EXPLORING THE TEACHING OF GRADE 12 PHYSICAL SCIENCES THROUGH INQUIRY-BASED PRACTICAL WORK IN DISTRICT 10, JOHANNESBURG, GAUTENG PROVINCE, SOUTH AFRICA

by

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DECLARATION

I declare that this dissertation titled: **Exploring the teaching of Grade 12 Physical Sciences through inquiry-based practical work in District 10, Johannesburg, South Africa,** is my work and that all sources that I have used or quoted have been indicated and acknowledged by means of complete references.

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ABSTRACT

The effective implementation of inquiry-based practical work poses an enormous challenge, especially in Township and rural schools. The challenges stem from the teachers' diverse understanding of inquiry-based strategy. In turn, these challenges cause poor academic performance in Physical Sciences. Thus, the study explored the teaching of grade 12 Physical Sciences through inquiry-based practical work in District 10, Johannesburg, South Africa. Six questions guided the study: To what extent do the Physical Sciences teachers understand the meaning of scientific inquiry? How do Physical Sciences teachers implement scientific inquiry in their Physical Sciences lessons? When is the practical work that is based on inquiry implemented by the Physical Sciences teachers in their lessons? What hinders the Physical Sciences teachers from implementing the practical work that is based on inquiry? What effects do Physical Sciences teachers' understanding of inquiry-based practical work has on learners' academic performance? To what extent do learners' academic achievement on a theoretical test and inquiry-based practical work differ in Organic Chemistry?

Moreover, the study was positioned on the constructivist learning and teaching of theory. A mixed-method design was used to analyse and interpret data generated quantitatively and qualitatively. Two instruments — semi-structured interviews and lesson observations were used to gather data. The participants were systematically randomly selected from sixteen schools, in District 10, in Soweto Township. The study's outcomes revealed that teacher participants had uninformed views about scientific inquiry, which in turn influenced their choice of teaching approach. Their ineffective teaching approach might have negatively affected learners' academic performance in Physical Sciences. Responding to the critical imperative, this study provided exploratory insights into the implementation of inquiry-based practical work as a tool to facilitating effective learning and teaching of grade 12 Physical Sciences and enhancing learners' academic achievement. The study, therefore, recommends, among others, that the Department of Basic Education, in line with the constructivist views, makes collaborative effort to help Physical Sciences teachers develop an informed view about scientific inquiry to enable effective teaching of Physical Sciences in order to improve learners' academic achievement. This can be achieved by replacing the current workshops with an inquiry-immersed teacher development, which will

enhance Physical Sciences teachers’ insight into practical work based on inquiry to improve the academic performance of Physical Sciences learners.

KEY TERMS OF THE TOPIC

Teaching conception: Teachers' comprehension of how learning should take place for learners' conceptual development.

Conceptual knowledge: The teachers' ability to apply laws and principles in imparting knowledge in Physical Sciences for the academic benefit of the students.

Constraints: Scarce teaching materials that can hinder the effective implementation of practical work that is based on inquiry in teaching Physical Sciences.

Constructivism: Is the process of learning in which learners build their own knowledge from their own environment.

Grade 12 physical science teachers: The professional teachers trained to teach both chemistry and physics within the Physical Sciences in grade 12.

Inquiry based approach: A constructive approach of teaching that usually promotes successful learning and teaching of Physical Sciences through learners' active participation.

Inquiry–based learning: the process where learners learn by posing scientific questions that can be investigated, and data is generated to make inferences.

Inquiry-based practical work: the learning and teaching approach of Physical Sciences in which learners construct new science knowledge through investigation, observation, asking questions, discussing among themselves and their teachers, thinking critically, analysing data and making conclusions about natural phenomena.

Physical sciences teachers' perceptions of practical work that is based on inquiry: The views that physical sciences teachers have concerning the implementation of practical work that is based on inquiry in teaching Physical Sciences for learners' benefit.

Practical work: the construction of scientific knowledge through an activity in which learners manipulate apparatuses in a Physical Sciences classroom.

Scientific Inquiry: Learning and teaching approach that promotes learning through asking questions, investigating phenomena, and analysing gathered data to make scientific conclusions.

