in schools to date. The study was conducted in Xhariep District in the Free State Province, a vast geographical area with scattered towns which are far apart from each other. The population is mainly poverty-stricken and almost all the black schools are receiving funding from government. The study used a narrative paradigm and methodology that employed purposeful sampling of five schools in the district, three of which were performing and two underperforming. Of the performing schools, one was a former Model C Afrikaans school and the other two were previously disadvantaged schools. The two underperforming schools were also previously disadvantaged. Five teachers from these schools were identified to participate in this study. The instruments used to collect data were interviews, classroom observations and document analysis. The study shows that teachers understand that they need both theoretical and practical knowledge for them to teach effectively; subject content knowledge is needed for teachers to select, sequence and pace their lessons; teachers do not integrate practicals/experiments in their teaching of physical science; and OBE and competence-based curricula have focussed on outcomes and so influenced how teachers teach CAPS content today, which is only results-oriented.

ACRONYMS AND ABBREVIATIONS

CAPS:	Curriculum and Assessment Policy Statements
CK:	Content Knowledge
CPA:	Grade Point Average
DBE:	Department of Basic Education
FRD:	Foundation for Research Development
IEA:	International Association for the Evaluation of Educational Achievement
NCS:	National Curriculum Statement
OBE:	Outcomes Based Education
PCK:	Pedagogical Content Knowledge
PK:	Pedagogical Knowledge
R-NCS:	Revised National Curriculum Statement
SGB:	School Governing Body
TIMSS:	Trends in International Mathematics and Science Study
TLRP:	Teaching and Learning Research Programme

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CHAPTER 1

OVERVIEW OF STUDY

1.1 INTRODUCTION

This chapter gives an overview of the study and outlines the background for conducting the study with a brief account of the problem that led the researcher to conduct it. Other elements covered include purpose and objectives of the study, brief description of research design and related elements including methodology and procedures, instrumentations, data sources, sampling as well as how the data were analysed.

1.2 BACKGROUND

Physical science, mathematics, technology and accounting are globally regarded as gateway subjects necessary for promoting economic development, equally critical in the development of scares skills for various professions. The Department of Basic Education (DBE) in South Africa has been assigned the task of ensuring that they are given priority and that learner performance in them is improved at all levels of the education system. A document by the DBE, "Action Plan 2014: towards the realization of schooling 2025" outlines a vision for the quality of education, the state of the schools and the role of stakeholders (DBE 2011). It also outlines the goal of improving performance in the key subjects, especially physical science and mathematics and how they will be met, stating the roles of each stakeholder.

Since 1994, when the new democratic government in South Africa took over, the DBE has sought means to improve the teaching of mathematics and physical science to obtain better results. One of the strategies employed to achieve this was the introduction of a new curriculum. In 1997, Outcomes Based Education (OBE) was introduced under the name of 'Curriculum 2005', intended to correct the flaws of the apartheid curriculum in existence prior to 1994, designed around and guided by racial policies. Curriculum 2005 focused on the achievement of skills and outcomes by learners but it was overtly criticized by scholars and academics (Jansen 1998; Mason 1999; Waghid 2003; Fakier & Waghid 2004), hence it was replaced by the revised National Curriculum Statements Grades R-9 (RNCS) in

2000, and the National Curriculum Statements grades 10-12 (NCS) in 2002. On review of the RNCS and NCS in 2009 it was recommended that this policy be replaced by the latest Curriculum and Assessment Policy Statements (CAPS), as the former imposed extra administrative work for teachers. The CAPS document is a single policy document which combines the RNCS and NCS, now known as the National Curriculum Statements Grades R-12 (DBE 2011).

These changes brought about confusion which is still observed with some teachers who are currently teaching grade 12 physical science. The subtle differences between OBE, NCS and CAPS are puzzling to most teachers as lack of differentiation emerged as a result of rapid changes in terminology. Some simply tried to adapt but without attending to their teaching goals, whilst others became lost in the process of change and were unable to teach effectively. OBE had been an approach that focussed on what learners could demonstrate at the end of a learning experience, paying attention to the learning outcomes rather than knowledge. Lack of focus on how the outcomes were to be achieved, resulted in fragmented teaching as teachers would only teach to achieve the required outcomes (Grussendorff 2014). In addition, OBE left too much room for teachers to select which outcomes they wanted their learners to demonstrate at the end of the learning experience, so if one had to move from one school to another what he or she had learned at the previous school might be different from what was taught at the new school. OBE was context-based and used jargon that teachers could not handle or understand, such as 'developmental outcomes', 'specific outcomes', 'learning outcomes' and 'assessment standards' (ibid.).

Likewise, the NCS followed an outcomes-based approach, based on learner-centred teaching and learning. Like OBE, it focused on the achievement of outcomes but prescribed very little what content to teach, or when. It differed from OBE in that it specified how to teach for the achievement of outcomes while OBE had mentioned the outcomes without specifying how to teach towards them. Thus, teachers were left to decide for themselves (ibid.). Unlike NCS, CAPS, which is a policy document, focuses on content which must be taught, is more teacher-centred, and organises learning in a more logical manner. It prescribes what must be taught and when. CAPS eases teachers' load in terms of pacing, progression and sequencing of topics, since these are already outlined for teachers. Even those who lack subject content knowledge do not have to worry about re-organising knowledge that they must teach. This was a challenge in NCS as pacing, progression and sequencing of topics was left to the teacher, hence teachers with little content knowledge struggled to re-organise the content. Both NCS and CAPS, however, emphasise knowledge, skills and values which learners in post-apartheid South Africa should acquire.

Following the above discussions, NCS was not a new curriculum but rather a review of the outcomes-based curriculum. Similarly, CAPS is a policy, which makes it easy to implement NCS, but it is not a new curriculum. Thus, both NCS and CAPS contain the elements of OBE and as such are influenced by it. Since CAPS only prescribes what must be taught and not how to teach the knowledge, skills and values, it is an aim of this study to bring into perspective the element of pedagogy in the teaching of grade 12 physical science. Doing so will bring in the 'how' of teaching the content prescribed by the CAPS document, currently lacking. The introduction of CAPS by the DBE was intended to ensure that what must be taught in the NCS would be prescribed clearly and in an orderly manner in order to assist teachers with the sequencing and progression of topics.

1.3 PROBLEM STATEMENT

Despite attempts by the DBE to change the curriculum and unprecedented increase of funding during the past 20 years, mathematics and physical science still face a major challenge of low performance in schools.

Learners in grade 12 are not achieving good grades in these subjects, as indicated by international scales such as the Trends in International Mathematics and Science Study (TIMSS) report of 2012, based on tests administered to grades 4 and 8 learners.

In grade 8 Science, for example, South Africa obtained an average score of 332, beating Ghana (306) but below Morocco (376) and Botswana (404), well below the low International benchmark of 400 (Martin, Mullis, Foy & Stanco 2012).

According to Matrin et al. (2012:48), in these tests, "there was evidence of many very low performing ninth grade students in South Africa, with the percentage of students with achievement too low for estimation between 15 percent and 25 percent".

The main problem emerging from the studies above is that grade 12 physical science teachers do not possess adequate content knowledge of the discipline or appropriate pedagogy of the subject. They have inadequate understanding of what constitutes knowledge of physical science in schools, what type of knowledge learners should acquire, and how theoretical knowledge of science as a discipline shapes pedagogical practices, including the use of practical work in the teaching. They also show lack of understanding of the unique properties of physical science as a discipline and lack of understanding of how the knowledge content impacts on its pedagogy.

1.4 PURPOSE OF THE STUDY

The purpose of this study was to examine grade 12 physical science teachers' understanding of knowledge underpinning the subject and its associated pedagogy, and how this (understanding of discipline knowledge) impacts on the integration of theory and practice in its teaching.

1.5 OBJECTIVES OF THE STUDY

The objectives of this study were, firstly, to examine the discipline content knowledge of grade 12 physical science teachers; secondly, to explore the pedagogy they used; thirdly, to investigate the influence of discipline content knowledge on its pedagogy; and fourthly, to investigate how OBE and competence-based curricula have affected knowledge of the subject.

1.6 RESEARCH QUESTIONS

In order to address the problem under study, the following questions were raised:

1) What type of knowledge do grade 12 physical science teachers require to teach effectively?

2) How does content knowledge of physical science shape pedagogy of physical science?

3) To what extent do grade 12 physical science teachers integrate practical work with theory in their teaching?

4) How have OBE and competence-based curricula affected the knowledge of physical science in the current grade 12 physical science curriculum, CAPS?

1.7 RESEARCH DESIGN

The researcher conducted an in-depth study of the problem through collection of qualitative data from the sources in the natural settings in which teaching was taking place, that is, from schools, classrooms and from teachers. Interviews and observations were conducted in the classrooms, with the teachers providing the most relevant, first-hand information to the researcher. The researcher collected the data and analysed them within two paradigms, normative (positivism) and interpretive (Cohen, Manion & Morrisson 2007; Creswell 2008). A narrative-discursive approach was used, described by Sikes (2006) as storytelling, whether told freely or as the result of enquiry.

The study used purposeful sampling, that is, a selection of information-rich sources by the researcher, with the aim of obtaining the most valuable information required to solve the research problem (Coyne 1997; World Health Organization and University of Amsterdam 2004). The study was conducted in Xhariep Education District in the Free State Province with a population from five high schools offering grade 12 physical science. A total of five grade 12 physical science teachers, one from each school were selected to participate. Focus group and individual interviews were conducted with the selected group of teachers and classroom observations made with this group. Data were obtained, analysed and interpreted with document analysis and all the collected data were used to draw conclusions after a thorough analysis of the results.

The propositions in this study were:

1) Teachers were unable to integrate practical knowledge with theory in their teaching of physical science

2) Teachers lacked discipline knowledge of physical science

3) Teachers lacked an understanding of how the knowledge of physical science impacts on its pedagogy

4) OBE and competence-based curricula have displaced the knowledge of physical science.

The research methods will be discussed in greater detail in chapter 3.

1.8 SIGNIFICANCE OF STUDY

This study will provide the framework to examine the relationship between content knowledge of grade 12 and its pedagogy, helping teachers to make informed decisions about their selection of content, sequencing and pacing. It will also draw to the attention of the DBE which content areas grade 12 physical science teachers need to develop and whether there is a need to strengthen their pedagogical skills.

1.9 ETHICAL CONSIDERATIONS

Permission to conduct the study was obtained from the Free State Department of Education, principals and school governing bodies (SGBs) of schools in which the study was conducted (see Appendices C, D, F and G). To protect the participants' rights the researcher articulated the research objectives verbally and in writing so that they were clearly understood. This included a description of how data would be used. Written permission was obtained from the participants, to proceed with the study as articulated (Appendix E) and they were informed about all data collection devices and activities. The researcher wrote verbatim transcriptions and interpretations and made reports available to the participants, considering their rights, interests and wishes when making choices in reporting the data. Participants' anonymity was assured (Creswell 2008).

1.10 CHAPTER LAYOUT AND TIMEFRAME OF STUDY

Chapter 1 has provided an overview of the entire study, with the context and background to the study, the statement of the problem, the aims of the study, the research questions, and an outline of the research design. It further presented the significance of the study, definitions of terms, and outline of the study.

Chapter 2 is a review of related literature, focussing on the historical and political background of mathematics and science in the country, the history of science as a discipline, experiments in science, science and pedagogy, and the theoretical framework underpinning the study.

Chapter 3 deals with research design, presenting the research methodology, data collection procedures and techniques, as well as data reduction and analysis.

Chapter 4 is a presentation of results and findings of the study.

Chapter 5 is a discussion of results and findings and provides recommendations for future research. Finally, the chapter draws conclusions based on the results and findings of the study.

1.11 DEFINITION OF TERMS

The following is a brief list of terms used in the study as understood in the context in which they are used.

PHYSICAL SCIENCE

This is a collective term for branches of natural science and body of knowledge which encompass other sciences. The term is understood here as including physics and chemistry but excluding astronomy and earth science.

PHYSICAL SCIENCES

The term refers collectively to a group of sciences which include physics, chemistry, astronomy and earth science.

CONTENT KNOWLEDGE

The term refers to a teacher's knowledge of the subject he/she is teaching, the depth of understanding the subject or discipline and how he/she organises the subject. According to Shulman (1986), content knowledge goes beyond so-called facts and concepts of a domain, and includes knowing the different ways in which the concepts and principles of a subject area are incorporated. The teacher also has to know the 'grammar' of the subject, so as to distinguish between the correct subject rules and the false. Content knowledge is the 'what' of teaching.

PEDAGOGY

"Pedagogy is the act of teaching together with its attendant discourse. It is what one needs to know, and the skills one needs to command, in order to make and justify the many different kinds of decisions of which teaching is constituted" (Alexander 2004:11).

PEDAGOGICAL KNOWLEDGE

Pedagogical knowledge is the knowledge of how to teach, going further than subject knowledge to include creation of an environment conducive to learning, learner motivation and understanding the needs of learners (Shulman 1987).

PEDAGOGICAL CONTENT KNOWLEDGE

Pedagogical content knowledge refers to the teacher's ability to represent content or subject knowledge to learners in ways that make it easy for them to understand. It involves knowledge of what constitutes barriers to learning, learner misconceptions, knowledge of learners and their circumstances (Shulman 1986). In contrast to content knowledge, pedagogical content knowledge is the 'how' of teaching.

1.12 CONCLUSION

This chapter has provided an overview of the entire study, outlining the background for conducting it. An account of the problem which led to the study being conducted was also given. Other elements of the study discussed included the problem statement, purpose and objectives, research questions, research design, and significance, ethical considerations, chapter layout and definition of terms used. Chapter two focuses on the review of literature pertaining to the study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter reviews the literature on theory and pedagogy of physical science and identifies gaps that might exist in it. The chapter consists of two parts, with part one providing background information about the historical and political developments in the South African education system both prior to and after the apartheid era. Specific reference is given to developments in science and mathematics. Part two focuses on the history of science as a discipline, science as a discipline, experiments in science and teacher knowledge. The chapter concludes by discussing three theoretical frameworks, namely, practical rationalism, social constructivism and social realism and the one guiding the study is discussed.

2.2 BACKGROUND

The current status quo in education in South Africa and in science education in particular has its origin in the apartheid system that existed in the country before 1994 to segregate people and provide unequal education to citizens (Christie 1991; Msila 2007; Black 2009). Even before apartheid was introduced, however, education was segregated and unequal, with English used as the language of teaching and learning in the schools belonging to the different education departments, particularly the British colonies such as the Cape colony (Msila 2007). The Bantu Education Act of 1953 introduced by the then minister of Native affairs of the ruling Nationalist party, H. F. Verwoerd, implemented an education system to prepare blacks as workers for the white masters. It would not make them aspire for marketable jobs such as in the field of mathematics, science and engineering, which were reserved for whites (Reddy 2005; Msila 2007; Black 2009) but instead train them to acquire skills that would enable them to be used back in their communities in the 'homelands'. Bantu education was meant to be inferior and produce inferior people (workforce) so, for blacks, education was meant to provide poor outcomes to produce unskilled labour (Thobejane 2013). According to Kallaway (1988, cited in Msila 2007) Bantu education was a way for the Nationalist government to restrict the development of both students and teachers by distorting knowledge provided in schools and ensure control over the intellect of the students and teachers, as well as perpetuating state propaganda to achieve their political goals.

Prior to 1953, before introduction of Bantu education, ninety percent of black South Africans attended mission schools, funded by the state. Education was under control of the Department of Native Affairs between 1954 and 1958, after which a separate Department of Bantu Education was formed to design new syllabi. On its introduction, the Bantu Education Act demanded that these mission schools register with the state, which took over the powers of churches to control the schools from provincial authorities, resulting in most mission schools being forced to close. Schools under the Roman Catholic Church were the only survivors, attempting to run their schools without state assistance (Black 2009).

During the same period, the extension of University Education Act 45 of 1959 stopped students from black communities from attending white Universities (Christie 1991). Black students were prevented from attending universities such as the Universities of Cape Town and Witwatersrand, and forced to attend black colleges and universities which were segregated according to tribal patterns. Fort Hare, Venda, Vista and Western Cape were set aside for black students.

The apartheid government created universities for different ethnic groups, the so-called "bush colleges" with the intention of perpetrating deep social and race divisions among the majority of black natives to reduce them to a smaller and weaker political force (Thobejane 2013; Reddy 2004). The University of Zululand was established for Zulu and Zwazi speakers; the University of the North for Sotho, Tswana, Venda and Tsonga speaking people; and the Universities of Durban-Westville and the Western Cape for Coloureds (mixed race) and those of Asian origin. These universities had been built by 1970 in the Bantustans of Bophuthatswana, Transkei and Venda (Reddy 2004).

In 1960 the Nationalist government saw the need to increase the black labour force, so government spending on Bantu education was increased, even though resources and facilities were still lacking and of a quality inferior to those of white schools. More black learners began to attend schools under Bantu education than in the former mission schools, leading to overcrowding in black schools. Teacher-learner ratios became higher in black schools than in white schools (Black 2009).

Between 1963 and 1965, government passed the Coloured Person's Education Act of 1963 and the Indian Education Act in 1965, both of which made education compulsory for Coloured and Indian communities, but they effectively separated the communities from white schools. The government's policy compelled African children to attend schools in the so-called 'homelands', in which new schools had been built for them. This segregated them further as the people of Soweto had to move to the homelands to receive education. Following the 1976 uprisings the Department of Bantu Education was replaced by the National Department of Education and Training, established in 1984. Homelands established their own departments which were controlled by the National Department of Education and Training and perpetuated the agenda of keeping the standard of mathematics and science low. This was achieved by making low budgets for black students in mathematics, science and technology and ensuring that their education enabled them to only do semi-skilled work through poor mathematics and science curricula. They could not participate in the development of their own country. (Thobejane 2013; Mbajiorgu & Mafumo 2014).

2.3 MATHEMATICS AND SCIENCE PRIOR TO 1994

An influence of the Bantu Education Act of 1953 was that mathematics and science were not offered equally to different racial groups, with Whites enjoying the best opportunities (education facilities and resources) (Reddy 2005). Table 2.1 (below), shows participation and performance of different racial groups by percentage, in mathematics in 1990.

Table 2.1: Participation and performance of different racial groups by percentage in mathematics in 1990

	Participation rate in matriculation mathematics	**Pass rate in mathematics**	**Participation in higher grade mathematics**
White	64	97	60
Indian	70	76	74
Coloured	45	74	38
African*	24	15	65

Source: FRD 1993 in Reddy (2005)

Note. *Education for Africans was fragmented and offered in the homeland and self-governing states as well as “South Africa”. The statistics for the African group are from the Department of Education and Training schools.

Table 2.1 (above) shows a poor participation and pass rate in mathematics, exacerbated by creation of the abovementioned ‘homelands’ or ‘Bantustans’ under the newly formed Department of Education and Training. It should be noted that due to the close link between mathematics and science, performance in the latter can be associated with that in the former, with most students who take one also taking the other (ibid.).