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ACRONYMS

AAAS: American Association for the Advancement of Science

CAPS: Curriculum and Assessment Policy Statement

DBE: Department of Basic Education

DOE: Department of Education

D10's Soweto Schools: Schools in Soweto under district number 10 in Johannesburg, Gauteng Education Department (commonly known as the Johannesburg North District)

LO 1: Learning Outcome number 1

NCS: National Curriculum Statement

NOS: Nature of Science

NRC: National Research Council

OBE: Outcomes Based Education

PCK: Pedagogical Content Knowledge

SES: Subject Education Specialist

SCORE: Science Community Partnership Supporting STEM Education

SASAMS: South African Schools Administration and Management Systems

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CHAPTER ONE: INTRODUCTION AND BACKGROUND TO THE STUDY

1.1 BACKGROUND

It has been 27 years since the start of an elective Government in South Africa. Yet, there has been no cohesion in the academic curriculum. The never-ending changes in the school curriculum policy have made it difficult for teachers to come to terms with and implement incessantly new changes (Ramanarain, 2016). As reported by Maringe, Nkambule and Masinere (2015), teachers are not provided with enough time to horn their skills prior the implementation new changes. Consequently, this directly affect learners, albeit inadvertently, in a schooling environment that does not guarantee a reliable and stable curriculum. Maringe et al. (2015) further contend that the education's system undesirable performance in South Africa in comparison to other countries in the Southern Africa Development Community (SADC) region and internationally, emanate from several that came into effect post 1994 in South Africa.

According to Ramnanarain (2013), whose argument is shared by Mupira and Ramnarain (2018), many changes in the school curriculum policy were aimed at correcting the injustices of the past, which were caused by the apartheid education system. The apartheid regime's policy on education was teacher centred. Thus, it did not equip the learners with the requisite skills for constructing or discovering their own knowledge (Samuel & Sigh-Pillay, 2017; Ramnarain & Schuster, 2014).

Feldman (2016) identifies content acquisition and not science process skills as the focus of the apartheid education system, which relied a lot on teachers. Feldman (1994) further testifies that during apartheid system, the teaching style was mainly teacher-cantered, depriving learners a chance for knowledge building. They were supposed to be knowledge receptors. This made teachers the only transmitters of science knowledge. At the same time, teaching and learning in most science classrooms were done through notetaking approach by learners. In the case of practical work, it took the form of a step-by-step practical lesson, limiting learners' reasoning and stifling their creativity. Ramnarain and Schuster (2014) posit that learners in schools located in disadvantaged rural and Township communities did not have the chance to do effective practical work. The teaching and learning in most science classrooms were based on giving the learners notes. In rare situations where practical work based on inquiry was implemented, the learners would merely follow the instructions given without involving their inquisitive minds. This limited the much-needed critical development of science skills and science knowledge in Township and rural schools (Schuster & Ramnarain, 2014). Callaghan and Akuma (2017) assert that by failing to implement the practical work based on inquiry to enhance the development of the concept to the learners, schools rendered learning the Physical Sciences a futile and meaningless enterprise.

After achieving democracy and as part of the democratic transformation of the education system, the policy was changed to ensure that all Physical Sciences teachers use inquiry-based teaching approaches in their classrooms. The aim was to promote learners' critical engagement with the learning process in Physical Sciences. According to the Physical Sciences policy, Physical Sciences should be taught by allowing learners to investigate the phenomenon through scientific inquiries (Department of Education, 2003; 2005). Elsewhere, Ncube (2015), and Sithole (2016) recommended a hands-on approach in which they see the scientific inquiry method is comprehended as being interwoven together with practical work, requiring learners to be more practically minded. Ultimately, learners may be in a better position to acquire knowledge by practically engaging in a practical work based on inquiry. However, the Physical Sciences diagnostic reports from 2012 to 2019, indicate that most learners in grade 12 performed below average when their inquiry skills were examined (Ncube, 2015). This prompted the Department of Basic Education to issue a statement to the effect that inquiry-based practical work was neglected and/or not effectively utilised in most schools in South Africa (Kazeni, Baloyi & Graigher, 2018). Maringe et al. (2015) reckon that below average performance by learners in Physical Sciences, is directly linked with questions related to inquiry skills, and the recurring curriculum changes. In particular, and worth noting, proposed changes did not consider the need for effective training of teachers so that teachers could implement these changes effectively and with confidence. Continuous training of teachers would also lead to getting their buy-in to the proposed changes.

Maringe et al. (2015) note that every time there is curriculum change, teachers are subjected to short term training courses, which are not enough to improve teachers' skills necessary for the effective implementation of the changes in the curriculum. Notwithstanding this glaring anomaly, teachers are still expected to confidently teach

Physical Sciences through inquiry-based practical work. Authors such as Kim, Tan and Talave (2013); Ramnarain (2016); Kazeni et al., (2018) suggest that learners may develop scientific inquiry and problem-solving skills through inquiry-based practical work; however, many teachers find it challenging to conduct the experiments due to factors such as lack of adequate training, lack of resources and skills to utilise the resources for learners' benefit. As a result, very few learners achieve above average in Physical Sciences to enable them to pursue courses in Science, Technology, Engineering and Mathematics (STEM), which are critical for the country's economy and well-being (Akuna, 2017).

1.2 CONTEXTUAL SETTING

The schools used as research sites are situated in an impoverished Soweto Township near the city of Johannesburg. The schools are non-fee-paying schools. The schools depend on the Gauteng Education Department for all resources. They have no other means to generate revenue that can assist them in fully resourcing the schools to benefit learners. All learners in these schools do not afford to pay school fees. They come from low-income families. Thus, resources for learning and teaching in these schools are limited.