Hartshorne (1985) provides statistics on the performance of black matriculation students in 1983: “In 1983 only 3.6% of the total Standard 10 entry gained a pass in Higher Grade mathematics and 2.7% in Higher Grade physical science.” This emphasises the impact of Bantu education on mathematics and science in the apartheid era, and the conditions in black schools, such as absence of libraries and laboratories, affected education negatively. These schools were characterised by high teacher to learner ratios, few or no textbooks, unqualified and/or underqualified teachers. Funding to black schools was also low (Carrim 2006; Mbajiorgu & Mafumo 2014). According to Auret (in FRD 1993), only 0.4 percent of African schools were responsible for 20% of the students who participated in science and engineering faculties at universities (Reddy 2005), a low figure considering that 75% of the total population of South Africa are Africans.

2.4 MATHEMATICS AND SCIENCE AFTER 1994

The introduction of Outcomes Based Education (OBE) in 1997 was the new government’s way of addressing the ills of the apartheid system of education, an attempt to unify the segregated communities and to develop a democratic alternative to Bantu education. Msila (2007) notes that OBE was adopted in order to correct the damage made by the apartheid system, especially with respect to the poor quality and standard of mathematics and science. Introduced under the name ‘Curriculum 2005’, it was intended to correct the flaws of the old apartheid curriculum through focussing on what learners could demonstrate at the end of a learning experience. Due to widespread criticism by scholars and academics and resistance to implementation by teachers, the Department of Basic Education was forced to review the curriculum in 2000, leading to the introduction and implementation of the National Curriculum Statements (NCS) in 2002. Later, in 2009, the minister of education Angie Motshega appointed a committee which further reviewed NCS and made inputs that led to the current Curriculum and Assessment Policy Statement (CAPS), as the former imposed extra administrative work for teachers (DBE 2011). The refined differences between OBE, NCS and CAPS are like pieces of a puzzle to many teachers, with a lack of differentiation between the terms emerging as a result of rapid changes in terminology which happened within a short period, giving teachers and some stakeholders no time to reflect on them. In a study by Lekhu (2013), teachers reported that even the CAPS training which was offered to them by departmental officials was too short for it to be effective.

It is not possible after 1994 to make a comparison among racial groups similar to the one provided in Table 2.1 for the period before that year since learners have been writing the same examination under one department (of Basic Education), but one can ask whether there has been an improvement in the performance of learners in mathematics and science during this new era.

A study by Mouton, Louw and Strydom (2012), shows that the Department of Basic Education recorded an increase in the pass rate from 1999 to 2003 by 24.4%. The most recent NSC results in grade 12 physical science are shown in Table 2.2 (below).

Table 2.2: NSC results in physical sciences over the period 2011 to 2014

Year	**Number Written**	**Number achieved at 30% and above**	**Percentage achieved at 30% and above**	**Number achieved at 40% and above**	**Percentage achieved at 40% and above**
2011	180 585	96 411	53.4	61 109	33.8
2012	179 194	109 918	61.3	70 076	39.1
2013	184 383	124 206	67.4	78 677	42.7
2014	167 997	103 348	61.5	62 032	36.9

Source: DBE 2014 Diagnostic report (DBE 2015)

The table (2.2) shows an increase in physical science results by 8.1% from 2011 to 2014 (column 4), in line with Mouton's (2012) findings as stated above, although lower than that recorded by Mouton in 1999 to 2003. Mouton argues that despite this increase in pass rate, standardisation of results by Umalusi distorts the true reflection of actual results obtained by learners. He maintains that the true test of the competency of our education system can be reflected in the TIMSS results, which are based on international standards, according to which South Africa is still faring poorly, suggesting that not much has been achieved since 1994.

2.5 THE HISTORY OF SCIENCE AS A DISCIPLINE

Knowledge of the history of science provides a firm basis for understanding how science developed and why scientists studied it. There is a strong relationship between the philosophy of science and the history of science, with Smith (2010:545) arguing that "philosophy of science without history of science is empty, and history of science without philosophy of science is blind." To understand the theoretical and practical components of science, one has to understand both the philosophy and history of science. According to Rheinberger cited in Fernbach (2011), both epistemology and history of experimentation developed concurrently and are inseparable. He regards experimental contexts as repeating situations in which new knowledge that arises strives to challenge the assumptions of the current methods with the intention of finding new ways of doing things. This scientific process of investigating permanently transforms what was considered true yesterday into what is found to be false today.

The central argument here is that there is history in the development of science and that science is a growing and changing subject. What were thought to be sound theories at some specific time may be changed by new developments and new knowledge on the subject. Earlier science emphasised accumulation of knowledge and memorization of facts, which Pickering (cited in Fernbach 2011) objected to as a "science as knowledge" agenda and regarded as "thin, idealized, and reductive." He further argued that the agenda did not provide conceptual tools needed to experience the value of doing science, the massive job of building instruments, planning, running, interpreting experiments, explaining theory, talking with laboratory managements, journals, grant-giving agencies and other stakeholders. The "science as knowledge" agenda stripped science of its essence. As a result, the prominent move in recent science studies has been a shift from perceiving science as knowledge to envisioning it as practice. The question to ask therefore would be: Should teachers regard science as mere knowledge or as practice? If the latter, to what extend should science be practiced in schools? Should learners grow up as practicing scientists or should they be taught science as knowledge? What role does practical work play in the acquisition of scientific knowledge?

2.5.1 Science as a discipline

Physical science as a discipline is guided by rules and principles, following a vertical discourse in what Gamble (2009:23) refers to as 'conceptual coherence'. A curriculum that is conceptually coherent is one in which the concepts build on one another with new themes based on previous ones in a logical manner. Sequencing of topics, their pacing and progression are of great importance in ensuring that concepts are understood by learners (ibid). In the same vein, Bernstein (2000:157, cited in Wheelahan 2006:7) differentiates between horizontal discourse, which incorporates mundane or everyday knowledge, and vertical discourse, which represents abstract and theoretical knowledge. The former is "likely to be oral, local, context dependent and specific, tacit, multi-layered, and contradictory across but not within contexts", the latter segmented on the basis of the specific context in which it is realised. Not all segments (or segmental discourses) are of equal importance, and different segments may be more or less related to each other, but each has its own logic, practices and forms of discourse. On the other hand, vertical discourse represents theoretical bodies of knowledge organised in disciplinary fields, and "takes the form of a coherent, explicit, and systematically principled structure, hierarchically organised, as in the sciences…" (Bernstein 2000:157). Vertical discourse differs from horizontal discourse in that the former is not segmentally organised. Integration of knowledge does not arise from the context, but through integration of meanings, which meanings are not fixed to a specific context (ibid).

There are contrasting views on the structure of physical science as a discipline, and OBE as an approach to teaching physical science. Whereas physical science follows a vertical discourse as Gamble and Bernstein argue, OBE focuses on the learning outcomes, which may be fragmented and follow a horizontal discourse. As a result, this gives rise to the questions:

- Should teachers possess some knowledge of the nature of science, its structure and how the knowledge of science as a discipline is acquired, so that they can teach science effectively?
- Do teachers need to know the subject content?
- How would their knowledge of the subject content help them to select relevant content, arrange this content into coherent, logical sections for teaching and be able to pace the teaching of the content accordingly in line with their work schedules?
- How would this affect how well teachers teach the syllabus and ensure its completion?
- Is what is taught relevant to the needs of learners and does it meet curriculum goals?

2.5.2 Experiments in science

Timur (2012) argues that children, during their early childhood, tend to explore objects and events happening in their environment by touching, hearing, seeing, smelling and tasting. They learn about things by asking questions out of curiosity and as they come across events in their environment they begin to build their own hypotheses. This manipulation of objects helps them to make meaningful learning of their own environment and to develop their own ideas about how equipment around them works. This means that children learn science by themselves and begin to develop positive attitudes towards the learning of science.

In the light of the above discussions, it appears that the teaching of science has to take into account that human beings, hence learners, are naturally inquisitive and like to handle things and experiment with objects. This way of inquiry into the world should start at a young age by allowing children to experiment in formal settings, such as the school environment and science laboratories. Science teachers should give learners opportunities to think like scientists, to solve problems in new and challenging situations and to carry out investigations (DBE 2011; Timur 2012). In addition, science should be taught in meaningful ways that are both appealing to the human side of learners and which are relevant to the daily lives of learners (Donnelly & Ryder 2010; Timur 2012). Science should be real and accessible.

Traditionally, science curricula placed emphasis on classroom teaching which focused on familiar factual knowledge, concepts, laws and theories of science, referred to as 'conceptual understanding' or 'substantive understanding' (Roberts & Sahim-Pekmez 2012). Such facts, concepts, laws and theories, although contributing to substantive understanding, are supported by empirical evidence or can be subjected to investigations. In science, substantive understanding is supported by evidence, experimentation and or scientific procedures. Science is not based on opinion or what the majority of the people believe (Harris & Farrell 2007; Roberts & Sahim-Pekmez 2012), but as understanding of evidence in science that Shulman (1986, 1987) referred to as 'content knowledge', and Grossman (1990) as 'subject matter knowledge'.

Being able to understand scientific evidence and apply it to solve problems, as well as to evaluate scientific claims, is debatably a key element of scientific literacy, which is what the latest curriculum developments aim to achieve (Gott & Duggan 2007). This engagement with evidence in science has implications for how education programmes should be developed and on how tertiary institutions take responsibility for preparing their student teachers to teach science. Furthermore, studies of science teaching pedagogy should be accompanied by discipline-based science study as well as exposure to the subject (Harris & Farrell 2007). Science education focuses on enabling learners to acquire knowledge, to enhance understanding of fundamental ideas about the nature and practice of science, as well as some of the principal conclusions reached by it. Learners will take this knowledge to other areas and stages in their lives, applying it to solve problems in new situations (Braund & Reiss 2006). Science education also focuses on equipping learners with appropriate skills in scientific inquiry, stressing that learners must develop procedural knowledge in the form of process skills (Department of Basic Education 2011; Timur 2012).

In South Africa, the CAPS document, Department of Basic Education (2011:8) emphasises the importance of inquiry in physical science as follows:

> The purpose of physical science is to make learners aware of their environment and to equip learners with investigating skills relating to physical and chemical

phenomena, for example, lightning and solubility. Examples of some of the skills that are relevant for the study of physical science are classifying, communicating, measuring, designing an investigation, drawing and evaluating conclusions, formulating models, hypothesising, identifying and controlling variables, inferring, observing and comparing, interpreting, predicting, problem-solving and reflective skills.

According to the CAPS document (DBE 2011), this procedural knowledge is regarded as a set of skills that learners can practice and learn through repeated exposure to practical work under the guidance of a teacher. In turn, teachers are expected to teach and guide learners through the process of experimentation in order to develop both practical and process skills that are required in scientific inquiry and for solving problems.

Teachers are required to assess learners' activities and scientific inquiry skills such as planning, observing, gathering information, comprehending, synthesising, generalising, hypothesising, communicating results and making conclusions. On the other hand, practical investigations should assess performance of learners at different cognitive levels, focusing on process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts (ibid.).

Whereas teachers in the United States of America (USA) are required by the National Standards and other documents to teach learners in inquiry based methods, teachers still lack knowledge of how science knowledge is generated by inquiry (Harlow, Swanson, Dwyer & Bianchini 2010; National Academy of sciences 2000). A similar situation exists in Australia, where science teachers, especially in the middle primary schools, lack confidence in their ability to teach science. They also feel inadequate with their knowledge of the content (Morgan 2012). A similar observation was made by Ramnarain and Fortus (2013) in South African schools, with teachers from previously disadvantaged schools, both in town and in the township, lacking pedagogical content knowledge (PCK) in certain newly introduced topics in the NCS. Some of these teachers lacked learner-centred (inquiry based) methods and resorted to teacher-centred methods. This prevented learners from asking questions in class, as teachers had full control of classrooms and avoided classroom discussions. If children are to be able to engage in inquiry and problem solving as they learn science and mathematics then their teachers also need to experience and practice inquiry and problem solving in their own education (NRC 2000a).

In a study conducted by Lekhu (2013) in the Free State schools in South Africa, it was found that physical science teachers rated themselves high on their knowledge of science, but this was based on a questionnaire to rate themselves rather than a test. The study suggested that teachers showed greater confidence rating in Physics teaching than in Chemistry, which resulted in better learner performance in the former. There was no integration of theory or practical work in schools and they cited lack of training by institutions supplying science equipment as the reason for this. The evidence suggests that teaching learners in inquiry-based methods as well as teaching scientific, practical skills is a challenge to teachers, not only in South Africa but also internationally. This occurrence then raises several questions:

- Can our teachers teach what they do not know?
- Are learners fairly exposed to inquiry learning or practical activities?

These questions need to be answered if the teaching of science is to be meaningful.

The use of practical work in schools should however be guided by a clear focus by teachers on using it to assist learners to develop substantive scientific knowledge rather than just performing procedural tasks or working with objects. Learners should be given opportunities to engage with the concepts in a variety of settings, such as models, simulations and video recordings before conducting experiments. This helps them form links and establish relationships between the concepts and heightens their interest in engaging with the practical task. Abrahams and Millar's (2008) investigation into the impact of practical work on learner achievement in United Kingdom schools found that learners made more meaning of practical work when a theoretical background of the phenomenon to be investigated had been presented prior to them conducting the experiment. Many teachers used an inductive discovery method of learning and were expecting learners to show the ideas that the teachers had intended them to find through observations and measurements: "... practical work in science could be significantly improved if teachers recognized that explanatory ideas do not 'emerge' from observations, no matter how carefully these are guided and constrained" (Abrahams & Millar, 2008:1965).

This section emphasises that physical science teachers have to know that learners learn through experiments, and that experiments are an integral part of learning science. As a result, teachers should have the curriculum knowledge and pedagogy that will help them to conduct experiments and integrate them with relevant theoretical concepts to enhance learning.

2.6 TEACHER KNOWLEDGE

Shulman (1986; 1987) proposed seven categories of teacher knowledge, however, in this study the researcher chose to focus on three, namely: pedagogical knowledge, content knowledge and pedagogical content knowledge. These, in the view of the researcher, are the most immediate of the teacher knowledges which are essential elements of teaching. This is further supported by other researchers who regard these as the most important forms of knowledge for a teacher (for example, Etkina 2010; Basson & Kriek 2012; Lucero, Petrosino & Delgado 2016). The others, (knowledge of learners and their characteristics, knowledge of educational contexts, knowledge of educational ends, and curriculum knowledge) are mentioned here for readers to research more about them since there is much literature on teacher knowledge.

2.6.1 Pedagogical knowledge

Pollard (2010:5) defines ‘pedagogy’ as “the practice of teaching framed and informed by a shared and structured body of knowledge”, which includes experience, proof, understanding moral purpose and collective transparent values. It involves the study and practice of how best to teach, and although different definitions are provided by different scholars all include teaching and learning as well as contexts surrounding these (Alexander 2003; Leach & Moon 1999).

Shulman (1987) regards pedagogical knowledge as the broad ideologies and strategies of classroom management and organisation that tend to go beyond subject content matter. McIntyre (1993), cited in Cogill (2008) suggested 14 qualities that create good teaching, all of which were provided by both teachers and learners:

1) Creation of a peaceful and enjoyable atmosphere in the classroom.

2) Maintenance of control in the classroom.

3) Presenting work in a way that is interesting and motivating.

4) Providing conditions that will allow learners to understand the work.

5) Making clear what learners are to do and achieve.

6) Judging what to expect of each learner.

7) Assisting learners with difficulties.

8) Encouraging learners to raise their expectations of themselves.

9) Developing mature personal relationships with learners.

10) Teachers' personal abilities.

11) Taking into account how planning relates with the management of classes and lessons.

12) Organisation and management of lesson introductions.

13) Proper management of question and answer sessions.

14) Building the confidence and trust of learners.

Pedagogical knowledge as described above is a broad concept, however one can argue that the same generic principles which apply to broader teaching as a field also apply to the teaching of physical science. Hence, if physical science teachers are aware of these they can make use of them in their teaching for improved results.

2.6.2 Content knowledge

Shulman (1987) describes 'content knowledge' (CK) as that which teachers have of the subject matter they are teaching. It helps them not only teach effectively but evaluate textbooks, software, appropriate technology and other teaching aids. In addition, teachers with sound content knowledge are more flexible and dynamic in their teaching, tending to design interesting lessons and inspire confidence in learners. Conversely, teachers with poor content knowledge tend to shy away from some topics which may be challenging to them (McNamara 1991, cited in Cogill 2008). CK is central to teaching as it affects planning of lessons, setting and selection of tasks, the kind of questions the teacher asks, explaining concepts, giving feedback to learners, and conducting assessment (Shulman 1987). The ideas above have been discussed in a general sense, however, studies conducted in mathematics classes on the relationship between teachers' mathematics content knowledge and student achievement, showed that the performance of learners is related to teacher knowledge of the subject matter and that teachers with more of this knowledge had significantly higher learner accomplishments in their classrooms (Harbison and Hanushek 1992; Ball and bass 2000, 2003). Similarly a study by Sadler, Sonnert, Coyle, Cook-Smith and Miller (2013) showed a correlation between science teachers' content knowledge and student achievement.

2.6.3 Pedagogical content knowledge

Teachers may have subject content knowledge, but if they do not have 'pedagogical content knowledge' (PCK) they will fail to impart their knowledge to learners in meaningful ways. Schulman (1987), cited in Deng (2007), expresses PCK as a form of knowledge in which for regularly taught topics in one's subject area, the teacher uses the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations. He or she must make the subject easily understood by others. PCK includes an understanding of the elements that make learning of specific topics easy or difficult. The teacher should understand the conceptions and preconceptions that learners of different ages and backgrounds bring to the learning of the most frequently taught topics and lessons. Teachers have to know the strategies to use in addressing the preconceptions that learners bring to the class, so as to organise the learning and understanding. Learners come to the classroom with some knowledge of those topics rather than as blank sheets.

Knowing how to teach the subject, how to make even difficult aspects seem simple and achievable to learners and making the subject more appealing and relevant to learners will improve the teaching of the subject. Teachers also need to understand the needs of their learners in order to effectively address them. Aydin et al. (2012) discuss Magnusson et al.'s (1999) pedagogical content knowledge (PCK) model that has currently been in use, with four main types of knowledge: content, pedagogical, educational context and content, with Aydin et al. (2012) and Demkanin (2013) adding another five sub-dimensions, namely: orientation to teaching science, knowledge of learners, curriculum, instructional strategies and assessment. All these components are vital to a teacher's 'toolbox' if his/her teaching of physical science is to improve.

Practicing teachers and student teachers in particular should be taught how to teach physical science. Studies have shown that teachers tend to teach the way they were taught and if they were taught using inquiry methods are likely to teach their learners using similar (Harlow et al. 2010). Research, conducted and published by a study committee of the National Research Council (1999d) on the need to advance mathematics and science results for K-12 learners indicates that teachers should use content-appropriate teaching strategies that improve their students' chances of knowing and understanding content in these subjects. Stoddard and Floden (1995) and Ball (1997), cited in National Academy of Sciences (2000) argue that this new understanding and research that examines the importance of guiding beginning teachers in order to learn to employ a variety of instructional practices implies the need for and advantages of sound preparation in both subject matter and pedagogical training for practicing and prospective teachers.