The student population in these schools is approximately 800 learners. The schools offer Physical Sciences from grade 10 to grade 12. The participating schools have laboratories and qualified Physical Sciences teachers. The participating schools are currently implementing CAPS, making them relevant sites for the study.

Before transitioning to democracy in 1994, the South African education system was structured and administered along racial lines. There was no equity in resource distribution to schools and teacher development. Under the Bantu Education Act of 1952, many schools in the Townships and rural areas were disadvantaged (Ramnarain, 2016). The schools chosen for the purposes of this study have also been affected by these historical challenges, which have had a negative impact on the teaching of Physical Sciences as a subject.

1.3 STATEMENT OF THE PROBLEM

Even though the democratic system introduced a single education system for all schools in South Africa, under the National Education Act, 27 of 1996, the use of an inquiry-based approach in teaching Physical Sciences in most Township schools is still a significant challenge. Admittedly, practical work based on inquiry is an essential tool for developing the scientific knowledge among the learners (Hodson, 1990; Osborne & Collins, 2001; Johnson, Hodges, Wilson & Watson, 2000). However, there is consensus on the challenges involved in implementing this teaching method to teaching Physical Sciences in the classroom situation the world over, and South Africa is not an exception. It is also worth noting that the notion of an inquiry-based method of teaching Physical Sciences is a recent phenomenon in the South African curriculum. Consequently, most teachers find it hard to implement this teaching approach during the teaching of Physical Sciences in classroom situations (Ramnarain, 2016).

After conducting research to determine the general qualities of the practical skills in about 266 students from grade 10 learners selected through random sampling in South Africa, Taber (2013) concluded that the argumentations of the learners were not of the required quality. The findings of this research also revealed that we still have a severe challenge of effective implementation of inquiry-based practical work for learners' benefit. The conceptual development of the learners in Physical Sciences depends on the effective implementation of inquiry-based practical work by Physical Sciences teachers. However, Physical Sciences teachers find it challenging to effectively implement inquiry-based practical work. This tremendously affect the overally performance of learners in the Physical Sciences.

Against this background, the study investigated the teaching of grade 12 Physical Sciences through inquiry-based practical work in District 10, Johannesburg, Gauteng Province, South Africa.

1.4 PURPOSE OF THE STUDY

The research investigated the impact of applying a practical work approach that is based on inquiry to the delivery of Physical Sciences lessons to grade 12 learners as delineated in the National Curriculum Statement (NCS). Mokiwa (2014) avers that it is possible for the Physical Sciences teachers to be strongly influenced by their beliefs and knowledge of whatever they do. Therefore, teachers of the Physical Sciences should use the innovative approaches and practices that speak to the NCS. The expectation is that the teachers should translate their understanding and knowledge to practical work that is based on inquiry into the teaching approach that is effective and efficient. A historical bottleneck is worth mentioning here; that many teachers who teach the Physical Sciences had been teaching well before the implementation of CAPS in the schools. Feldman (2016) identifies acquisition and not science process skills as the focus of the apartheid education system, which relied on teachers. Feldman (2016) further comments that the learning style amid the apartheid system, was more teacher cenetred, disadvantaging learners from building their own knowledge. Inevitably, they were using the apartheid system of education that was anchored on a highly rigid syllabus (Samuel & Sigh-Pillay, 2017). Antithetical to the rigidity and fixity of the apartheid system, the post-apartheid National Curriculum Statement states that teachers should change their perception of the learning activities. Therefore, the new education system focuses more on how the learners can achieve the expected outcomes of the lesson through practical activities. Arguments have been put forward that evidence exists of positive attitude and commitment of teachers towards the practical work that is based on inquiry in offering Physical Sciences lessons to the learners. It was also realised that there is nothing concerning effective implementation of the practical work that is based on inquiry in the classrooms during the teaching of Physical Sciences (Hobden & Ramnarain, 2015; Graigher, Lederman & Ledeman, 2014).

Grayson and Rogan (2003, p.117) as quoted in Ramnarain (2014) argue that most of the policy documents have educationally and visionary sounding ideas. However, it has been realised that the implementation of such ideas has proven difficult and much slower. This is the challenge faced by teachers who are offering lessons to the Physical Sciences grade 12 students by means of practical work that is based on inquiry. These teachers will not implement it as an activity for assessment within CAPS. It is on the basis of these challenges that the research focused on gaining understanding of the way teachers of Physical Sciences in grade 12 implement the practical work that is based on inquiry within CAPS. Furthermore, the research focussed on their effects on real teaching as well as the academic performance of the learners. It was hoped that the outcome would help the designers of the curriculum with an overview of what they are supposed to do to help grade 12 teachers to effectively teach Physical Sciences by means of practical work that is based on inquiry. Additionally, it could help the teachers to learn from the conceptions of other teachers of Physical Sciences. The conceptions of others ultimately transform the approaches of their teaching using practical work that is founded on inquiry. Hopefully this would improve the methods of teaching Physical Sciences, so that learners' academic achievements will change for the better.