In Texas and California there has been a struggle to fill in posts for maths and science teachers due to lack of teachers with suitable qualifications in the subject (Harrell 2010). Further evidence of this is given by Monk (1994), cited in Harrell (2010), who conducted a study to find the relationship between the course work completed by a teacher and learner achievement. He found that higher achievement by learners correlated with the teacher's completed coursework in the teacher's major. Learners are more likely to achieve if their teachers have completed their course work in their subject major. In studies conducted by Ingersoll (1999) and Wirt (2004), cited in Harrell (2010), 20% of all science teachers did not have a major or minor in the subject which they taught, and 20% of middle school science teachers did not hold a major, minor or certification for the subjects they were teaching.

In the 1980s, in the USA, there were protests that teachers did not meet the expected standards of teaching because teacher development programmes focused on ‘educational methods’ courses only (Deng 2007; You 2011). It was found by Harris and Farrell (2007) that teachers contended that tertiary preparation of science teachers requires both discipline-specific science study as well as pedagogy in the teaching of science. In a study conducted by Harrell in 2005 in Texas, on eighth grade science teachers, it was found that they had little formal training in chemistry, physics, or earth science, although 38% of the eighth grade curriculum included topics for earth science. Science content knowledge as measured using grade point average (GPA) was low and more than half of the teachers did not have a degree in science. Interdisciplinary degrees and single-subject content degrees were not statistically significant related to the grades 8-12 science. This was confirmed by Aydin et al. (2012), who found in some of the studies conducted into the PCK of both experienced and pre-service teachers (Geddis, Onslow, Beynon, & Oesch 1993) that both, especially inexperienced teachers had inadequate content knowledge as well as PCK. These teachers could not use teaching methods effectively (Kagan 1992; van Driel, Verloop, & de Vos 1998).

In a study conducted by Selvaratnam (2011) on the competence of matric physical science teachers in some basic problem-solving strategies in South African schools, it was evident that teacher knowledge in the subject was lacking. The majority of the teachers could not execute the skills necessary to solve science problems, such as sketching appropriate diagrams from statements given in the question, using relationships obtained from equations to solve problems, identifying and using relevant theories and principles to solve problems and identifying the goal of the question. This lack of skills translates to lack of pedagogical skills as one has to have the know-how in order to determine the most effective ways of teaching learners to solve science problems. All these studies point to a grave global situation including South African schools (Council on Higher Education and South African Institute of Physics 2013).

To take this discussion further, some studies report a need for training of teachers who have a sound knowledge of physical science content at all levels (Harlow, Swanson, Dwyer, Bianchini 2010), which with content knowledge and pedagogy are ingredients for quality teaching (Aydin & Boz 2012; Mcleod, Steinert, Chalk, Cruess, Cruess, Meterissian, Razack & Snell 2009; National Academy of sciences 2000; Parker 2004). For

Harris and Farrell (2007), teachers must have insight into the process of science as well as a thorough understanding of scientific concepts and principles, regarding science as an activity, way of thinking and pure knowledge. Such insight and knowledge will translate into good pedagogy and improve teaching and learning.

It appears from these discussions that teachers need to have a firm foundation of PCK as well as sound subject knowledge as some of the tools they need for meaningful teaching. According to Deng (2007), PCK, as advocated by prominent authors such as Bruner, Schwab and Dewey is not as simple as it sounds, but rather is a complex activity of carefully changing subject matter of academic discipline into a school subject. As such, teachers have to make an effort to understand PCK in order to improve their teaching. It can be argued that this can still be achieved through strong willpower and concerted efforts if teachers are determined to improve their own practices in order to achieve results in physical science. For a teacher, *selection* means that he or she is able to select relevant material from the content to be taught; *sequencing* involves arranging topics in a logical, coherent manner that is meaningful to the learner; and *pacing* allows the selected content to be taught within a specified time in line with the syllabus (Gamble 2009).

2.7 THEORETICAL FRAMEWORK

The study's theoretical framework examines three ontological and epistemological strands of knowledge construction, hence the following will be discussed: practical rationalism, social constructivism and social realism.

2.7.1 Practical rationalist perspective

Schuh and Barab (2008) describe rationalism as a belief that reason is the main source of knowledge and one influences the practical experience encountered in the world through senses, thus creating the world itself. Rationalists argue that learners discover what is already there and that which existed in their minds before. Practical rationalists believe in the dual existence of knowledge both in the external world and in the individual's mind, and that neutrality in the perception of reality as it exists in the external world should be maintained by an individual. He or she should be objective and detach his/her personal beliefs from the external world, whilst the mental world is self-evident and what his/or her concern could be is how the mind operates in order to function adequately in nature. Practical rationalists emphasise the cognitive development of an individual and as a result subjects such as mathematics, philosophy and languages are their main targets (Gergen 2001). A weakness of this perspective is that it emphasises reasoning to the exclusion of observation of the real world. Science is not philosophy and depends not on reasoning and logic alone but also on experimentation. Based on these reasons one argues that practical rationalist epistemology is not relevant to this study.

2.7.2 Social constructivist perspective

According to Mastin (2008), constructivism views all knowledge as 'constructed' in that it relies on convention, human perception and social experience. As a result, our knowledge does not necessarily reflect any external or 'transcendent' realities. Its proponents consider it to be an alternative to classical rationalism and empiricism, a point of view that is both pragmatic and relativistic in nature. It opposes positivism and scientism in that it holds that scientific knowledge is constructed by scientists and not discovered from the world through strict scientific method, maintaining that there is no single valid methodology, and that other methodologies may be more appropriate for social science (Mastin 2008; Schwandt 2000). One figure, Dewey (1933/1998), is frequently cited as the philosophical founder of constructivism whilst scholars of the social constructive perspective, Piaget (1972) and Bruner (1990) are regarded as the chief theorists among the cognitive constructivists, and Vygotsky (1978) as the major theorist among the social constructivists. The main principle or belief behind social constructivism is that knowledge has inherent cultural and social dimensions in particular contexts. Knowledge in general, and teachers' knowledge(s) in particular, has within it cultural and social dimensions of particular contexts in which knowledge and experiences of what constitute it are shared by, for example, a community of practice. Underpinning this view is the assertion that there are multiple sites of teacher knowledge and that universities are not necessarily the sole custodians of teacher knowledge(s) (Jackson, Karp, Patrick, Thrower 2006; Kim 2001; Mastin 2008).

The common denominator among all forms of constructivism is that they do not focus on an ontological reality, 'reality-as-it-is-in-itself', which constructivists regard as incoherent and unverifiable, but rather on constructed reality. As a result, they reject out-rightly any claims to universalism, realism or objective truth, and admit that their position is merely a view, a coherent way of understanding factors that have worked for them as a model of the world (Mastin 2008; Schwandt 2000). Although reality exists through interpretations, society and an individual's relationship to it have a primary role in the shaping of that reality, with social constructivists contending that knowledge is distributed in the world, among objects and individuals, a shared rather than individual experience, progressing through social negotiation (Prawat & Floden 1994; Savery & Duffy 1995, cited in Schuh & Barab 2008).

Social constructivists disagree with practical realists arguing that what one takes to be knowledge of the world is not a product of induction, or of the building and testing of general hypotheses. The terms in which the world is understood are social artefacts and products of historically situated interchanges among people. The process of understanding is not automatically driven by the forces of nature but is the result of an active, purposeful co-operative enterprise of persons in a relationship (Gergen 1985).

The social constructivist perspective has the following shortcomings as far as this study is concerned. It views knowledge as constructed by society, however, the same occurrence or knowledge can be interpreted differently by people in different settings based on how they construct their knowledge in their specific context. Science as a discipline is based on laws and principles which remain the same in different contexts. It is a universal subject which cannot be socially constructed but that follows a vertical discourse (Gamble 2009). It does not help explain how science develops or is practiced, but rather is based on relativism instead of universal principles which are formed as a result of experimentation and research (the scientific method), as social realism advocates. By relativism, it is meant that since contexts are not the same, what is accepted as knowledge in one context may be based on knowledge constructed in another, hence this knowledge becomes relative, and may not necessarily be the same in both contexts. Schwandt (2000) argues that social constructivism is silent about the existence of the external world, which social realists seek to understand.

2.7.3 Social realist perspective

According to Schuh and Barab (2008), realism is an ontological view which supports the existence of a real, physical world that is external to individuals and includes human experience. Realism assumes there is a reality of some sort 'out there', which is a separate entity from the mind and human perceptions. Critical realist elements emphasize ontology of knowledge and underscore the distinction between the real world and knowledge of it, pointing out that what exists does not depend on what one thinks about it or know about it. Realism therefore assumes that knowledge is about an objective world which exists independent of one's social constructions of it. Hence, knowledge and pedagogy of curricula have a realist element in that they exist independently of one's existence though being given meaning by people in social environments. Social realists place more emphasis on keen observation of the external world and are careful that emotions and personal views should not influence the accuracy of what a learner (observer) records about the external world (Gergen 2001).

Prawat (1995), cited in Schuh & Barab (2008) adds that truth or knowledge in realism is established as having correspondence between the structure of the mind and what is present in the world. Bernstein (2000) and critical realists agree that knowledge has social and real dimensions that do not depend on who produced it or the context in which it was produced, but rather that it is socially and historically constructed. They further agree that knowledge is not reducible to a specific context and that sometimes it is necessary to go beyond 'sense' data for one to understand the real world, as reality (Wheelahan 2006).

Bernstein and Durkheim hold a view that "all societies distinguish between sacred or esoteric knowledge on the one hand and profane or mundane knowledge on the other" (Bernstein 2000:29, cited in Wheelahan 2006:4). Esoteric knowledge refers to theoretical and conceptual knowledge, while mundane knowledge is "knowledge of the other... knowledge of how it is (the knowledge of the possible)" (Bernstein 2000:157, cited in Wheelahan 2006:4). As cited in Wheelahan (2006:5), Young (2003:102-103), describes esoteric knowledge as consisting of... "collective presentations of a society that allow it to make connections between objects and events that are not obviously related and to project beyond the present to a future or alternative world". Arguing in its favour, Bernstein (2000) describes esoteric knowledge as powerful knowledge which constitutes the site of the 'unthinkable' and the 'yet-to-be-thought'. This is the knowledge that creates scientific theories and that makes it possible for these theories to be refined or discarded at a later stage.

Arguing from Bernstein's point of view, questions arise about South African physical science teachers. Firstly, do they teach this esoteric, conceptual and theoretical knowledge to high school learners? Secondly, do they teach in such a way that learners can make connections, abstract and real, between components of the syllabus that will eventually form a coherent whole body of knowledge in physical science? Thirdly, do they teach for exams, working towards achievement of fragmented outcomes? Fourthly, can Bernstein's theory add value to how teachers in South African institutions of higher learning are taught in order to influence how they teach high school physical science? These questions may form a basis for further discussion or for other research studies.

On the basis of the weaknesses of the other two strands discussed above, namely, practical realistic perspective and social constructive perspective, the researcher chose the social realist framework to guide this study. The subject physical science calls for a social realist view, that there is knowledge existing 'out there' which is external to the human mind and not context-dependent and can be understood through scientific procedures of careful observation and experimentation. Science requires an observer to make use of the five senses to investigate phenomena and to give meaning to the surrounding world.

2.8 CONCLUSION

In this chapter, part 1 has focussed on the review of literature on the historical and political background of education in South Africa, with emphasis on its impact on science and mathematics. Part 2 focused on the review of literature on the theory and pedagogy of physical science, looking at the history of science as a discipline, the nature of science, practicals in science and teacher knowledge.

Literature on South African education shows that unequal education and Bantu education in particular led to inequalities in the provision of subjects such as mathematics and science. Black communities were the most affected by these inequalities but even after the new government took over in 1994 little has been achieved in improving the performance of learners in the subjects, as suggested by TIMSS results over the past few years.

An understanding of the history and philosophy of science may help teachers to understand the origins of science as a discipline, scientific discoveries, the scientific method and processes as well as scientific arguments that have led to the current developments in the subject. These include challenges scientists encountered in making their discoveries over the years. With this background knowledge, teaching of science could be grounded in principles and theories behind the discipline.

Institutions of higher learning which produce teachers should look into their programmes in order to ensure that they produce teachers who are able to conduct experiments with or for their learners. Emphasis is placed on learners not only being taught theories and factual knowledge, but also being given opportunities to acquire empirical evidence of such theories. It seems that, currently, grade 12 physical science teachers in South African schools do not expose learners to science experiments; hence one of the research questions is based on this aspect.

Teachers should have good subject knowledge, and so be more confident and able to interpret, arrange and pace content according to the syllabus, whilst evaluating books and other resources. Literature emphasises that despite a teacher's knowledge of the subject content, if he or she does not have necessary pedagogical content knowledge then his/her content knowledge may not be effectively transferred to learners. Teachers need to have both content knowledge and pedagogical content knowledge.

Whereas studies by Ramnarain and Fortus (2013) indicate that South African teachers in their area of study showed lack of confidence in inquiry-based teaching this does not arise clearly as referring to lack of confidence in performing experiments with learners. Lekhu (2013), on the other hand, investigated teachers' confidence in performing experiments through a self-portraying questionnaire, which was open to teachers' biasness towards their own abilities. In addition, the results of her study cannot be generalised and as such this research hopes to contribute to her findings and add another dimension to her methods of data collection by physically observing teachers in their field of work.

Although other studies have criticized OBE with regard to its approach and implementation, none have looked at how OBE and competence-based curriculum influenced the teaching of physical science in NCS and the current CAPS curriculum in a South African context. This study hopes to address this identified gap in the review of literature consulted. Among the many different theoretical frameworks, this study is guided by the social realist perspective of the nature of knowledge and how knowledge is acquired, in support of the scientific approach to knowledge acquisition. Chapter three describes the research design of the study.

CHAPTER 3

RESEARCH DESIGN

3.1 INTRODUCTION

This chapter describes the research design undertaken to conduct this study, including different types of paradigms and the one used in the study. It details elements of research design including methodology, sampling, propositions, sources of data, data collection, instruments used in data collection, data analysis, dealing with data, and justifying the choice of the research design for this study.

3.2 PARADIGM

A paradigm is a lens through which the researcher sees a problem, defined by Guba and Lincoln (1994:105) as "the basic belief system or worldwide view that guides the investigator, not only in choices of method but in ontologically and epistemologically fundamental ways". A distinction is normally made between normative paradigm (positivism) and interpretive paradigm (Creswell 2008; Cohen, Marion & Morrison 2007). In a normative paradigm quantitative data is collected in the form of numbers, measurements, surveys and experiments. According to Patton (1997), the quantitative paradigm works towards precision by focusing on things that can be counted. When information concerning people is gathered, items are categorized into predetermined groups that can be handled as interval data and used for statistical purposes. Critics of the normative paradigm however argue that, firstly, the control of variables associated with normative paradigm strips the study of its context and as such deprives it of the contextual variables which if otherwise included would influence the results of such study. Secondly, it does not take into account that human behaviour, unlike that of physical objects, cannot be separated from the meanings given to it by humans (Guba & Lincoln 1994).

In the interpretive paradigm, on the other hand, the researcher is an instrument of research and gathers qualitative data in the form of group interviews and participant observations as participants are involved in their day-to-day running of a programme (Patton 1997; Sale, Lohfeld & Brazil 2002). For Patton (1997), the researcher gathers information about what experiences participants have put in their own words. The data obtained contains detailed accounts of situations, events, activities, people and peoples' behaviour as well as attitudes, beliefs and what people think about their situation. After gathering the data the researcher interprets it from different sources to make meaning. The interpretive paradigm is based on constructivism, with multiple truths and realities in nature, depending on how one constructs reality. Reality is continually changing since it is socially constructed (Hudson & Ozanne 1988), whilst for Sale et al. (2002), it cannot be accessed without the human mind, and truths or their claims cannot be compared to a certain reference point. It is not possible to separate the investigator and the object of the study; hence research findings are mutually borne within the context of the situation which shapes the research. In the same vein, others argue that quantitative research is essential in uncovering emic views of studied individuals, groups, societies or cultures, and in order for theories to be valid they should be qualitatively grounded (Glaser & Strauss 1967; Patton 1990; Strauss & Corbin 1990). According to Cohen et al. (2007:257), the interpretive paradigm is "seeing the situation through the eyes of participants", though the normative and interpretive paradigms are concerned with viewing phenomena through different lenses. Whereas positivism attempts to achieve objectivity, measurability, predictability, controllability, patterning, the construction of laws and rules of behaviour as well as the acknowledgement of causality, the interpretive paradigm advocates understanding of the world and its interpretation in terms of its actors. Reid (1996), cited in Sale et al. (2002), argues that the interpretive paradigm uses small, purposeful samples of articulate participants because these can provide important information, not necessarily because samples are representative of a larger group.

In this study, the interpretive paradigm was used because a small purposeful sample of participants was required, rather than for it to be representative. Data pertaining to individual cases was not gathered for the purpose of generalising, but from the sources in their natural settings, namely teachers in their classrooms. This allowed participants to talk about their situations, experiences, practice and other relevant contextual factors. Interviews and observations took place in the classrooms, with grade 12 physical science teachers providing the most relevant, first-hand information. The researcher conducted an in-depth study of the problem, collecting personally, thus acting as the research instrument.

3.3 METHODOLOGY

A narrative-discursive approach was used, defined by Sikes and Gale (2006), as research that deals with story-telling, whether those that are told to us or that we inquire about. Bruner (1996), cited in Sikes & Gale (2006), maintains that this is vital to constructing an understanding of the world into which a person can feel he or she belongs. He claims that all cultures have ‘logical-scientific’ and ‘narrative’ forms of thinking, both interdependent, and that not all cultures treat these two forms in the same way. The researcher’s aim was to capture in-depth views of the physical science teachers and so put into perspective the context in which the teaching and learning of physical science took place in the selected schools.

Although this study was purely narrative, following the interpretive paradigm, the nature of data collected from document analysis was qualitative. This does not have to be considered to be in conflict with the research paradigm chosen for the study as the nature of data collected from these sources in order to answer the research questions had to be obtained in that form. The researcher maintained the analysis and description of data in a purely narrative-discursive fashion, in line with the chosen paradigm.

3.4 SAMPLING

The study used purposeful sampling from a selection of information-rich sources with the aim of obtaining the most valuable information required to solve the research problem (Coyne 1997; World Health Organization and University of Amsterdam 2004). At the time the study was conducted the researcher was working in Xhariep district and so able to collect data from Xhariep schools. The district consists of widely separated towns, each having a maximum of two high schools, Some of which did not offer physical science due to lack of willingness of teachers to work in this remote and rural district. There were a total of 18 high schools offering physical science in the district, 13 of which taught physical science in English, five in Afrikaans (former Model C schools) and one in both languages of learning and teaching.

For this study, a total of five schools were used as a sample, divided into three categories: one former model C school, two performing, previously disadvantaged schools and two underperforming, previously disadvantaged schools. A total of five grade 12 physical science teachers were selected, that is, one teacher per school. The schools were located in three Municipalities, namely Letsemeng, Mohokare and Kopanong.

3.5 PROPOSITIONS

Propositions developed for this study were:

- Teachers were unable to integrate practical knowledge with theory in their teaching of physical science
- Teachers had inadequate discipline knowledge of physical science
- Teachers had no understanding of how the knowledge of physical science impacts on its pedagogy and
- An OBE and competence-based curricula had displaced the knowledge of physical science.

3.6 INSTRUMENTATION/INSTRUMENTS

This research made use of interviews, observations and document analysis to collect data for the study.

3.6.1 Interviews

Two types of interviews used were focus group and individual. Powell and Single (1996:499) define a focus group as "a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research". Generally, about eight people are selected for a focus group, however it can be larger or smaller if appropriate (Berg 2001; Kamberelis & Dimitriadis 2011). The advantage of focus group interviews is that researchers are able to obtain information which they would not be able to obtain from using other methods, such as participants' views, attitudes, feelings, beliefs, experiences and reactions to their situation

(Gibbs 1997). They create a platform for participants to express their behaviours, attitudes, and opinions freely and entirely (Berg 2001).

In this study, before interviews were held, a pilot study was conducted, in which the questions were first posed to a few teachers to ensure that the participants would be able to understand what the researcher wanted. In this pilot project it was found that some questions were not understood by teachers so it became clear to the researcher that they had to be refined. The interview protocol was then reviewed and sharpened. Appendices H and I provide information about the tools used in the interviews, both before and after they were refined.

During the actual interviews, participants were invited into a quiet room, with minimum disturbance from outside noise, and sat in a circle, facing one another. The researcher, as part of the circle, then introduced the session and explained to the participants that the interview was voluntary and each one of the participants was free to discontinue participation in the event that he or she did not feel comfortable participating. The researcher then asked questions, one at a time, each time allowing participants to take turns in sharing their views, responding to and commenting about the questions that were asked. Discussions were allowed to flow with as few interruptions as possible from the researcher. The discussions were recorded using an audio recorder. Participants were allowed to add information that they might have forgotten while they were given a chance to speak, by re-emerging when the other participant reminded them of some point they had missed or forgotten earlier in the discussions. The researcher was overseeing the discussions to guarantee that participants respected the process, even though the meeting allowed participants to be free and relaxed. No specific order of answering questions was established. Each participant was allowed to answer as and when they felt they could answer. This approach ensured that the interviews ran smoothly without any tensions associated with the anxiety of knowing that one is the next person to answer a question, and one may not have a response.

Individual interviews are one-on-one interviews designed to obtain specific information from participants, for example, when researchers wish to address certain types of assumptions, understand participants' perceptions and perspectives of their lives in their own words, or determine how participants attach certain meanings to events or phenomena

(Taylor & Bogdan 1998, cited in Berg 2001; Gubrium, Holstein, Marvasti & McKinney 2012).

In qualitative research, researchers use open-ended questions which allow participants to talk about issues that are of greatest importance to them rather than focus on the researchers' interests. Data is collected as open-ended narrative descriptions without pre-determined categories (Patton 1997; Barbour 2014). Semi-structured interviews are preferred by most qualitative researchers since they allow for ordering of questions in a flexible manner to take into consideration the priority given to each by the participant (Barbour 2014). In this study, Interviews were semi-structured and consisted of a set of written questions that were answered by participants (see Appendix H and I). Due to the semi-structured nature of the interviews, only a few questions formally structured by the researcher were asked, most emerging from the discussions that ensued as the participants answered and elaborated on the initial structured questions posed to them.

For individual interviews a quiet room was prepared by the participants at the school, usually the science laboratory. The interviews were one-on-one, with the researcher and participant sitting on opposite sides of the table and having a face-to-face conversation. The researcher would start by introducing the study, as with the focus group interviews, then explaining to the participants in the introduction that the interviews were confidential and that the participant's identity would be protected, thus helping him or her feel at ease. Participants were also informed of their right to withdraw from the interview if they felt that they were uncomfortable. As in the focus group interviews, discussions were allowed to flow with as few interruptions as possible from the researcher. Audio recordings were also made in these interviews, helping the researcher to keep records of the data well after interviews were conducted. This allowed the researcher to refer to the recorded information for data analysis as the tapes could be re-played at the researcher's will, thus ensuring that no information was left unattended.

In both interviews, the participants' views about their understanding of the concept of content knowledge and pedagogy in grade 12 physical science were gathered, followed by the relationship between content knowledge and pedagogy in grade 12 physical science, as well as their perception of which pedagogical tools teachers used in their teaching of physical science. Further questions focussed on the influence of OBE and competence-based curricula on the knowledge of physical science in the grade 12 NCS curriculum, and on the knowledge of grade 12 physical science in the CAPS curriculum.

3.6.2 Observations

Cohen et al. (2007:396) regard observation as distinctive in that “it offers an investigator the opportunity to gather ‘live’ data from naturally occurring social situations”. Observations offer other advantages in that they allow the researcher to see participants in their workplace, providing first-hand information and dispelling uncertainties in the evidence that might arise from secondary sources. One is thus able to pick up even small points which might be valuable to the study but would not be captured by other instruments (Cohen et al. 2007; Creswell 2008). Observations were conducted to study the classroom situation; to gain insight into the way participants taught physical science; to develop a deeper understanding of how participants integrated practical work with theory in their teaching of physical science; and to acquire a deeper understanding of what pedagogical tools participants used in teaching specific sections of the grade 12 physical science curriculum.

The participants were contacted telephonically for availability. Then on the proposed date the researcher visited them individually in class, observed each lesson in action and videotaped it. The challenge with this exercise was that the researcher visiting alone only managed to take video recordings and could not write notes. Recordings of classroom proceedings allowed the researcher to study the videos after classroom observations in order to get data which could not be captured by observations only. The recorded lessons lasted between 20 and 30 minutes. Participants taught different topics, depending on which time the visit was made, however, the researcher looked for specific items as outlined in the observation grid that was used across the sample (see Appendix J).

To be able to elicit relevant data from the study, the researcher obtained training and solicited assistance in observation skills and strategies, interview strategies and data collection methods that helped answer the research questions. The researcher also sought assistance about going through large volumes of data to make meaning of what would seem chaotic to an untrained person (Leedy & Ormrod 2010). The training and assistance were acquired from skilled and experienced researchers from the Central University of Technology (CUT), books and Internet sources.

3.6.3 Document analysis

Lincoln and Guba (1985:227) define a document as “any written or recorded material” not prepared as a result of a request from the inquirer (Cited in Rodwell 1998; Westat, Frierson, Hood, & Hughes 2002). These records include financial statements, reports, and minutes of meetings. Westat et al. (2002) found that several internal records can be used to evaluate educational innovations in educational institutions, such as student transcripts, mission statements, annual reports of the institution, budgets, grade reports and test reports, minutes of meetings, policy manuals, institutional histories, official correspondence and mass media reports. These documents are useful in providing a description of the institutional characteristics, such as background, academic performance of students and many other relevant data which would help the evaluator understand the institution’s policies, values, goals and priorities. Most importantly, the information they provide is free of recall bias, as it would be well-documented.

For this study, document analysis was carried out by examining primary and secondary sources on the subject as well as curriculum documents and policies pertaining to grade 12 physical science. The purpose of document analysis was to identify which parts of the curriculum appeared difficult for learners, which would be of help in answering some of the research questions. Moderators’ reports, from 2012 to 2014, for example, were analysed, studying the charts and reading about these sections. An attempt was then made to establish what moderators found to be the main causes of failure for learners to understand them. These reports were compared with other sources to corroborate information and make deductions about the curriculum knowledge and pedagogy of grade 12 physical science teachers.

3.7 SOURCES OF DATA

Sources of data were grade 12 physical science teachers, physical science CAPS document, teachers' guides, moderator's reports and Department of Basic Education (DBE) reports. Physical science CAPS document and teachers' guides provided data about the aspects of the curriculum that must be taught, which were then compared and contrasted with those from teachers during the interviews for meaningful deductions (see section 3.8, below). The moderators' reports and DBE reports provided data about parts of the physical science curriculum in which learners performed well and those in which they did not. The data helped the researcher to give meaning to the impact of content knowledge and pedagogy on the teaching and learning of grade 12 physical science with regard to learner performance and learner responses in the area in which the study was conducted.

3.8 DEALING WITH DATA

Analysis of the data was performed as follows.

3.8.1 Data reduction and analysis

Data reduction, according to Miles and Huberman (1994), is the process of selecting, focussing, simplifying, abstracting and transforming data that appears in written-up field notes or interview transcriptions, and other raw data collected by the researcher. It entails clustering the data into identifiable themes, groups, or issues for interpretation (Creswell 2008), writing summaries, coding, making partitions and writing notes (Miles & Huberman 1994). It is a continuous process that takes place after fieldwork, to completion when the final report is written. Often the approach taken in the narrative discursive method attempts to make a familiar phenomenon strange, through a process of sorting and sifting so as to uncover features of the data which were not necessarily obvious on an initial reading or listening (Taylor & Littleton 2006).

In this study, recorded information from interviews was transcribed, selected and sorted into themes, groups and issues. Information from other sources, observations, video recordings and documents was compared with the data from interviews in order to establish patterns, themes and issues for the purpose of corroborating findings. Data were then analysed and interpreted to give it meaning.

3.8.2 Reliability

According to Ritchie and Lewis (2003:270), reliability is "generally understood to concern the replicability of research findings and whether or not they would be repeated if another study using the same or similar methods was undertaken". Different scholars hold diverse views about the replicability of a study in qualitative research; however, qualitative studies cannot be replicated due to their complexity and their dynamic nature (Lincoln & Guba 1985; Holstein & Gubrium 1997). In order to avoid these complexities, qualitative researchers replace reliability with trustworthiness, confirmability of findings, consistency and dependability of evidence, which are associated better with qualitative than quantitative studies (Gaser & Strauss 1967; Lincoln & Guba 1985; Hamersley 1992; Robson 2002). The essence of reliability, therefore, irrespective of which term is used to describe it, is the soundness of a study; that is, how a researcher can ensure that reliability is evident (exists) in the results or how it can be measured or demonstrated. The researcher has to ensure that his/her data are consistent, dependable and replicable, with some form of assurance from the available data that an occurrence can arise in a similar study and to show that it was not just an isolated incidence particular to the study sample at the time.

Richie and Lewis (2003) emphasise that the researcher must ensure the sample design/selection was conducted without bias; that the field work was carried out consistently; that data analysis was carried out systematically and comprehensively; that multiple assessments were made; that the interpretation of results was well supported by the evidence; that the design/conduct allowed equal opportunities for all perspectives to be identified; and that there were features that led to selective or missing coverage.

3.8.3 Validity

Validity is defined by many as referring to the correctness or precision of a research finding, (Richie & Lewis 2003); representing accurately the features of the phenomenon that it is intended to describe, explain or theorise, (Hamersley 1992); giving what is observed by the researcher the right name, based on the interpretations of the observations of the researcher, (Kirk & Miller 1986); and providing justifiable evidence for the researcher to conclude that an observed relationship is causal, (Johnson & Christensen 2014). As with reliability, validity in qualitative studies is replaced by terms such as credibility, transferability, and plausibility of research claims (Glaser & Strauss 1967; Lincoln & Guba 1985; Guba & Lincoln 1989) as these terms are better associated with qualitative studies than quantitative studies.

A researcher should work on dealing with threats to validity, for example, bias and the influence of the researcher on the setting or individuals studied (Bickman & Rog 1998; Cohen, Manion & Morrison 2007). Bias refers to how the researcher distorts the data that he or she collects or analyses as a result of personal theories, values, preconceptions, beliefs and attitudes. The researcher can try to avoid this by being honest and open about his or her preconceptions and explain how he or she tried to deal with them to limit their influence and prevent him or her from viewing the data objectively. Even though it is difficult to eliminate the researcher's influence on the participant's responses, since he or she determines which questions to ask, this influence can be moderated by avoiding leading questions, for example, and by being aware of how the researcher can influence responses so as to minimise this influence (Guba & Lincoln 1989; Patton 1990; Bickman & Rog 1998).

Most researchers agree that validity in qualitative research data can be achieved by using *triangulation* (Guba & Lincoln 1989; Bickman & Rog 1998; Patton 1990; Berg 2001; Richie & Lewis 2003; Cohen, Manion & Morrison 2007; Johnson & Christensen 2014) that is the use of multiple ways such as interviews, observations and questionnaires to gather data. Triangulation has an advantage of strengthening the validity of data in that it reduces bias which could be caused by the use of one method. The researcher becomes more confident if two or more methods produce contrasting results and this curbs overreliance on the use of one method which a researcher happens to favour over the others (Berg 2001; Cohen et al. 2007). Among the many types of triangulation methods that researchers can use, two were relevant to this study, namely, *methods triangulation*, in which the researcher uses multiple methods of collecting data, such as interviews, questionnaires and observations (Johnson et al. 2014) and *data triangulation*, in which the researcher uses multiple data sources such as interviewing different types of people or using observations in different settings. In this case the use of more than one data source is chosen over relying only on one source (ibid.).

To ensure reliability of data collected in this study, observation grids were developed and used uniformly across the sample. Each participant was asked to provide the researcher with a suitable time for lesson observation, during the normal teaching period and according to the school timetable. The researcher, guided by the items on the observation grid, observed a lesson for each of the participants to ensure that there was no bias. Interview schedules were also developed to enhance consistency in the information gathered. However, the interviews were semi-structured, so participants provided additional information, depending on the flow of the conversation during the interviews. This additional information provided insight into the study. Video recordings and transcriptions of the interviews were kept by the researcher as records.

Validity in this study was achieved by obtaining data from multiple sources using different instruments, namely, interviews, observations and document analysis. This ensured accuracy of results through triangulation and corroboration of evidence from different sources. The use of multiple sources ensured that the relationships observed were justifiable. The method used in the validation of data was constant comparison, described by Tesch (1990), cited in Boeije (2002) as a way of analysing tasks by forming categories, creating boundaries of these, creating segments for them, making summaries of each and looking for negative evidence in the data. This exercise establishes separate conceptual similarities to perfect the discriminative power of categories and to determine patterns. In this study, comparison was made first, within focus group interviews, second, within individual interviews, third, between individual and focus group interviews and, fourth, between documents and interviews. This approach strengthened the credibility and trustworthiness of the results.

Comparison was made, firstly, listening to segments of the tapes from the interviews and assigning codes or themes, then for each code or theme other segments provided similar information that was searched and compared with the first for similarities or differences. This procedure was carried out for both individual and focus group interviews. Secondly, information gathered from document analysis was also coded or categorised into themes, which were then compared with those from interviews for similarities and differences.

These processes were repeated until the information in the tapes and documents was thoroughly scrutinised to the researcher's satisfaction that all details had been attended to.

3.9 ETHICAL CONSIDERATIONS

Permission to conduct the study was obtained from the Free State Department of Education, principals and school governing bodies of schools in which the study was undertaken. Letters requesting permission were sent to each stakeholder by the researcher (see Appendices C-D). In order to protect the participants' rights the researcher firstly articulated the research objectives verbally and in writing so that they were clearly understood. This included a description of how data would be used. Secondly, the researcher obtained written permission from the participants to proceed with the study as articulated. Thirdly, participants were informed about all data collection devices and activities. Fourthly, verbatim transcriptions and interpretations were written and reports made available to the participants on request. Fifthly, the participants' rights, interests and wishes were considered, first, when making choices regarding reporting the data, then to ensure that the final decision regarding participants' anonymity rested with them (Creswell 2008).

3.10 CONCLUSION

This chapter has provided a detailed description of the research design, its elements, including research paradigms, and which one was chosen for this study. It presented a description of methodology, sampling processes, propositions, instrumentation, sources of data and data collection procedures used. A paradigm was defined as the lens through which a researcher sees the problem and an interpretive one was found to be more relevant because the nature of the study lent itself to qualitative data collection and analysis. The study investigated teachers in their natural settings (classrooms) and sought to understand their teaching as well as other factors surrounding their practice in their classrooms. The purpose of the study was not to generalise findings but to get an in-depth understanding of the problem.

A narrative discursive method was used as it provided a thick description of how the study was conducted and how data was collected. Purposeful sampling was carried out by identifying, on purpose, which schools would be studied so as to obtain relevant and detailed information pertaining to the problem under study. The study used interviews, observations and document analysis to investigate the problem. Both focus group interviews and individual interviews were used to collect information from participants. Document analysis involved viewing official documents from DBE, such as moderators' reports, curriculum documents and policies pertaining to the problem being studied. Data reduction involved transcriptions of interview tapes, and interpretation of documents to obtain relevant information. Validity and reliability of data was ensued in the study to make the results authentic. Finally, ethical issues were taken into consideration, with all relevant stakeholders informed about the study. Permission was sought from relevant stakeholders and was granted. Participants agreed to participate voluntarily, thus making the whole process smooth and complete as initially planned. In chapter four, the results and findings of the study are discussed.

CHAPTER 4

RESULTS AND FINDINGS

4.1 INTRODUCTION

This chapter presents results of the study, and explains the methods of data analysis used. It presents findings from focus group interviews, individual interviews, classroom observations and document analysis.

4.2 METHODS OF DATA ANALYSIS AND PRESENTATION OF DATA

Data analysis comprises organizing, accounting for and explaining the data, making sense of it in terms of the participants' definitions of the situation, which includes observing and identifying patterns, themes, categories and regularities (Cohen et al. 2007). In this study, descriptive data analysis was used to identify patterns in the data from the following sources: 1) Moderator's reports for 2012, 2013 and 2014; 2) 2014 June common examination results; 3) Transcriptions from focus group interviews and individual interviews; 4) Classroom observations and 5) the CAPS document.

4.3 FINDINGS

All the data from these different sources were scrutinised to compare, contrast, and match the existing information for triangulation purposes.

4.3.1 Interviews

Following are participants' responses to the questions that the researcher asked in focus group and individual interviews, shaped by the questions that the researcher formulated as stated in the research design section of this report (see Appendix I). In this report, when transcriptions were made the researcher did not change the words of the participants. The interview questions were intended to solicit information required to answer the focus questions as listed in chapter one.

Research question 1 - What type of knowledge do grade 12 physical science teachers require to teach effectively?

All participants felt that teachers needed to have both theoretical content knowledge and practical knowledge in order to teach effectively. They argued that both types complemented each other to facilitate understanding of concepts taught to learners. Whereas all participants agreed that they did not have a problem with most of the topics they were teaching, they did acknowledge that they had challenges with some of the topics. Among those mentioned were electrodynamics, redox reactions and electrochemistry, polymers, work and energy, organic reactions, vertical projectile motion and electric circuits. Those who mentioned organic reactions reasoned that they did not like it because that section of the work required intensive study and memorisation of reaction conditions, which was confusing for both teachers and learners. The majority of the participants cited polymer chemistry as challenging, particularly because this section was new to them, having only been introduced in 2014 in the new CAPS syllabus. The following responses by participants illustrate this point.