1.5 AIMS OF THE STUDY

In the past fifteen years, I was employed as a grade 12 Physical Sciences external moderator for the districts. During the moderation of SBA, I discovered that most learners were performing much better in their experiments. However, they performed poorly in their theoretical tests of the same concepts. When I raised this glaring concern with the Physical Sciences facilitators, they seemed unbothered. Three years later, it was discovered that most schools' year marks were rejected by the examination body. I finally realised that there is a gap that needs to be closed. Hence, I decided to embark on the study. The aim of the investigation was to assess the Physical Sciences teachers' understanding of inquiry-based strategy. It is my firm belief that teachers' understanding of inquiry-based strategy can have an impact on how they use the inquiry-based practical work. Similarly, teachers' effective use of inquiry-based practical work might improve learners' conceptual development in Physical Sciences. Leaning on the two hypotheses above, it is my hope that this study will improve the methods of teaching Physical Sciences, so that learner academic performance will improve.

1.6 OBJECTIVES OF THE STUDY

The Physical Sciences teachers' understanding of inquiry-based practical work investigation is based on esterification experiment. The experiment on esterification will be employed to investigate the Physical Sciences teachers' understanding of inquiry-based practical work. The experiment on esterification can trigger learners' conceptual development in Chemistry, provided an inquiry-based approach was followed. Esterification forms a correlation between different chemistry concepts such as the rates and extent of reaction, organic chemistry, chemical equilibrium, acids, and bases.

The main objective of the study was to explore the Grade 12 Physical Sciences teachers' comprehension of scientific inquiry, and how Physical Sciences teachers implement scientific inquiry in their classrooms.

1.6.1 THE SUBSIDIARY RESEARCH OBJECTIVES ARE:

(a) To ascertain the degree of understanding scientific inquiry among the Grade 12 Physical Sciences learners and teachers. The degree of teachers' understanding will be measured by Views About Scientific Inquiry instrument;
(b) To determine the use of inquiry-based practical work in teaching Physical Sciences;
(c) To investigate the integration of theory within some inquiry-based practical work lessons by the Grade 12 Physical Sciences teachers. The observation schedule will be used for this investigation;
(d) To ascertain the conditions under which Physical Sciences teachers execute the inquiry-based practical work during some of their lessons;
(e) To determine the effects of inquiry-based approach in Physical Sciences on learners' academic achievement in a theoretical test on the same topic; and,
(f) To establish if there is a significant difference between learners' academic achievement on a theoretical test and inquiry-based practical work in organic chemistry.

1.7 RESEARCH QUESTIONS

The investigation was anchored on the endeavour to answer the following main research question: What is the Physical Sciences teachers' understanding of inquiry-based practical work, and how does their understanding impact the learners' achievement? To respond effectively and efficiently to the main research question, the subsidiary questions below assisted in directing the research:

- To what extent do the Physical Sciences teachers understand the meaning of scientific inquiry?
- How do teachers use scientific inquiry in their Physical Sciences lessons?
- When is the practical work that is based on inquiry used by the Physical Sciences teachers in their lessons?

- What hinders the Physical Sciences teachers from implementing the practical work that is based on inquiry?
- What effects do Physical Sciences teachers' understanding of inquiry-based practical work has on learners' academic performance?
- To what extent do learners' academic achievement on a theoretical test and inquiry-based practical work differ in Organic Chemistry?

1.8. THE SIGNIFICANCE OF THE STUDY

This researcher believes that this study offers background information on the effect of using inquiry-based practical work on the academic performance of the learners in Organic Chemistry. For the grade 12 Physical Sciences learners and teachers for instance, the study will shed some light on the effectiveness of the inquiry-based method in facilitating teaching and learning, which might encourage its adoption against the backdrop of fear and reluctance to use the method. For the Department of Basic Education, the study will ensure that adequate resources are put in place to facilitate Physical Sciences learning through inquiry-based methods. The study is also significant for the policy makers to develop policy that guides how inquiry-based methods could be used in the teaching of grade 12 Physical Sciences subject for the benefit of learners.