> I am very comfortable with organic chemistry; I think naming is really one of those comfortable topics to teach to learners (children). Physical and chemical properties also goes well. I think there is something that is added this year as far as CAPS is concerned and I think I will be teaching it for the first time. Polymers; and I'm still getting into that section of the content. Not to say that it is difficult, but I will be encountering it for the first time.

Another participant responded in this way to the same question, emphasising the same point.

> I am comfortable with everything. The problem is that I feel like polymer science; I think is too complicated for learners. That's how I feel something has to be done. Imagine they have problems with simple things like momentum, for example, that formation of polyester stuff… It is like the combination of a diol and terephthalic acid, something like esterification reaction but the problem is.... even the word terephthalic acid, grade 12 learners…. will they be able to remember that? – That's

> the problem ... Because if we like maybe reverse the whole situation, even on tertiary level, you don't start with polymer science at first year level, it's beyond - close to second year or third year but now they have decided to take it to grade 12 syllabus- Hi, serious?"

The third respondent with the same view as the other two had this to say.

> Also in physical sciences so far, everything is fine. It's only this chapter that Mr X is talking about... Polymers; "You see *baya di beha mane, o be o fumane hore baya di breika,* something like that and *di a forma this side..... Ayikhona*!
>
> (*Translation: these are presented 'in an equation' with reactants this side and products forming that side, but the participant does not understand what is going on, exclaiming no!*).

There was also a common feeling by participants that teachers had not studied polymers at university level, as one participant explained:

> I am having the same problem that everyone else is having with polymers because even at university we don't do much of it even in chemistry III; we did part of it and did not go large with it and it is a serious problem.

Regarding vertical projectile motion, the majority of the participants stated that the time available to teach all different aspects of vertical projectile was insufficient, noting that participants had problems with the topic as well. This was something that authorities had to take into consideration when developing the syllabus. To illustrate this point, the following participants responded as follows:

> Teachers do not have time to teach all the different scenarios in vertical projectile – this creates a problem – so there should be restrictions on what should be addressed.

In the same vein the other participant added:

> The time frame to do all scenarios is limited and may appear as if a teacher did not do the work well – the time is limited.

Further, most participants felt that physical science teachers experienced a problem of having to teach both physics and chemistry, while at tertiary institutions they specialised in only one of the two. This becomes the root of the problem. There was a shared view that physics was more challenging than chemistry, the majority viewing teaching chemistry as easier than teaching physics. The participant's response below represents these views:

> Science teachers at universities major in one of the two subjects making up physical sciences; that is, either physics or chemistry but not both, hence one teacher will be more comfortable with one and be uncomfortable with the other – physical sciences comprises physics and chemistry. In most schools a teacher has to deal with both - this means that the teacher is at the same level as the learners. The effect is that one spends more time on the subject he did not major in and his learners do better in that subject than the other paradoxically, which he has majored in.

This participant shared the view:

> I majored in physics but I enjoy teaching chemistry than physics. Physics is more difficult – it is abstract, more especially due to the fact that schools have no apparatus.

Participants further pointed out that the way they were taught at tertiary institutions had a bearing on how they taught certain topics, and also that this influenced the teachers' attitude towards certain topics:

> The teacher who taught me emphasised on one topic – momentum - and did it repeatedly; hence I am more comfortable with that topic.

In tertiary institutions, some teachers were not exposed to certain topics which are taught at high school level, for example, vectors. One participant recalled doing vectors in a mathematics class, otherwise he/she would not have been able to teach the topic as he/she did not do it in his/her physical science class. The other participant argued that what they did at university was not relevant to what he/she was teaching. However, the group agreed that a teacher should be further ahead in terms of knowledge (theoretical and practical) than his/her learners. How teachers teach impacts on their learners and this in turn influences their liking of the subject. It also influences learners' choice of subjects, hence their choice of careers. Learners see their teachers as role models and as such are influenced by them in their choice of subjects and eventually in choosing their careers.

In order to answer research question 1, the researcher further analysed moderators' reports from the DBE, for reasons stated in section 3.6.3. The next few pages provide some data obtained from this analysis.

Figures 4.1 and 4.2 show the analysis of the 2014 June P1 results in the five participating schools, obtained from the common, internal mid-year provincial examinations written by all learners in the Free State Province. These results are gathered by respective Subject Advisors from schools and are analysed to provide feedback to the Provincial Department of Education as well as other stakeholders.

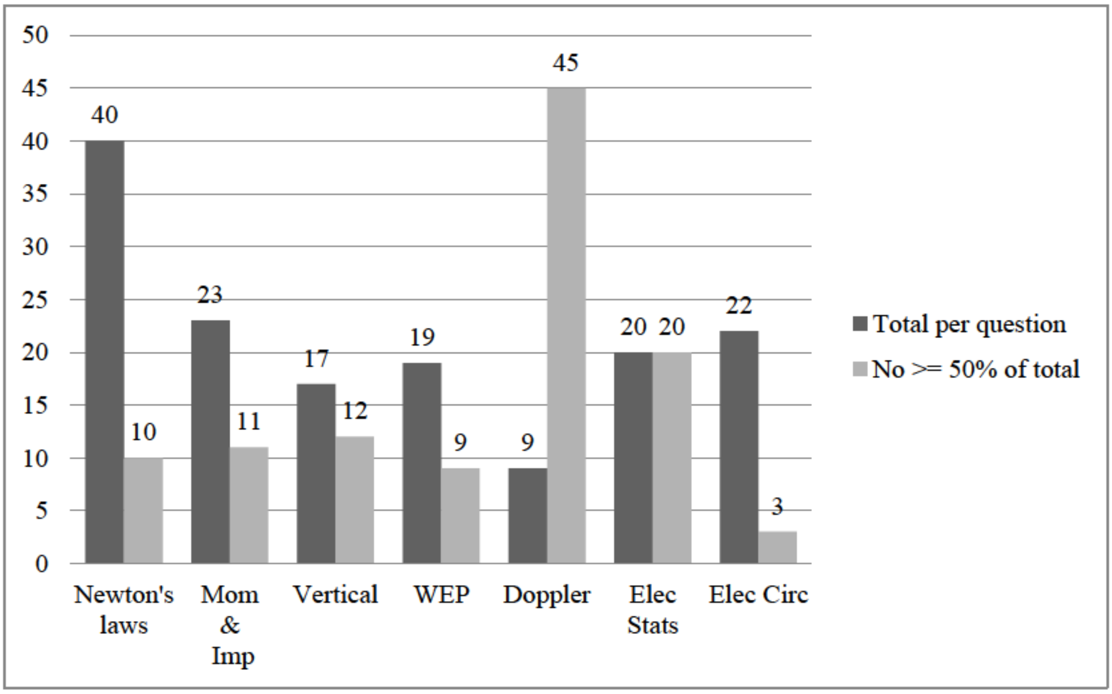

Figure 4.1: Total mark per question/section and the percentage of learners obtaining 50% or above in each section for the five participating schools.

Ninety (90) learners wrote paper 1 of the June examination in the five participating schools. According to figure 4.1 (above), Newton's laws carried the most marks, followed by momentum and impulse, then electric circuits. The figure suggests that only ten (10) of the ninety (90) learners obtained above 50% in Newton's laws, eleven (11) of the ninety

(90) learners obtained above 50% in momentum and impulse, while only three (3) learners out of ninety (90) obtained above 50% in electric circuits. On the contrary, half of the learners (45) were able to achieve above 50% in Doppler Effect. This question however carried the least marks of all in the paper; only nine (9) marks.

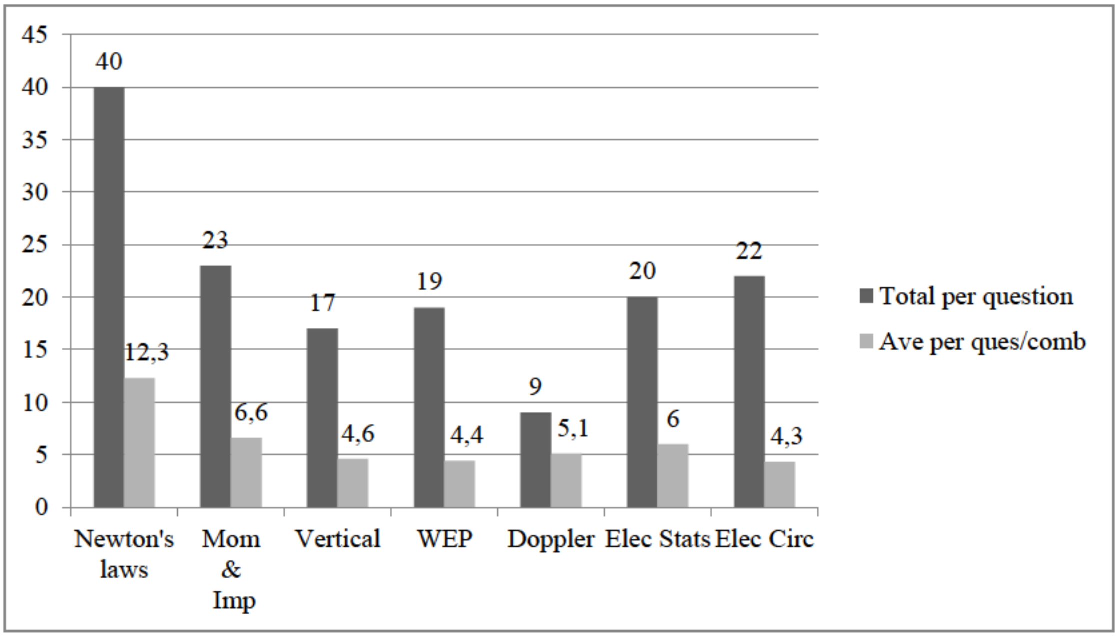

Figure 4.2: The total mark per question/section and the average learner's marks per question/section for the five participating schools.

In Newton's laws, the average mark out of 40 is 12, 3. Momentum averaged 6,6 out of 23 marks, while the average for electric circuits was 4,3 out of a total possible mark of 22. In the Doppler Effect question, the average leaner mark was 5,1 out of 9 marks. Vertical projectile had an average of 4,6 of the 17 marks; work, energy and power had an average of 4,4 out of the possible 19 marks. Electrostatics had an average of 6 marks out of 20.

Figures 4.3 and 4.4 (below) show the graphs of analysis of 2014 June paper 2 results for the participating schools.

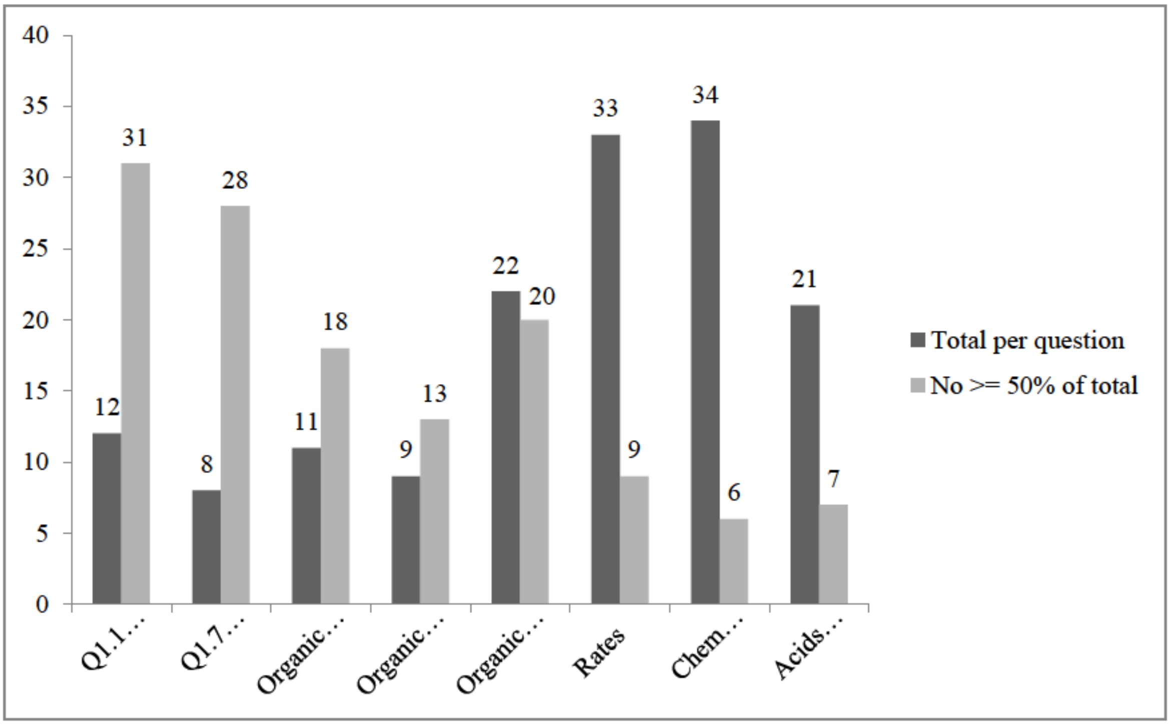

Figure 4.3: The total mark per question/section and the average learners' marks per question/section for the five participating schools.

As in paper 1, a total of 90 learners wrote paper 2 of the June examination in the five participating schools. Figure 4.3 shows that chemical equilibrium, reaction rates, physical and chemical properties of organic molecules and acids and bases carried the most marks. Chemical equilibrium carried the highest marks. The figure suggests that only 6 of the 90 learners were able to obtain above 50% in chemical equilibrium, 9 of the 90 learners obtained above 50 % in rates of reactions, 22 learners out of 90 obtained above 50% in physical and chemical properties of organic molecules. 7 of the 90 learners obtained above 50% in acids and bases. In nomenclature of organic molecules, 18 of the 90 learners obtained above 50%. In the same vein, 13 of the 90 learners obtained above 50% in physical properties of organic molecules. Physical properties of organic molecules however carried the least marks of all in the paper; Only 9 marks as in paper 1. The first two sets of bars in the graph (questions 1.1 to 1.10) were multiple choice questions, each counting 2 marks. Of the total 20 marks of this section, 59 of the 90 learners obtained above 50%.

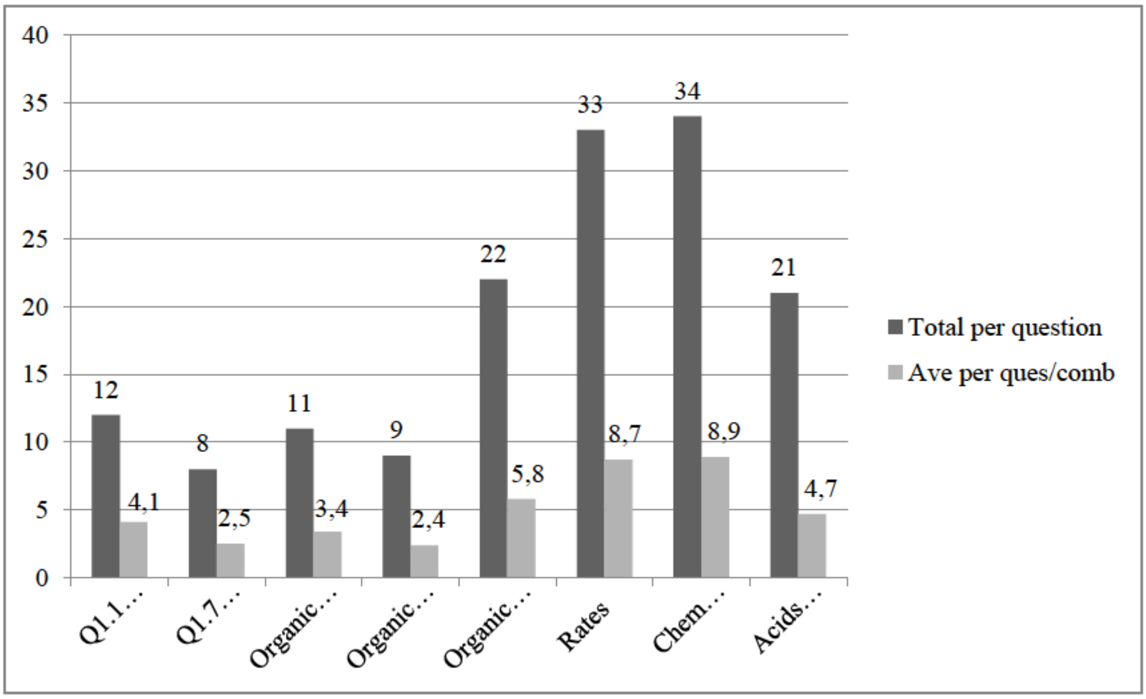

Figure 4.4: Total mark per question/section and the average learners' marks per question/section for the five participating schools.

Figure 4.4 shows that the average of the learners' marks in chemical equilibrium was 8,9 out of 34 possible marks for that question. Rates of reactions averaged 8.7 out of 33 marks; organic reactions had an average of 5,8 of a total of 22 marks. Acids and bases averaged 4,7 in a total of 21 marks and learners obtained an average of 6,6 in the multiple choice section totalling 20 marks, (questions 1.1 to 1.10). Physical properties of organic molecules recorded an average mark of 2,4 out of a possible 9 marks.

Table 4.1: 2012 November examination results analysis for paper 1 (Physics)

Question	Content	Average performance (%)
Q1	One word items	47.5
Q2	Multiple choice questions	46
Q3	Vertical projectile motion	51.1
Q4	Momentum and relative velocity	47
Q5	Work and energy	45.8
Q6	Doppler Effect	48.9
Q7	2D and 3D wave fronts	40.7
Q8	Parallel plate capacitors and electric fields	54.3
Q9	Electric circuits	50.9
Q10	AC circuits	60.9
Q11	Photo-electric effect	43.9

Source: Department of Basic Education 2013

Table 4.1 shows average marks in each question expressed as a percentage (Paper 1). It shows that 47.5% of the 2012 grade 12 learners who wrote paper 1 performed well in the one word items, 46% in the multiple choice questions, 51.1% in vertical projectile motion, 47% in momentum, 45.8% in work, energy and power, 48.9% in Doppler Effect, 40.7% in two and three dimensional wave motion, 54.3% in parallel plate capacitors and electric fields, 50.9% in electric circuits, 60.9% in Motors, generators and alternating current circuits and 43.9% in Photoelectric Effect.

Table 4.2: 2012 November examination results analysis for paper 2 (Chemistry)

Question	**Content**	**Average performance (%)**
Q1	One word items	73.6
Q2	Multiple choice	54.5
Q3	Nomenclature of organic compounds	60.5
Q4	Physical properties of organic compounds	58.1
Q5	Reactions of organic compounds	44.5
Q6	Rate of reaction	33.2
Q7	Chemical equilibrium	44.4
Q8	Galvanic cells	53.8
Q9	Electrolytic cells	45.6
Q10	Batteries	50
Q11	Fertilizers	42.5

Source: Department of Basic Education 2013.

Table 4.2 (above) shows average marks per question expressed as a percentage (Paper 2). The table shows that 73.6% of the 2012 grade 12 learners who wrote paper 2 performed well in the one word items, 54.5% in the multiple choice questions, 60.5% in nomenclature of organic compounds, 58.1 in physical properties of organic compounds, 44.5% passed reactions of organic compounds, 33.2% did well in reaction rates, 44.4% in chemical equilibrium, 53.8% in galvanic cells, 45.6% in electrolytic cells, 50% in batteries and 42.5% in fertilizers.

Table 4.3: 2013 November examination results analysis for paper 1

Question	Content	Average performance (%)
Q1	One-word items- all topics	49.0
Q2	Multiple choice questions	36.2
Q3	Vertical projectile motion	30.0
Q4	Momentum	31.2
Q5	Work, energy and power	39.2
Q6	Doppler effect	43.0
Q7	2D and 3D wave motion	52.8
Q8	Electrostatics	34.0
Q9	Electric circuits	15.5
Q10	Motors, generators and alternating current	36.9
Q11	Photo-electric effect	34.2

Source: Department of Basic Education 2014.

Table 4.3 shows average marks in each question expressed as a percentage (Paper 1). It shows that 49% of the 2013 grade 12 learners who wrote paper 1 performed well in the one word items, 36% in the multiple choice questions, 30% in vertical projectile motion, 31.2% in momentum, 39.2% in work, energy and power, 43% in Doppler Effect, 52.8% in two and three dimensional wave motion, 34% in electrostatics, 15.5% in electric circuits, 36.9% in Motors, generators and alternating current and 34.2% in Photoelectric Effect.

Table 4.4: 2013 November examination results analysis for paper 2

Question	Content	Average performance (%)
Q1	One-word items- all topics	38.4
Q2	Multiple choice questions	44.4
Q3	Organic nomenclature	40.4
Q4	Physical properties of organic compounds	45.8
Q5	Organic reactions	37.0
Q6	Reaction rate	23.7
Q7	Chemical equilibrium	30.5
Q8	Galvanic cells	29.4
Q9	Electrolytic cells	17.2
Q10	Batteries	19.1
Q11	Fertilizers	31.5

Source: Department of Basic Education 2014.

Table 4.4 shows average marks per question expressed as a percentage (Paper 2). Table 4.4 above shows that 38.4% of the learners who wrote paper 2 in 2013 did well in the one word items, 44.4% did well in multiple choice questions, 40.4% passed organic nomenclature questions, 45.8% performed in physical properties of organic compounds, 37% passed organic reactions, 23.7% did well in reaction rates, 30.5% in chemical equilibrium, 29.4% in galvanic cells, 17.2% in electrolytic cells, 19.1% in batteries and 31,5% in fertilizers.

Table 4.5: 2014 November examination results analysis for paper 1

Question	Content	Average performance (%)
Q1	Multiple choice questions	43
Q2	Newton's laws of motion	45
Q3	Vertical projectile motion	63
Q4	Momentum	63
Q5	Work, energy and power	40
Q6	Doppler Effect	67
Q7	Electrostatics	40
Q8	Electric circuits	47
Q9	Motors, generators and alternating current	54
Q10	Photoelectric Effect	39

Source: Department of Basic Education 2015.

Table 4.5 shows average marks per question expressed as a percentage (Paper 1).

Table 4.5 shows poor learner performance in the following topics; Photoelectric effect (39%), work, energy and power (40%), electrostatics (40%), Newton's laws (45%) and electric circuits (47%). Learner performance in multiple choice questions was also poor (43%). Topics where the performance of the learners was good are, Doppler Effect (67%), momentum and vertical projectile (63% each).

Table 4.6: 2014 November examination results analysis for paper 2

Question	Content	Average performance (%)
Q1	Multiple questions	52
Q2	Organic nomenclature	65
Q3	Physical properties of organic compounds	47
Q4	Organic reactions	61
Q5	Reaction rates	36
Q6	Chemical equilibrium	43
Q7	Acids and bases	48
Q8	Galvanic cells	45
Q9	Electrolytic cells	33
Q10	Fertilizers	58

Source: Department of Basic Education 2015.

Table 4.6 shows average marks per question expressed as a percentage (Paper 2).

Table 4.6 shows that learners performed poorly in electrochemical cells (33%), followed by reaction rates (36%), then next is chemical equilibrium (43%). Galvanic cells follows, with an average of 45%. Learners performed best in Organic nomenclature (65%), followed by organic reactions and fertilizers, 61% and 58% respectively.

Research question 2 - How does content knowledge of physical science shape pedagogy of physical science?

All participants agreed that sound subject knowledge helps when planning lessons and teaching. It helps the teacher to identify important parts of the subject, to select activities and to deliver content. Knowledge of subject content also helps the teacher to understand the cognitive levels of his/her learners, so that the teacher is enabling better selection of appropriate questions to ask learners during instruction. This is highlighted by the following response:

> Subject knowledge helps you to make lessons easier and preparations easier. A person who does not know physical sciences cannot teach it. When you know the subject you are able to identify important parts of the subject. You are able to know where to start. Gives you confidence – Helps you to prepare and deliver the content. You are able to select activities that are relevant based on what you are teaching or what you have taught. It helps you to identify learners that can assist others – thus enhancing your teaching strategies, the knowledge of content (subject) as well as learners and their perceptions also. Knowing the subject helps the teacher to simplify concepts (topic).

This participant also emphasised the role of content knowledge in the selection of content, although in a different scenario, when a teacher can select appropriate questions for his/her instruction:

> Selection of activities – we are teaching for knowledge and also to achieve results. So I use past exam papers since questions are repeated – learners must be coached. Even when using past question papers, selection is important – concepts are linked in past papers therefore one has to be able to select the relevant parts of the questions to what the teacher is teaching at that particular point. When one knows the subject – helps you to know the outcomes that learners must show at the end of the lesson. Hence this informs your assessment.

On the prerequisites for teaching the work energy theorem, the following were cited as pre-knowledge by participants: definitions, Cartesian plane, movement or transition from F $x\ s$ to $F\ x\ s\ cos\ \theta$, how to interpret/understand definitions and be able to apply these in equations; learners' ability to draw free body diagrams, progress from simple to more complex aspects, know what is frictional force and the direction in which friction acts, and resolving vectors into perpendicular components. The definition of work, types of energy, kinetic and potential energy, mechanical energy, learners' ability to explain gravitational potential energy, Newton's laws, forces moving in a straight plane with angle, forces with friction and without friction, mechanics from grade 11, integration of maths – trigonometry and vectors.

Research question 3 - To what extend do grade 12 physical science teachers integrate practical work with theory in their teaching?

All participants agreed that it is important to do practical work in the teaching of physical science. Some argued that practical experiments bring excitement to learners, make them like the subject and encourage them to participate in class discussions.

The following are some of the extracts from the interviews.

> Practicals are the best. Simulations can be used when no apparatus is available. Practicals reduce time to cover the work. They tend to be more learner centred therefore they help the teacher to cover work quickly.

> You don't believe it until you have experienced it. It makes things clearer than mere reading theory. Learners should discover through experiments. Teachers should use technology as an alternative if there is no apparatus.

Regarding when practical work should be carried out, responses were divided among those who preferred to do practicals before teaching theory and those afterwards. Some argued that it depended on the topic under discussion. In some cases the teacher could give a demonstration during a normal theory lesson to illustrate what he/she was teaching.

This participant argued that theory should come before practicals.

> Experiment is to put in practice what you have already learned about. It should be theory first, then the practicals; this leads to learners making connections between theory and practical.

Research question 4 - How have OBE and competence-based curricula affected the knowledge of physical science in the current grade 12 physical science curriculum, CAPS?

Some participants mentioned that they could not comment on this question since they were products of OBE themselves. They could not view it objectively from their standpoint as teachers so they preferred to be neutral.

One participant argued that OBE had focussed on results and not on the understanding of concepts:

> OBE changed teacher mind-set with a focus on results, results, results. There was a perception that OBE focused on production and as such teachers now prepare learners to pass matric without thinking objectively about what happens to such learners after they pass matric (grade 12). This paradigm has also rubbed off to CAPS as a result CAPS still perpetuates focussing on outcomes – The mind-set of teachers, consciously or not, in the new curriculum is still OBE!!

On the contrary, one participant expressed the importance of OBE in that it guided his/her teaching by focussing on the outcomes that his/her learners were to achieve. This ensured that he/she used these as guidelines for preparing lessons to achieve the required outcomes.

> When we are talking about outcomes…the focus is not on the way that I am teaching; it's not on the strategies that I am using. The focus actually is on the outcomes… that which learners are gaining becomes main one. So now the thing is, whenever you are teaching a lesson you need to know your aims. What is it that you want learners to... to…to… to achieve? So in my planning therefore I stick to those things. If I want my learners to be able to state Newton's first law second and third law, then I stick to that. If my learners must apply Newton's second law and third law to real life situations, then that's my focus; that is what I only teach….

The other participant argued that OBE was group work, when the same child did the work for others, while they hid behind. According to the participant, CAPS was better than OBE since it outlined what has to be taught and provided a syllabus that teachers could follow. With CAPS, teachers know exactly what to do. This view supports that of the former participant and it is contrary to that of the latter participant:

> I don't like OBE. I don't believe in doing group work for everything that they have to discover, discover, discover... it's always the same child doing all the work. Uh…I believe when students listen to the teacher and do the practical parts in between

where your teacher does it or sometimes the child also can do it, but then not group work- group work every day, because then the child won't work. I think uhh… CAPS is much better than OBE if I have to compare the two because now we have got a syllabus we exactly know what to do. I think in the OBE that was in the past it was very broad, in the subject. You just didn't know exactly what they want.

The majority of the participants believed that the learner-centred approach adopted by OBE was better than the previous approach, which was teacher-centred. They believed that it had rubbed off to CAPS:

> OBE emphasised a more learner centred approach. OBE was better than the teacher centred approach prior to it.

They did however disagree with the exaggerated emphasis on outcomes, which had shifted the goal from 'teaching for understanding' to 'teaching for exams'. This is exemplified by the comment of one participant:

> Learners are taught to pass - they are not prepared for life after matric.

The majority of participants showed mixed feelings about this question and responses were relatively few.

4.3.2 Classroom observations

The tool used for classroom observation focused on the following five areas: 1) classroom environment. 2) teacher-learner interaction. 3) teacher's demonstration of content knowledge. 4) teacher's pedagogical tools/skills. 5) integration of practical work with theory in the lesson. A room for additional notes on observations relevant to the study was also made available on the tool. For the tool used for classroom observations, refer to Appendix J of the report.

Classroom environment

All participating schools had laboratories, the majority of which were old with traditional fixed tables arranged in two rows. Two schools had newly built laboratories, and one had no laboratory tables or stools. Learners used ordinary classroom tables and chairs. Most of the laboratories did not have running water and the majority had charts displayed on the walls. The number of charts varied from school to school, but even the one with fewest charts still had something displayed. Teaching took place in these laboratories in what seemed to be a daily routine. Learners in all the participating schools were attentive during class and were disciplined. The seating arrangement in all schools was orderly and there was control over the learners.

Teacher-learner interaction

In the majority of the schools, teachers kept their learners engaged in the lesson by asking questions during the lessons to individual learners, and ensuring that all were participating. In School E, the lesson was introduced by giving learners an explanation of the relevance of the topic to their everyday lives. The presentation of content showed that the teacher was conversant with the topic and mastered the content, demonstrating clear and neat use of the chalkboard, with good use of examples. In School A, however, the teacher began the lesson engaging learners but later asked whether learners were following. In School C the teacher asked and answered all the questions for the learners, with no learner involvement evident. In this class, the teacher did virtually everything, writing on the chalkboard and giving learners no opportunity to answer any of the questions. Learners sat passively, not even taking notes, obviously bored but paying attention to what the teacher was doing.

Teacher's demonstration of content knowledge

In all the schools, teachers showed a good understanding of their content. They were able to coin their lessons and did not seem to have problems with what they were teaching. Their use of scientific language in explaining concepts was good and free of confusion. This, however, does not rule out the possibility that teachers did have some challenges with other sections of the content other than the one with which they were dealing during the time of the observations.

Teacher's pedagogical tools/skills

The common denominator in all the lessons observed is that all the lessons were teacher-centred. All teachers used the traditional lecture method and chalkboard for their teaching. In School C the teacher used the textbook method in addition to the chalkboard. None of the teachers gave any written task in a form of class activity that required learners to engage with the content being taught. In all observed lessons, the only time learners were engaged in the lesson was when the teacher asked them questions. The level of demand of the questions varied from one participant to the other. In School A the teacher asked learners questions that only confirmed that they were following. The questions did not challenge the understanding of learners. In School B there was no learner involvement as the teacher did all the talking.

Integration of practical work with teaching

In all the participating schools none of the teachers had any form of demonstrations for their learners. There was no sign of intent to perform a demonstration or an experiment and no apparatus set in front of the classroom, or anywhere else in the classroom, which could indicate that practical work was ever done or would ever be done. In no part of the lesson did teachers mention some possibility of conducting an experiment with the learners, either in the class or in the future lessons. It was observed that teaching without experiments or demonstrations seemed normal for the teachers.

4.4 CONCLUSION

This chapter has presented the findings of the study. First, the methods of data analysis used in the study were described. Second, the findings of the study from document analysis, interviews and classroom observations were presented. Third, the views of the participants in the study were represented verbatim. Document analysis focussed on the reports by DBE on the performance of learners in physical science. Interviews focused on the four research questions re-stated at the beginning of this chapter, and classroom observations focused on the following five points: classroom environment; teacher-learner interaction; teacher's demonstration of content knowledge; teacher's pedagogical tools/skills; and the integration of practical work with theory in the lesson.

The following chapter discusses the findings of the study, draws conclusions and makes recommendations based on the results.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 INTRODUCTION

This chapter discusses the results of the study and offers conclusions. It begins by stating the purpose of the study and re-stating the research questions. It summarises how the study was conducted and presents the findings in order to answer the research questions. Comparison between data and the literature review is also presented. Limitations of the study are discussed and recommendations for further research are made.

5.2 SUMMARY OF STUDY

5.2.1 Purpose of study

The purpose of this study was to examine the grade 12 physical science teachers' understanding of knowledge underpinning the content and its associated pedagogy, and how this impacts on the integration of theory and practice in teaching grade 12 learners.

5.2.2 Re-statement of research questions

The research questions for this study were as follows: 1) What type of knowledge do grade 12 physical science teachers require to teach effectively? 2) How does content knowledge of physical science shape pedagogy of physical science? 3) To what extent do grade 12 physical science teachers integrate practical work with theory in their teaching? 4) How have OBE and competence based curricula affected the knowledge of physical science in the current grade 12 physical science curriculum, National Curriculum Statement (NCS)?

The researcher's propositions were: 1) Teachers were unable to integrate practical knowledge with theory in their teaching of physical science; 2) Teachers lacked discipline knowledge of physical science; 3) Teachers lacked an understanding of how the knowledge of physical science impacts on its pedagogy; and 4) OBE and competence-based curriculum had displaced the knowledge of physical science.

5.2.3 Research methodology

The research used narrative discursive methodology to collect qualitative data from participants in five selected schools in the Xhariep district. Interviews and classroom observations were used to gather data from participants. Further, document analysis was undertaken to collect data from primary and secondary sources obtained from moderators' reports from DBE. The data were analysed to give meaning to the results.

5.2.4 Limitations of study

The research focused on a small population of participants so the findings apply to the sample of the study and may not be generalised to a larger population. The challenges met in the study included participants who were intimidated by interviews, especially the idea of being recorded in a live interview. The reason for this was that some had not been exposed to this kind of setting before and were afraid to make grammatical mistakes, knowing that what they said first time was recorded and that they could not get a chance to edit it, in contrast to when they were writing their responses. As a result of this uneasiness, they might not have been in as good a position to be open to give their true stories as they would have been had the setting been different. In one case, a participant refused to conduct the interview despite an appointment having been made and confirmed, and with all the necessary arrangements having been made by the researcher. The reason for refusal was that he/she would be comfortable answering the questions in writing rather than in oral form. The researcher had to leave the participant with the questions to allow him/her to respond in writing. This was one of the inexperienced teachers who participated in the study. Another challenge was that the researcher would visit a school to make observations only to find that the school on that day had an unplanned activity, which interfered with the smooth running of the school, and such observations could not be made on the day. A new appointment would have to be set with the teacher for lesson observations.

Language was another challenge. For the former model C teachers, who teach in Afrikaans, the participants were not comfortable to be interviewed in English. Although the interviews were conducted in English eventually, this created some uneasiness on the side of the participants as they could not express their views freely or in a fluent manner. Another limitation is that the study did not focus on testing teachers' knowledge per se, by administering a test to determine the teachers' knowledge. Had this been done, perhaps it could have made it clearer whether the challenges which were faced by learners (in the identified topics) as implied by empirical evidence from the study were due to teachers' lack of content knowledge or other factors, particularly in the said subject. This identified limitation (gap) might then open avenues for other researchers to pursue the phenomenon further.

The fears that participants expressed were minimised by assuring the participants that the interviews were not an end in themselves, that it was human to make mistakes and as such they should not be intimidated by the fear of making mistakes. Participants from former model C schools were assured that English was not their home language, thus they did not have to worry about the language but should look at the impact the study would make in the teaching of the subject. Further, assurance was given to participants that the interviews were confidential and no judgements would be made against anyone.

The researcher discovered during the analysis and interpretation of data that other aspects should have been added to the data collecting tools, namely, the biographical information, qualifications and experience of the participants. This information would have shed light on whether teachers' content challenges in some topics were due to limited qualifications or experience, or both. Information about their age could also provide insight into the grouping of teachers experiencing problems with the content. Thus, omission of these aspects is regarded as a limitation to the study.

5.3 THEORETICAL FRAMEWORK

Three theoretical frameworks identified and reviewed to guide the study were: 1) practical rationalism; 2) social constructivism; and 3) social realism.

5.3.1 Practical rationalism

The main emphasis of practical rationalists is on reasoning and cognitive development, hence practical rationalists focus on mathematics, philosophy and languages. They believe in neutrality and expect a researcher to detach his/her personal beliefs from the external world he/she is studying. Results of the study reveal that all the participants taught in a way that encouraged the development of knowledge through cognitive development, reasoning and philosophy. The reason for this is that participants used the lecture method, which according to the researcher encourages learners to mentally process the information given to them. The lessons were purely theoretical, even on topics that required practical work to clarify concepts. For example, a topic such as ‘rates of reactions’ was taught theoretically. It can be argued that concepts such as how concentration affects the rate of reaction can easily be understood by conducting a practical so that learners “see” the effect rather than “be told” what the effect would be. Given the nature of the subject, physical science, this framework would not be appropriate as the subject demands that learners reinforce their understanding of theoretical facts through practical work. Pure lecturing, in a way that does not allow two-way communication between the teacher and learners, is not an appropriate method to teach science as some of the participants did. Even when the teacher allows for dialogue and engages learners cognitively (as one of the participants did), it is not enough if this is the only method that the teacher uses. A variety of strategies should be used in a single lesson, including experimentation, in order to cater for different learning styles of the learners. This would also ensure that lessons were interesting and meaningful to learners. The use of experiments in teaching is further highlighted in the later sections on this report. Results of the study suggest that in some instances participants did not even challenge their learners cognitively, except for ‘filling them up’ with new information, while learners sat passively in class.