1.9. THEORETICAL FRAMEWORK

A theoretical framework, according to Ngulube, Mathipa and Gumbo (2015), is an analytical tool that introduces theory as a lens to investigate, understand and interpret social reality. In the case of this study, the social constructivist theory was used to guide this investigation (Vygotsky, 1978). Social constructivist theory offers the opportunity of comprehending how processes of learning occur. In the constructivist environment of learning, there is a dialectical relationship between the cognitive development of the learners and their interactions with other people in the society. This theory argues that knowledge is anchored in the social environments and used by people (Kazeni et al., 2018; Amineh & Asl, 2015). The environment of a constructivist classroom enables the learners to acquire knowledge through the observation method, discussing concepts with one another, responding to the questions of the teachers, and making implications and explanations on various phenomena. The learners have the opportunity of developing new knowledge on science from the knowledge that already exists (Kazeni et al., 2018). The constructivist theory argues that the students go to the classrooms with preconceived scientific knowledge learnt from the communities they interact with (Kim, 2005). However, they should be helped and guided by the teachers to develop critical skills to distinguish what they have in their mind as a result of their social experiences, and what has been scientifically proven and accepted. Furthermore, prior knowledge of science is indeed a prerequisite for the occurrence of effective learning, since the new scientific knowledge is discovered from the existing knowledge (Kim, 2005).

The inquiry approach to teaching deals with involving the learners during the learning process. This approach is process and skills development oriented instead of concentrating on the transmission of knowledge (Carlson, 2003). During the experiments, the learners are placed into groups and thus, are given the opportunity to learn from one another as well as their own environments. The constructivist approach aims at encouraging learners to actively participate in the tasks that require them to work in a cooperative way—teamwork—so that they can discover scientific knowledge by themselves from various experiences.

In working as a team, learners are able to build new scientific knowledge on top of what they already know. Thus, the constructivist approach results in the scaffolding of knowledge when they are working as a group (Niederhauser, Salem & Fields, 1999). Even as they are discussing a given topic, learners discover new knowledge on science that is anchored on prior knowledge. This speaks to Kiemer, Groscchner, Pehmer and Seidel (2015) who argue that the major way of constructing meaning is peer cooperation. Similarly, Roth and Lee (2006) point out that in the constructivist classrooms, the learners get fully involved in the discussion in classrooms and they are likely to get involved in a learning experience, which is sustained and meaningful. Likewise, the National Research Council (1996) argues that constructivism helps the learners in discovering scientific concepts that are meaningful, as they are involved in the scientific arguments all the time. They are able to expand their comprehension of the way scientists grow the mastery of the universe.

Elsewhere, Lunetta and Hofstein (2003) allude to the fact that the constructivist approach encourages learners to be fully engaged in the learning process. It allows learners to explore topics, make their own connections, judgements, and ask questions. This enables more effective learning. Furthermore, Polman (1999) argues that for a productive lesson to take place in a Physical Sciences classroom, an environment should be created where learners can actively ask questions, constructively discuss among themselves, while teachers should be part of the discussion giving direction to the learning process.

When it comes to the constructivist classrooms, the learners are in charge of their learning; the lesson is centred on them, and not the teacher. Vonglaserfeld (1989); and Llewellyn (2005) argue that learners discover new knowledge if they have been effectively involved in the process of learning. This argument is shared by Cheeck (1992) who argues that people are not passive recipients of knowledge of any subject, but they discover new knowledge through linking it with their experiences. Therefore, learning science should be a process involving active engagement of learners in activities with the teacher giving directions (Tobin, 1990). The construction of new science knowledge in Physical Sciences is possible when learners deal with daily challenges (Brown, Collins & Durguid, 1989).

As learners construct their own scientific knowledge from their own personal experiences, the teacher can expand their knowledge by posing relevant thought-provoking questions and encouraging them to ask questions for better comprehension of concepts. In the process, learners develop better understanding of learning resulting in broadening their conceptual knowledge, and ultimately leading to enhancement of their academic performance (Hart & Cheval, 2005).

The constructivist theory gives important knowledge on the ways of enhancing the effective development of the process of learning (Vygotsky, 1978; Binns & Popp, 2013; Chapman, 2003; Gredler, 2008). For instance, during the constructivist lesson, teachers are supposed to trigger the process of learning and create opportunities for learners to think critically during the practical work that is based on inquiry, as opposed to playing the facilitator’s role. Teachers are, therefore, responsible for helping learners broaden their conceptual knowledge during execution of practical work that is inquiry oriented.

Literature describes constructivism as a speculation of learning in which learners construct their own understanding from their direct experience, and not from what they have been taught (Lederman, 2009; Chapman, 2003; Lederman, Lederman, Bartos, Barles, Meyer & Schwartz, 2014). Thus, the study centred on the constructivist theory of gaining and acquiring knowledge that the South African education system promotes. The constructivist conjecture put forward in this research concentrates on the provision of opportunities to the learners, so that they can construct knowledge by themselves, through inquiry-based practical work with their peers but guided by teachers' advice.

1.10. SUMMARY TO CHAPTER ONE

Chapter one provided the background to the study, its contextual setting, and statement of the problem, study aims and objectives, research questions as well as the study's significance. The theoretical framework that guided this study has also been clearly discussed. The following chapter focuses on the review of related literature on the teaching of grade 12 Physical Sciences through inquiry-based practical work.