5.3.2 Social constructivism

Social constructivists argue that knowledge relies on convention, human perception and social experience. They contend that knowledge does not necessarily reflect any external realities and that scientists construct knowledge rather than discover it through strict scientific methods. There is no single valid methodology to gather knowledge from the world, but it is context-based and thus can be interpreted differently in different contexts. They reject universalism, realism or objective truth.

From the available evidence from this study, even under different contexts, teachers still used the same method of teaching. The lecture method does not allow learners to construct their own knowledge or to work in a social environment in which their knowledge would be generated by means of an understanding among the participating members. Learners were not afforded an opportunity to work in groups but instead worked individually. They were taught ‘facts’ (objective truths), which constructivists do not accept. The study thus shows that physical science is taught outside the constructivist theoretical framework, which was not surprising to the researcher as it was noted in chapter 2 that physical science is a universal subject, is not context-bound and its concepts apply across different contexts. The study supports this.

5.3.3 Social realism

Social realists argue that knowledge exists independently of the human mind, and is ‘out there’, whether one knows about it or not. The force of gravity, for example, is a phenomenon that exists independently of knowledge. Emphasis is placed on keen observation of the external world and the observer should not let his/her observations be clouded by personal feelings or emotions. Social realists talk about esoteric or conceptual and theoretical knowledge.

From the results of the study, it is evident that the teachers taught this conceptual, theoretical knowledge, however, learners were denied, at least from the available evidence, the opportunity to observe the world and to manipulate it through experimentation. This was a difference between what was happening in the science classrooms and what social realists advocate.

Both practical rationalists and social realists view neutrality of the researcher as key to studying the world, thus separating his/her opinions and feelings from the study. However, due to the nature of this study (qualitative) it was not possible for the researcher to become detached from the environment in which the gathering of information took place, because the researcher was both a data-collecting instrument and a researcher at the same time. Personal feelings and opinions, knowledge and experience were brought to the environment in which classroom observations took place, making bias inevitable. The researcher’s presence alone influenced how participants responded to questions and the researcher’s position as a senior official also affected how the participants provided information as well as which information. In narrative research, the researcher cannot be separated from the environment from which he/she gathers data; hence the researcher differs over what the two theoretical frameworks stand for, based on the nature of this study.

Both practical rationalists and social realists emphasise theoretical knowledge, the difference being that practical rationalists are logical, philosophical and theoretical in their approach, while social realists are concerned with observation of the external world and gathering of factual, conceptual and theoretical knowledge based on experimentation. With respect to theoretical, factual knowledge, the study shows that teachers provide learners with this type of knowledge, which is book knowledge. There is a merger between the two frameworks, though social realists also expect learners to interact with their outside world. At this point the scientific method, the conducting of experiments, is significant. As far as practical knowledge is concerned the study shows that the teachers lack in its execution.

5.4 DISCUSSION OF RESULTS

Themes identified from the research questions in this study were the following: 1) Teacher pedagogical and theoretical content knowledge; 2) Relationship between content knowledge of physical science and its pedagogy; 3) Integration of theory with practice in the teaching of physical science; and 4) Influence of OBE and competence based curricula on the teaching of NCS and CAPS.

5.4.1 Theme 1- Teacher pedagogical and theoretical content knowledge

On the first theme, literature as presented in chapter 2 indicates that physical science teachers should understand the nature of science and understand how, as a discipline, it is structured and works. This is a highly philosophical phenomenon which the study did not investigate in depth. Teachers were rather asked to elaborate on the type of knowledge that they as grade 12 physical science teachers needed in order to teach the subject effectively that is, practical versus book knowledge.

In this regard, as stated in the results, all participants agreed that teachers need to have both content knowledge and practical knowledge. From this, it can be argued that teachers should first give learners basic theoretical knowledge, that is, knowledge which is transferrable from one context to another. Without this foundational knowledge the learners would not be able to put into practice what they had learned in new contexts, hence practical knowledge would be meaningless and context-bound. A good theoretical foundation leads to meaningful, applicable practical knowledge. It is also important for teachers to understand the relationship between theoretical knowledge of physical science and its practical applications, so as to ensure that a balance is struck between theory and practice as teachers teach. Relevance of the subject to real-life situations of learners will make the learning of physical science meaningful and worthwhile.

It was stated in the limitations of the study that a direct method to evaluate the theoretical and curriculum knowledge of grade 12 physical science teachers in the selected sample would be employed by administering a test for teachers. An alternative route was to look at the results of learner performance in the grade 12 June and end-of-year NSC examinations. The researcher deliberately avoided the test for various reasons, one of which would be the reluctance of teachers to participate in the study, given that their knowledge of the subject was to be evaluated by means of a written test.

In order for the researcher to come to a decision about the performance in a topic, an arbitrary benchmark had to be decided upon; otherwise it would be difficult to compare the results. An average of 50% was selected for this purpose, i.e., when learners attained an average of 50% and more in a topic then the topic was regarded as well performed. When they obtained an average below 50% then this topic was regarded as poorly performed. The discussions that follow are thus based on this assumption and criterion.

With regard to the problem areas for learners, all the sources, i.e., document analysis and the analysis of June results for 2014, indicate the following:

In paper 1, the majority of the learners struggled with the following topics: work energy and power, electric circuits, photoelectric effect and 2D and 3D waves. All the consulted sources agree on the abovementioned topics as the most problematic for learners. It should be noted however that 2D and 3D waves is no longer in the CAPS document for grade 12 and has been moved to grade 11. The reasons are not known and speculation difficult. In addition, this topic is not included among topics in grade 10 and 11 which are examinable in grade 12.

Performance per year differs for each topic. Some topics show good performance in one year, and poor performance in another. Despite these annual fluctuations the consistency with which poor performance was recorded in these four areas/topics remains noticeable, whether the overall performance for that particular year was high or low.

When data from focus group interviews are compared with the data from the analysis of June results it is found that the majority of the participants had indicated that they did not have problems teaching most of the grade 12 topics, except reaction rates, polymers, electrodynamics, work energy and power, redox reactions, electrochemistry, organic reactions, vertical projectile motion and electric circuits. However, learner performance in the June exams revealed additional topics such as momentum, electrostatics, equilibrium and acids and bases that seemed to be a problem to learners. This was corroborated by the 2012 and 2013 National Diagnostic Reports, in which some of these topics appear as challenging to learners. For example, all the three documents highlight momentum, work, energy and power and electric circuits in paper 1 as challenging to learners. Similarly, all the three sources agree on organic reactions and reaction rates and equilibrium as the main topics that offer a challenge to learners in paper 2. The data do not, however, reveal whether the problem with these topics is due to teacher's lack of content or due to factors related to learner incompetence or other external factors.

Compared to work, energy and power, as well as electric circuits and electrostatics, examiners and teachers regard photoelectric effect as a fairly easy topic. Further, evidence from the interviews suggests a similar opinion expressed by examiners, since teachers did not mention photoelectric effect as a challenging topic for them. However, results of the study from document analysis reveal that photoelectric effect is one of the most challenging topics for learners. It is consistently showing poor performance, as suggested by all the three reports from 2012 to 2014 (see tables 4.1, 4.3 and 4.5).

When one studies the grade 12 syllabus, this topic (photo-electric effect) is the last in paper 1 to be tackled on the work schedule, suggesting a possible number of reasons learners do not perform well in it. It could be that teachers do not give it enough time to enable learners to grasp the concepts, with poor teacher knowledge, lack of mathematical skills of learners or learners not having sufficient time to revise it as the examinations follow immediately after it has been taught. In some instances, teachers are not even able to teach this section due to insufficient time available for teaching in the normal school hours. The study could not delve into all these questions.

In paper 2, results of the study show that learners struggle in the following topics: chemical equilibrium, rate of reactions, electrolytic cells, organic reactions, acids and bases and fertilizers. Of these topics, it is only organic molecules that teachers named as giving them problems, but even then they mentioned polymers rather than reactions of organic compounds. This is another contradiction between the outcomes of the interviews and those of document analysis. Given this scenario, one argues that the information from the two independent documents outweighs the one raised by the interviews. Teachers may not have wanted to be open about their challenges as a result of the observer's/researcher's presence and being their senior in the subject. This could have been averted if the study assessed the teachers' knowledge in these areas using appropriate tools, such as tests.

Contrary to what was gathered in the interviews, more topics appear to be problematic in chemistry (paper 2) than in physics (Paper 1). Almost all participants in the interviews shared the view that chemistry was easier for them and for learners than physics. One would therefore expect learners to perform better in chemistry than physic, but this is not what the study shows. Learners seem to have performed poorly in paper 2 than in paper 1, which raises three possible questions. Could it be that teachers think they know paper 2 content while they do not? Could the problem lie with the teaching strategies of the teachers (pedagogy)? Or could the problem be with learners?

In a study conducted by Lekhu in 2013 on the science teaching efficacy of the physical science teachers in the secondary schools of the Free State province of the Republic of South Africa, it was found that teachers were more comfortable teaching physics than chemistry. Although the results of this study (dissertation) differ from those of Lekhu (2013) with regard to teacher acknowledgement of their inability to teach chemistry (P2), the two studies agree in respect of the outcome of the learner results, confirming poor performance in chemistry than in physics. These results are also supported by document analysis discussed in chapter four.

As in paper 1, the topic 'fertilizers', is the last one in paper 2 to be treated in the work schedule/syllabus. The same argument as for photoelectric effect can be made about this topic. That the two topics are the last in the work schedule and that both are poorly performed forms a basis for one to link the poor performance to their position in the syllabus. The same poor performance in this topic was reported in Lekhu (2013), and the evidence is supported by document analysis in chapter four (Tables 4.2, 4.4 and 4.6). In Table 4.6, however, the performance in the topic is better than in the other two tables.

The topic ‘acids and bases’ was introduced in CAPS in 2014 so most of the participants had not been exposed to it, either as high school learners or as pre-service teachers. This could be the reason for poor performance in the topic. Notable about the topic on acids and bases is that teachers did not mention it as challenging to them. It must also be noted that there was not much data available to provide sufficient evidence for learner performance in this topic at the time this study was conducted. The only available data were obtained from the 2014 June results and the 2014 November report. Little conclusive evidence could be made about the topic as a result of this, though it is evident from available results that subject advisors have to make plans to assist teachers in order to solve the eminent problem.

It is difficult from the available evidence to make conclusive deductions about the impact of polymers on the performance of learners, because polymer chemistry is part of the wider organic molecules topic, which is further sub-divided into three main areas in the grade 12 syllabus, namely, nomenclature, physical properties and chemical reactions of organic molecules. The available evidence from interviews suggests that this topic, being new, is relatively challenging to teachers. Secondly, participants mentioned that they felt inadequately equipped to teach it as the majority of them had not covered it as part of their courses at tertiary institutions. From the interviews it was evident that one of the participants could not describe his/her problem using appropriate subject terminology on polymers and could not understand the equations representing polymer reactions. This gives credibility to teachers’ views about their lack of knowledge about this topic. Further, the topic is new in grade 12 in the CAPS syllabus. Despite teachers’ concerns about their lack of knowledge and exposure to polymers it is apparent from the results that learners generally perform better in this section of the work (organic molecules) than in other areas in chemistry, hence organic molecules have not been listed in the interviews among the topics learners struggle with.

It is significant to note that in the examination papers, polymers form part of chemical reactions of organic molecules, the section of organic chemistry in which learners perform relatively poorer than the other two (nomenclature and physical properties). One can thus conclude from the results of the study that polymers do contribute to the poor performance of learners in this section, even though the overall performance in organic molecules is good. It does not come as a surprise therefore that learner performance in organic reactions was low, considering that polymer chemistry is part of organic reactions. This suggests that measures need to be taken by officials to train teachers in this section of the work. If more emphasis can be placed on this section by subject advisors, with the training of teachers, the performance would possibly improve further.

Chemistry is a practical subject. Most of the reactions and phenomena (concepts) require learners to be able to see what happens, for example, colour changes, how fast a certain reaction occurs compared to another, or even how changing one variable/factor affects the rate of one reaction compared to the other. All these cannot just be explained to learners theoretically without experimentation. Telling a learner that a catalyst speeds up a reaction requires the learner to learn this by rote, as opposed to showing the learner what the addition of a catalyst to a reaction mixture does to the rate of a reaction.

Evidence from classroom observations indicated that practical work was lacking in the participating schools. Lekhu (2013) reported that teachers rated themselves highly on the performance of practical work and showed enthusiasm for performing experiments. This enthusiasm, positive attitude towards performing experiments and understanding by teachers of the importance of practical work to the teaching of science was also recorded in the current study. However, this study does not support the above claims, as classroom observations in all the participating schools revealed that teachers did not perform experiments in their teaching. In the same findings of Lekhu (2013), it was reported that there was no integration of theory with practical work in schools. This is corroborated by moderators' reports from 2012 to 2014. One can thus conclude that learners' poorer performance in paper 2 than in paper 1 should not have been unexpected. Physics mostly requires learners to make calculations, with little practical work, and learners can practice the method of solving problems more easily than in chemistry (P2).

The available, consulted literature on experiments suggests that learners learn by doing, touching, hearing, smelling and tasting, that is, by using their senses (Timur 2012). This is natural and happens from an early age, however, when learners attend school the teachers tend to forget this important natural instinct to learn and subject them to formal, rigid methods of teaching and learning. These methods are often boring for learners and make them dislike learning, which should occur through questions which they ask out of curiosity. Manipulation of objects helps learners to understand how things work; thus promoting a positive attitude towards the subject. Timur (2012) and the DBE (2011) argue that learners should be given opportunities to think like scientists and to solve challenging, real-life problems, whilst teachers should make science both meaningful and real to learners by being relevant to their daily experiences. This aspect was lacking in most of the observed lessons in this study, with little creativity shown by teachers and no relevance to learners' daily life experiences evident in the delivered lessons. The literature points out that traditional science teaching paid more attention to teaching 'factual' knowledge, concepts and laws of science, which can be supported by empirical evidence through experimentation (Roberts & Sahim-Pekmes 2012).

The CAPS document (DBE 2011), as explained in chapter 2, expects teachers to guide learners through experimentation to develop scientific skills. This is a policy issue which all science teachers should observe, as they are obliged by policy to allow learners to conduct experiments even if they did not wish to. The study, however, shows that the majority of the teachers did not plan their lessons to accommodate this curriculum policy issue. As other studies have shown (Harlow et al., see chapter 2), teachers still lack knowledge of how science knowledge is generated by inquiry, which can be reduced to experimentation. This study supports the abovementioned observation from earlier studies referred to in the literature review section of this report.

5.4.2 Theme 2 - Relationship between content knowledge of physical science and its pedagogy

On the second theme, teaching strategies, literature suggests that teachers should have substantial pedagogical content knowledge (PCK) and be able to use the most powerful analogies, pictures, examples, descriptions and demonstrations to teach the topics that are commonly taught in the subject (Schulman 1987, cited in Deng 2007). PCK means that a teacher should know which parts of the content are challenging to learners, what the misconceptions of learners are and be able to deal with these situations in meaningful ways. Literature further indicates that even a teacher who knows his/her subject content can fail to produce results if he or she does not have the strategies to teach that knowledge.

This study revealed that although the majority of the participants in the study were conversant with their subject knowledge they only used one method of teaching throughout the entire lesson in each observed case. Most used the traditional lecture method, mainly relying on the textbook and chalkboard. There was no variation of methods during the lessons or variation of activities in any of the observed lessons. As Stears (2009) in Tshiredo (2013) found, the majority of South African teachers seem to resist change in their teaching of science and still prefer to use the old approaches. It may be that they try to teach in the way they were taught themselves. It can thus be concluded that if lecturing were the only method that the teacher used in his/her teaching, learners would be bound to become bored at some stage, irrespective of how good the teacher's content knowledge was, hence the poor performance of the learners in the subject.

Studies by the NRC (1999), show that teachers should use content-appropriate teaching strategies that would improve learners' chances of knowing and understanding the subject content. This study showed that teachers used them because the content they taught during classroom observations was prescribed by the syllabus, as suggested in the grade 12 work schedules. This, however, is also subject to debate as the teachers had to teach the prescribed content. The questions to ask are: who prescribes the content to be taught; and who determines the appropriateness of the prescribed content for that particular level? It might also be that the content so prescribed for grade 12 learners was difficult for the teachers to interpret for learners.

Studies by Aydin et al. (2012) revealed lack of teacher knowledge for experienced and pre-service teachers, of both content knowledge and PCK; therefore these teachers lacked appropriate teaching methods. On the other hand, Harris and Farrel (2007) argue that teachers must have insight into the scientific process and a thorough understanding of scientific concepts and principles if they are to improve their teaching. Further references to PCK are elaborated upon in chapter two, section 2.6 of this study.

From the study, it can be said that the teachers' pedagogy was of low quality; however their content knowledge could not be determined by objective means other than observation in their classrooms. Their lack of pedagogy may not conclusively be attributed to their lack of understanding of the process of science and the scientific process as literature suggests, but the link made in the literature makes sense, because someone who is highly knowledgeable in content will most likely be able to devise good, effective strategies.

Teachers' understanding of pedagogy and PCK can ensure that they teach in meaningful ways and enable them to understand what barriers learners encounter in their learning of the subject. As such, teachers would be able to work towards improving their own practice.

While the study showed that teachers lacked in pedagogy, they also failed to bring excitement to learners through demonstrations or experiments in all the observed lessons. The issue of practicals/experiments will be discussed next.

5.4.3 Theme 3 - Integration of theory with practice in the teaching of physical science

On the third theme, noted in the report of the DBE (2012:166), the moderator's comment with regard to practical work in schools was: "The responses of many candidates showed that they were not exposed to practical work. Candidates who were exposed to practical work were in a better position to answer some of the questions in this paper." This observation was made for paper 1, and reappears word for word in the same report (DBE 2012:18) for paper 2.

These comments on practical work agree with the findings of this study, where in all the schools visited none of the teachers had apparatus to demonstrate or to carry out any experimental work. Participants did not make use of the power of demonstrations, the actual doing of experiments or even the use of technology to play animations or videos for learners. Notable from these observations is that the same participants in the interviews indicated that practical work was important for making concepts clearer to learners. However none of this was reflected in the actual teaching encounter. The study cannot however explain the reasons which led to teachers failing to demonstrate in practice what they understood to be essential for meaningful teaching of physical science.

Lekhu's study (2013) however advances the following reasons for teachers' failure to conduct experiments in physical science: 1) lack of resources, 2) overcrowding and 3) insufficient time.