CHAPTER TWO: LITERATURE REVIEW

2.1. INTRODUCTION

This chapter provides a review of various literatures related to the study. The review is necessary to place the study within a proper scholarly context by identifying and analysing the literature that is relevant to the study (Tashakhori & Creswell, 2007). The review is also relevant to identifying gaps in existing scholarly material and providing a scope for further research and exploration. Both primary (books and journal articles) and secondary (biographies and index to sources) sources of information were consulted for purposes of the review. The following key themes that are entwined with the research objectives of the study are the focus of the review: (i) the concept of scientific inquiry, (ii) the types and forms of scientific inquiry, (iii) the implementation of scientific inquiry in teaching science, (iv) the importance of using scientific inquiry in science, (v) the effects of scientific inquiry in learning science, and (vi) the challenges associated with using scientific inquiry in teaching science ─ some of which include, inefficient teaching approach, lack of teachers' adequate pedagogical content knowledge, lack of laboratory equipment, and inefficient teacher development.

2.2. THE CONCEPT OF SCIENTIFIC INQUIRY.

The concept of scientific inquiry has earned itself diverse descriptions and definitions from various researchers. After reviewing various literature on how other science teachers have described a scientific inquiry, it became clear to this researcher that the scientific inquiry is an activity that is learner centred. It gives learners the opportunity to discover and build knowledge while carrying out the practical experiments in a Physical Sciences class (Ifeoma & Oge, 2013).

Scientific inquiry is also referred to as one of the ways of seeking new knowledge by means of finding out about a phenomenon through gathering data and making conclusions after data analyses (Ifeoma & Oge, 2013). Song, Lee, and Lim (2004) describe a scientific inquiry as the strategy of learning science that allows students to follow similar practices as that of the professional scientists in constructing their new knowledge. Acknowledging the inclusive and participatory nature of scientific inquiry approach, De Jong and van Joolingen (1998) describe a scientific inquiry as a learning strategy that emphasizes the participation of learners in their learning process. Students often carry out experiments in investigating the relationship between various variables, for instance, independent and dependent variables in the learning process (Wilhelm & Beishuizen, 2003). Applying problem solving skills is one of the many tenets of scientific inquiry, which has earned it the definition of an approach to solving problems (Pedaste & Sarapuu, 2006). On the other hand, Martinello and Coock (2000); Anderson (2002); the National Research Council (2012); Bell, Smetanana and Binns (2005) concur in their description of an inquiry as a process by which learners' world is investigated by them through questioning and seeking answers to those questions.

The revised National Curriculum Statement (NCS) defines an inquiry as one of the approaches of teaching, which encourages the students to acquire content knowledge, process skills and conceptualize knowledge (DBE, 2012). Likewise, Jiang and McComas (2015) argue that inquiry is a pedagogical tool that is used by the learners to learn the scientific content and make practices by going through the process of inquiry.

The National Research Council (NRC,1996, p. 23) has added its voice to defining scientific inquiry thus:

Scientific inquiry refers to the diverse ways in which scientists study the natural world and purpose explanations based on the evidence derived from their work. Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known considering experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical thinking, and consideration of alternative explanations. Students will engage in selected aspects of inquiry as they learn the scientific way of knowing the natural world, but they also should develop the capacity to conduct complete inquiries.

In this research, the researcher investigated the execution of practical work that lends itself to being inquiry in nature in the learning processes of Physical Sciences. Thus, the researcher concurs and adapts to this research the view of scientific inquiry as an approach of teaching that is indeed effective in helping the learners to discover scientific knowledge.

2.3. THE TYPES AND FORMS OF SCIENTIFIC INQUIRY

Scientific inquiry as a teaching approach can be designated into three categories, namely: open inquiry, structural inquiry, and guided inquiry (Cheval & Hart, 2005; Parkinson, 2004; Johnson, Hodges, Botha, Wilson, Sadock, & Watson, 2000). When taught appropriately, all three categories can be of great benefit to science learning. The approach that is teacher centred among the three is structured inquiry (Johnson, Hodges, Botha, Wilson & Watson, 2000). The structured inquiry is mostly witnessed in Physical Sciences classrooms where laboratory activities are carried out (Parkinson, 2004). The teacher offers a structured experiment that learners must carry out following a specific set of instructions. According to Cheval and Hart (2005), structured inquiry can be described as the traditional strategy to inquiry, which most teachers adopt.

On the other hand, the open inquiry requires less involvement of the teacher; it is learner centred. In this type of an inquiry, students formulate the investigation question, make an hypothesis and design the experiment in groups to answer the investigation question without their teacher's influence or interference (Cheval & Hart, 2005). It promotes creative thinking and gives students a sense of scholarly independence.

The guided scientific inquiry falls in between structured scientific inquiry and open inquiry. In this approach, students are introduced to the concept or topic by means of a lecture method. The lecture method will guide learners in seeing the relationship between experiment and theory by emphasizing main points. The guided scientific inquiry allows for the teaching technique that integrates verbal explanation with experiment to convey facts, concepts, and processes. All scientific processes are involved in a guided scientific inquiry. Therefore, it is an effective teaching approach that can be observed (Cheval & Hart, 2005). It empowers both the teacher and the learner in a collaborative way.

2.4. THE IMPLEMENTATION OF SCIENTIFIC INQUIRY IN TEACHING SCIENCE

During the teaching of Physical Sciences by means of an inquiry approach to teaching and learning, the science teachers are expected to encourage the learners to ask questions concerning the phenomenon under study, discuss it with each other, learn from one another, and understand the new knowledge on science. In so doing, the goals of the learners of developing their individual comprehension of the phenomenon under study are achieved. The learning of scientific knowledge from the constructivist perception can take place effectively when the learners are taking part in doing the experiments and responding to their formulated questions (Mokiwa & Nkopodi, 2014).

The practical work that is based on inquiry provides teachers with the opportunity to facilitate the lessons through asking the learners thoughtful scientific questions that enhance their comprehension of the phenomenon under study. This provokes thought and makes learning of the Physical Sciences meaningful to the learners. Any approach of teaching and learning that is based on inquiry, in which the learners aim at getting answers to their formulated questions, enables them to discover scientific knowledge with less guidance from the teachers, hence they become active learners (Mokiwa & Nkopodi, 2014). The learners discover scientific knowledge by immersion themselves in various environments (Laurillard, 2013). Hence, the teachers of Physical Sciences should give the learners an opportunity to discover scientific knowledge without much interruption.

After the learners have discovered the scientific knowledge by themselves using practical work that is based on inquiry, they become confident of the capabilities they possess. Consequently, they can carry out various activities on their own. Millar (2004) argues that the approach that is based on inquiry motivates the learners to carry out the learning activities by themselves and enables them to understand and pursue knowledge by themselves without the help of their teachers. Ooyo (2009) adds his voice to the argument when he says that the learners can learn effectively when they are given the opportunity to carry out the experiments by themselves compared to when the teachers do some of the demonstrations for them.

The Physical Sciences Curriculum Assessment Policy Statement (CAPS) appreciates the value of teaching the knowledge of Physical Sciences using practical work that is based on inquiry. It argues that scientific inquiries enable the learners to carry out the activities confidently when exploring to satiate their desire concerning a given natural phenomenon and carrying out investigations on the relationships of various natural phenomena while answering questions in technological, environmental, and scientific context (DBE, 2011, p. 8).

Likewise, Harlen (2014) argues that the skills of inquiry that are gained by the learners do not only help them in improving their academic performance, but also in dealing with the challenges they face during their lifetime. In addition, Levy and Petrulis (2012) submit that inquiry approach is important in developing critical thinking as well as practical and cognitive skills that are needed in the life of learners. Evidently, the engagement of a teacher and learners by means of practical work with inquiry orientation has great benefits on learners' holistic development. However, it is important to know that the traditional methods of teaching are failing. Hence, the need for teachers to shift to the new approach of engaging learners in the Physical Sciences classes at schools.

2.5. THE IMPORTANCE OF USING SCIENTIFIC INQUIRY IN SCIENCE

The Physical Sciences practical work that is based on inquiry has been included in the curriculum the world over ─ South Africa included. Most teachers of science concur with the view that the teaching of the Physical Sciences should not be teacher centred. Instead, the learners should be actively involved in the construction of new science knowledge. There seems to be consensus among Physical Sciences teachers that inquiry-based lessons are the most effective approach of teaching. It enhances effective learning processes because of its learner centeredness approach (Bell, Smetana & Martinello, 2005).

During an inquiry, learners get an opportunity to investigate their world by means of formulating questions about the world and responding to them by studying the world (Cook & Martinello, 2000; Anderson, 2002; Bell et al., 2005; National Research Council, 2012).

This study recognized the inquiry approach of teaching as the most efficient and effective method of engaging teachers and learners in Physical Sciences. Through this approach, learners are assisted to discover scientific knowledge by themselves. When using the inquiry approach of teaching in the classroom situation, the learners can engage in the questions that are related with science, explore the phenomenon, make clear observations, and describe the observations, collect information, analyse the information during the learning process and draw logical conclusions. By doing this, the learners develop scientific based knowledge and skills, and grow into critical thinkers.

Hackett and Pratt (1998) argue that the learners can develop clear understanding of the concept of Physical Sciences and gain the critical skills of thinking upon being taught using the inquiry approach of teaching and learning. When using this approach, the teachers act as facilitators during the teaching and learning and solve any misconceptions that might arise.