As suggested by literature reviewed in chapter 2, teachers should give learners an opportunity to conduct experiments as it is natural for children to learn by doing. Nonetheless the results of the study reflect negligence of this by teachers in this study.

Literature on practicals/experiments as outlined in chapter 2 section 2.5.2 of this report indicates that learners learn by touching and manipulating objects, creating curiosity and leading to their asking relevant questions which help them to learn better and develop a positive attitude towards science. In addition, they need to substantiate scientific theories and principles with empirical evidence obtained from their performance of experiments. Conducting experiments develops their ability solve real-life problems in varying contexts and helps them construct logical arguments and important basic ideas about nature and how it behaves.

Based on the evidence presented here, the teaching of science should have two facets. First, it should consist of the acquisition of basic, factual theoretical knowledge which will be provided by the teacher; and second, it should be followed by experimentation. This will enhance further understanding of the acquired science principles and concepts and establish relationships between theory and practice. It will lay a solid conceptual foundation for learners to use in their everyday lives in solving real-world problems, hence the learning of science will be meaningful and free from mere memorization of 'facts'.

Practical work should be planned to promote links and relationships between learners' observations and ideas that they already have when they conduct a practical activity. Teachers should not take for granted that mere performance of the tasks means that learners understand the meaning and purpose of the experiment and the relationships that the experiment seeks to illustrate/investigate. Rather, they should ensure that learners understand the objectives of the experiment and help them to pay attention to key elements to look out for (observe) while carrying out experiments.

5.4.4 Theme 4 - Influence of OBE and competence-based curricula on the teaching of NCS and CAPS

According to Donnelly (2007), OBE focuses on outcomes that learners should be able to demonstrate or achieve at the end of their learning process. On the other hand, a syllabus outlines the content that teachers should teach from the beginning of the year, provided in an accurate outline for teachers with the knowledge of what each lesson will involve. It also concentrates on formative and criteria-based assessment as opposed to summative assessment and standardised tests (high-risk tests). It takes the constructivist, developmental approach/framework to learning. Syllabuses structure and emphasise knowledge as part of curriculum. In OBE, teachers take a different role in teaching, and must change from being transmitters of information to becoming facilitators of learning in the classrooms (ibid.).

OBE does not have a specific style of teaching; rather classes, opportunities as well as assessments given to learners should assist them to achieve the specified outcomes. Donnelly (2007) discredits OBE by arguing that it is conceptually flawed, difficult to implement and superficial in its approach to detailing essential learning. This is in comparison with a syllabus or standards-based approach. OBE has been criticised as having failed in many countries such as Australia, USA and South Africa itself (Jansen 1998; Watt 2000).

Based on the literature thus discussed, it is evident that OBE paid attention to the learning outcomes rather than knowledge. It did not focus on how the outcomes were to be achieved, which resulted in fragmented teaching as teachers would only teach to achieve the required outcomes. In addition, OBE left too much room for teachers to select which outcomes they wanted their learners to demonstrate at the end of the learning experience. The result of this was that if a learner had to move from one school to another, what the learner had learned at the previous school would probably be different from what was taught at his/her new school. This suggests that OBE was context-based, and as explained above, in a South African context, OBE contained jargon that teachers could not handle or understand, for example, terms such as 'developmental outcomes', 'specific outcomes', 'learning outcomes' and 'assessment standards' to mention a few (Black 2009). OBE also used a constructivist approach to learning, making it context-bound and difficult to manage (Tshiredo 2013).

Likewise, NCS was driven by an outcomes-based approach, based on learner-centred approaches to teaching and learning. Like OBE, it focused on the achievement of outcomes but prescribed little on what content to teach or when. It differed from OBE in that it specified how to teach for the achievement of outcomes, while OBE only mentioned the outcomes without specifying how to teach towards them, leaving teachers to decide for themselves. Unlike NCS, CAPS is a policy document, focussing on content which must be taught. It is more teacher-centred and organises learning in a more logical manner, prescribing what must be taught and when. As Donnelly (2007) notes, CAPS differentiates between a syllabus-based approach to teaching and learning, easing teachers' load in terms of pacing, progression and sequencing of topics, since these are already outlined for teachers. Even teachers who lack subject content knowledge do not have to worry about re-organising knowledge that they must teach. This was a challenge in NCS as pacing, progression and sequencing of topics was left to the teachers, so those with little content knowledge struggled to re-organise the content. Both NCS and CAPS however, emphasise knowledge, skills and values which learners in post-apartheid South Africa should acquire.

Although the study shows some mixed opinions about teachers' understanding of OBE, there were arguments by some participants, who agreed to a great extent with literature, on criticisms levelled against OBE. These included a perception that OBE focussed on the outcomes and not on the content to be learned, nor on how the outcomes were achieved, or on teaching strategies and methodology. As such, OBE encouraged fragmented teaching in which learner outcomes were context-bound, thus teachers felt that they were being pressured to produce results irrespective of whether learners understood the scientific concepts. This emphasis on results thus encouraged rote learning, leading to high failure rate of learners at tertiary institutions, especially during their first year of study.

It is therefore argued that OBE did not encourage the teaching of knowledge which could be transferred across contexts. Some participants in the study argued that OBE did not prepare learners for facing life challenges. CAPS, on the other hand, is trying to address this by bringing in the knowledge part of the curriculum, which when well-grounded can produce learners who will be equipped with the proper scientific knowledge to address the challenges of life, irrespective of the context in which they find themselves.

5.5 CONCLUSION

Some remarks made in relation to classroom observations are: 1) the laboratory in the performing former model C school was more organised and the environment was more welcoming for learners than in schools with poorer performance. 2) The level of preparation was higher from the side of the teacher, making a chalkboard summary prior to learners coming to class for example; 3) The questions asked were mentally engaging for learners; 4) Learners were taking notes as the teacher was teaching; 5) The teacher showed good command of the subject content.

On the Other hand, the two underperforming schools showed some differences in these respects. In one there were no charts on the walls, while in the other a few charts were pasted on the walls. There was low engagement of learners with low-level questions in one school, while there was no engagement with learners in the other. Teachers in both schools had content knowledge of what they were presenting but pedagogical skills were limited. It was evident in the context of the study that the performing school managed because of the qualities demonstrated by the teacher, as well as the environment in which teaching took place (the state of the laboratory). It can be argued that in addition to a favourable learning environment, as exemplified by the performing schools, teachers must have good pedagogical knowledge. As discussed in the literature review, teacher content knowledge alone is not enough to ensure success in the teaching of physical science, but in addition teachers should have pedagogical content knowledge. They should be able to make concepts easier for learners, relevant to their everyday life and the subject interesting to learn. These attributes of pedagogical content knowledge seemed to be lacking in the teachers from low performing schools. They seemed to adhere to only one method of teaching, the lecture, a teacher-centred method which does not allow learners to participate actively in the class. Most prefer this method because they want to be in control, as noted in the literature review, in which a study by Ramnarain and Fortus (2013) in some South African schools revealed the same results of teachers using teacher centred methods. One would encourage teachers to start engaging in more learner-centred approaches that take into consideration that learners are participants in shaping their own learning. A variety of methods should be used during a lesson to stimulate learner participation and interest.

Based on the research questions, it seems teachers understand the importance of having a sound theoretical content knowledge of physical science as well as having a firm practical background of the subject. They acknowledge that good subject knowledge impacts positively on pedagogy and as a result can lead to improved learner performance. Even though all teachers acknowledge that practical work improves learners' understanding of physical science concepts, none of the teachers in this study demonstrated integration of practical work into their teaching. Neither did any of them mention a possibility of learners doing practical work to reinforce what they taught during their presented lessons. This poses a question as to why teachers failed to demonstrate this while in theory they asserted that it was essential. There were divisions among teachers about the influence of OBE on their teaching both in the NCS and in the current CAPS curriculum. However, they all agreed that OBE placed too much emphasis on the achievement of outcomes by learners, irrespective of how teachers achieved these outcomes. The general perception was that OBE did not prepare learners for life. This discussion shows that the objectives of the study have generally been achieved. The research questions were answered.

Concerning the propositions made by the researcher in this study; the study has shown that teachers were unable to integrate practical knowledge with theory in their teaching of physical science as proposed. Thus this proposal was supported by the study. On discipline knowledge of physical science teachers, the study showed that teachers had discipline knowledge or demonstrated it in some way. Hence the researcher's proposal was not supported by the study. The third proposal that teachers lacked an understanding of how the knowledge of physical science impacts on its pedagogy was also not supported by the study as it is clear from the results of the study that teachers have an understanding of the impact of subject knowledge on the teaching of physical science. On the last proposition, teachers argued that OBE and competence based curricula focused on outcomes and not on knowledge. Hence it can be argued that the study supports the researcher's proposal that OBE and competence based curriculum have displaced the knowledge of physical science.

5.6 RECOMMENDATIONS FOR FURTHER STUDY

The highlight of this study was that although teachers understood the importance of practical work in the understanding of concepts by learners, they did not engage them in it. One therefore sees a possibility of conducting further study into what could be the factors that prevent or hinder teachers from carrying out practical activities in their day-to-day teaching. The CAPS document prescribes formal experiments that teachers have to do with their learners for assessment purposes, but while attempts are made by some teachers to conduct these experiments there is a danger that they may just do these experiments only for assessment purposes, but not for learning and understanding of scientific knowledge and concepts, which could destroy teacher innovation. Some teachers may be inclined to stick to prescribed experiments and neglect other experiments not prescribed, which would otherwise strengthen their teaching and learning of scientific knowledge and concepts. This approach of prescribing experiments for formal assessment may not solve the science problem that the country is currently facing, especially if the number of selected experiments is so small. Rather, a larger pool of experiments should be used if the educational goals of teaching for understanding and meaning are to be met.

Another possible area of further study revealed by the current study is that of determining the influence of the position of a topic on the work schedule on learner performance. This is based on the observation made with the position of the two topics, namely electrodynamics and fertilizers. Although the two topics appear in separate physical sciences fields, i.e., physics and chemistry, there is an observed possible link between how learners perform in them and their position in the work schedule.

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APPENDICES

APPENDIX A

Analysis of P1 June performance by learners in participating schools.

Topic	Total marks	Average mark	Average %
Newton's laws	40	12,3	30,8
Momentum	23	6,6	28,7
Vertical projectile	17	4,6	27,1
Work and energy	19	4,4	23,4
Doppler Effect	9	5,1	56,7
Electrostatics	20	6	30,0
Electric circuits	22	4,3	19,5

Analysis of P2 June performance by learners in participating schools.

Topic	Total marks	Average mark	Average %
Organic nomenclature	18	11	61,1
Physical properties	13	9	69,2
Organic reactions	22	20	90,9
Reaction rates	33	9	27,3
Equilibrium	34	6	17,6
Acids and bases	21	7	33,3

NB: Calculations and analyses of the tables 4.1 and 4.2 were made in order to have the results arranged in the same format as the other tables from moderators' reports. This was done to make comparison easy and fair.

APPENDIX B

SUMMARY OF COMMON PROBLEM AREAS FROM DIFFERENT SOURCES.

Document analysis							
June 2014 results		**2012 moderator's report**		**2013 moderator's report**		**2014 moderator's report**	
Paper 1 (Physics)	**Av %**	**Paper 1 (Physics)**	**Av %**	**Paper 1 (Physics)**	**Av %**	**Paper 1 (Physics)**	**Av %**
Electric circuits	19,5	2D-3D waves	40,7	Electric circuits	15,5	Photoelectric Effect	39
Work and energy	23,2	Work and energy	45,8	Vertical projectile	30,0	Electrostatics	40
Vertical projectile	27,1	Photoelectric Effect	43,9	Momentum	31,2	Work and energy	40
Momentum	28,7	Momentum	47,0	Electrostatics	34,2	Newton's laws	45

Electrostatics	30,0	Doppler Effect	48,9	Photoelectric effect	34,2	Electric circuits	47
Newton's laws	30,8	Electric circuits	50,9	Motors and generators	36,9	Motors and generators	54
Doppler Effect	56,7			Doppler Effect	43,0	Vertical projectile	63
				2D-3D waves	52,8	Momentum	63
						Doppler Effect	67

Document analysis							
June 2014 results		**2012 moderator's report**		**2013 moderator's report**		**2014 moderator's report**	
Paper 2 (Chemistry)	**Av %**	**Paper 2 (Chemistry)**	**Av %**	**Paper 2 (Chemistry)**	**Av %**	**Paper 2 (Chemistry)**	**Av %**
Chemical equilibrium	17,6	Rate of reactions	33,2	Batteries	19,1	Electrolytic cells	33
Rate of reactions	27,1	Fertilizers	42,5	Electrolytic cells	17,2	Rate of reactions	36
Acids and bases	33,3	Chemical equilibrium	44,4	Rate of reactions	23,7	Chemical equilibrium	43
Organic nomenclature	61,1	Organic reactions	44,5	Galvanic cells	29,4	Galvanic cells	45
Physical properties	69,2	Electrolytic cells	45,6	Chemical equilibrium	30,5	Acids and bases	48
Organic reactions	90,9	Physical properties	58,1	Fertilizers	31,5	Physical properties	47
		Nomenclature	60,5	Organic reactions	37,0	Fertilizers	58
				Nomenclature	40,4	Nomenclature	65
				Physical properties	45,8	Organic reactions	61

APPENDIX C

APPENDIX D

4/14/2014

P.O. Box 1800

Bloemfontein

9300

The Director,

Strategic Planning, Policy Development and Research,

Old CAN building,

Maitland street.

Dear sir/madam,

Re: Approval to conduct research in the Free State Department of Education.

Thank you for granting me the permission to conduct research in the Free State Department of Education.

This letter serves to confirm my commitment to adhere to the conditions stipulated in your approval letter dated 01.April 2014.

Yours Sincerely,

Lethena M.S

Physical sciences Subject Advisor

Xhariep District Office

APPENDIX E

4/14/2014

P.O. Box 1800

Bloemfontein

9300

Dear participant,

You are kindly invited to take part in a study which aims to examine the teaching and learning of physical science in grade 12.

Your participation in this study is voluntary. Your identity will be protected. Nowhere will your name or the name of your school or any information linking you to your school appear in the report. Should you need further clarity, please do not hesitate to contact Motsienyane Simon Lethena by phone or by email on the following:

Cell number: 072 295 3597

Email: thenzam@gmail.com

Participant's signature: .... Date: ....

Thank you. Your interest in participating in this research study is greatly appreciated.

Yours Sincerely,

Lethena M.S
Physical science Subject Advisor
Xhariep District Office

APPENDIX F

4/14/2014

P.O. Box 1800

Bloemfontein

9300

The Principal,

Dear sir/madam,

Re: Application for permission to conduct research.

I wish to apply for permission to conduct a study at your school for a Masters degree, which I am currently enrolled for with the Central University of Technology (CUT).

My study aims to examine the teaching and learning of physical science in grade 12.

Your assistance in this regard will be highly appreciated.

Yours Sincerely,

Lethena M.S
Physical science Subject Advisor
Xhariep District Office.

APPENDIX G

4/14/2014

P.O. Box 1800
Bloemfontein
9300

The Chairperson,
School Governing Body.

Dear sir/madam,

Re: Application for permission to conduct research.

I wish to apply for permission to conduct a study in your school for a Masters degree which I am currently enrolled for with the Central University of Technology (CUT).

My study aims to examine the teaching and learning of physical science in grade 12.

Your assistance in this regard will be highly appreciated.

Yours Sincerely,

Lethena M.S
Physical sciences Subject Advisor
Xhariep District Office

APPENDIX H

Group Interview Schedule. (Pilot)

Date: ....

Research question	Interview questions
1. What type of knowledge do grade 12 physical science teachers require to teach effectively?	As a grade 12 physical science teacher what type of knowledge do you require to teach physical science in a meaningful way?
2. How does content knowledge of physical science shape pedagogy of physical science?	In what way do you think your knowledge of the subject content helps you to device meaningful teaching strategies? You can use any grade 12 physical science topic to explain your response.
3. To what extend do grade 12 physical science teachers integrate practical work with theory in their teaching?	How often do grade 12 physical science teachers do practical work and to what extend is practical work integrated with theory? Explain with examples.
4. How have OBE and competence based curriculum affected the knowledge of physical science in the current grade 12 physical science curriculum, National Curriculum Statement (NCS)?	How has the focus on outcomes brought about by OBE and competence based approach affected the teaching of content knowledge in physical science in the current syllabus that you are teaching?

APPENDIX I

M.S. Lethena

Student no: 20072430

Research Topic

Re-examining theoretical and pedagogical curriculum knowledge of grade 12 physical science teachers.

Focus Group Interview Schedule. (Final)

Date:..

Research question	**Interview questions**
1. What type of knowledge do grade 12 physical science teachers require to teach effectively?	Tell me about grade 12 physical science topics which you feel comfortable teaching and those that you are uncomfortable teaching? What makes you comfortable teaching these topics and what makes you uncomfortable teaching the others? Some people argue that in order to teach effectively, teachers need theoretical (book) knowledge, while others argue that teachers need practical knowledge required to address specific contexts.

	What type of knowledge do you think you need as a grade 12 physical science teacher in order to teach effectively?
2. How does content knowledge of physical science shape pedagogy of physical science?	How does your knowledge of the subject content help you to : • Plan lessons? • Select learner activities and to • Teach the subject? If you were to teach the Work-Energy theorem, what prior knowledge would you expect your learners to have before you start teaching them?
3. To what extend do grade 12 physical science teachers integrate practical work with theory in their teaching?	What role does practical work play in effective teaching of physical science? When do you do practical work and how do you go about doing practical work with your learners? Are there any specific points/challenges that you would like to share with me regarding practical work in grade 12 physical science?

4. How have OBE and competence based curriculum affected the knowledge of physical science in the current grade 12 physical science curriculum, National Curriculum Statement (NCS)?	OBE and competence based approach focussed on the achievement of outcomes. In what way did OBE affect the way you are currently teaching physical science? How did the introduction of OBE affect the way you teach the basic scientific concepts?

APPENDIX J

M.S. Lethena

Student no: 20072430

Classroom Observation Schedule.

Date: ....

Class:...

Item	Notes
1. **Classroom Environment.** (Sitting arrangement, display of charts, apparatus, learning materials)	
2. **Teacher-learner interaction.** ◦ Are learners active? ◦ Are learners on task? ◦ Is lesson teacher/learner centred? ◦ The general attitude of learners towards the lesson.	
3. **Teacher demonstration of content knowledge.** ◦ Correct use of concepts/terminology. ◦Asking questions that elicit knowledge.	

◦ Clarity of instructions/explanations.	
4. **Pedagogical tools/skills.** ◦ Use of examples, models, illustrations, experiments, demonstrations – relevance ◦ Simplification of concepts to make learning of difficult aspects easy. ◦ Use of alternative approaches/ arguments.	
5. **Integration of practical work with theory in the lesson.** ◦Is practical work done? ◦Is practical work linked with theory?	

APPENDIX K