Hacket and Pratt (1998) further contend that the practical work that is based on inquiry gives teachers the opportunity to assist learners in developing all necessary inquiry skills such as, skills of scientific process, critical thinking, and scientific reasoning, which are applied by scientists. During the lesson in which the inquiry approach is applied, learners have the potential to develop cooperative skills of learning such as teamwork and collaborative problem-solving, which give them the opportunity to discover scientific knowledge by interacting with one another and their teachers.

2.6. THE EFFECTS OF SCIENTIFIC INQUIRY ON LEARNERS' ACADEMIC ACHIEVEMENT

Authors such as Yagger and Akay (2010) believe that inquiry-based practical work is efficient especially in assisting learners'comprehension of science concepts and process skills (Yagger & Akay, 2010). Mupira and Ramnarain's (2018) study in the Mpumalanga Province, South Africa, confirmed efficiency in inquiry-based practical work is most effective in improving learners' scientific knowledge and supporting their conceptual development. Additionally, existing literature attests that knowledge attained through inquiry-based practical approaches can be preserved longer than the knowledge realised through the traditional learning approach (Lagowski, 1990). Furthermore, Millar (2008) posits that when learners discover knowledge through their own efforts, they remember what they learnt much better than the knowledge imparted by someone else, in this case, the teacher.

Lagowski (1990) adds that the retention of scientific knowledge by the learners is arranged as follows: 10% is that which has been read; 26% is made of what we hear; 39% is made up of what we perceive; 50% comprises of what we perceive and hear; 70% comprises of what others say, and 90% is made of what we say when we are taking part in the activities. According to this data, the learners store most of the scientific knowledge that they have constructed by themselves through active involvement. And the ability to store more science knowledge results in enhanced academic achievement of the learners (Lagowski, 1990).

Ejedike and Oyelana (2015) emphasize that as inquiry-based practical work enhances deep-rooted memory of the scientific knowledge acquired by the learners, so does their academic achievement improve? Akay and Yagger, (2010) admit that the practical work that is inquiry oriented is indeed effective in the comprehension of scientific concepts and the skills that are required in the science learning process. Mupira and Ramnarain (2018) note that inquiry based practical work is the most successful and proficient approach towards improving the academic achievement of the learners through improved knowledge accumulated by systematic study and organized by general principles. As this is activity-based process learning, scientific concepts broaden experientially, thus improving academic achievement.

In the study done by Witt and Ulmer (2010) in rural Missouri public school, in which the purpose of the study was to identify the impact of inquiry-based on student academic achievement. The study was designed to determine which teaching approach between constructivism and traditional approach is more effective in improving learners' academic achievement. The results of their study revealed that using the inquiry-based approach appeared to have an impact on student academic achievement.

Furthermore, the study in Nigeria by Zudonu (2010) which compared the mean achievement scores of learners taught with inquiry teaching with those who were taught in a traditional approach found that there is a significant difference in the mean achievement scores of learners taught through inquiry, and those who were taught in a traditional approach. The study found that learners who were taught through inquiry-based practical work achieved higher scores compared to those taught in the traditional method. Another study by Uzezi and Zainab (2017) found that the guided-inquiry laboratory experiments were more effective on learners' academic achievement than the traditional approach.

A study by Seylan and Morgil (2007) compared two classes taught through inquiry-based practical work, with other two classes taught through traditional method. The study discovered that classes taught through inquiry-based practical work had greater understanding of concepts, which resulted in higher academic achievement. Similarly, Abdi (2014) conducted a study in which two different classes were involved. One class was taught through inquiry-based experiment and other through traditional way of teaching. The results of the study revealed that learners taught through inquiry-based experiment, academically achieved higher scores than the traditionally taught class. Pandey et al., (2011) and Akpulluke et al., (2011) found that inquiry-based teaching has a statistically significant effect over conventional teaching method on academic achievement of learners.

2.7. CHALLENGES ASSOCIATED WITH THE IMPLEMENTATION OF THE SCIENTIFIC INQUIRY IN TEACHING SCIENCE

Although inquiry based practical work is seen as an important tool for developing the scientific knowledge among the learners, (Hodson, 1990; Collins, 2001; Johnson, Hodges, Botha, Wilson & Watson, 2000), there are challenges in carrying out this method of teaching Physical Sciences in the classroom situation. Firstly, the notion of inquiry-based method of teaching Physical Sciences is a recent introduction in the curriculum of South Africa. Secondly, a vast number of teachers are finding it hard to implement this method during the teaching of Physical Sciences in classroom situations (Hodson, 1990).

In this study, the researcher has analysed the relevant literature materials on the key challenges affecting the implementation of practical work that is based on inquiry (Hodson, 1990; Halai, 2008; Cook & Taylor, 1994; Lazarowitz & Tamir, 1994 in Hodson, 1990; Ramnarain, 2014). The study has identified factors like lack of comprehension of practical work that is based on inquiry and how the learners learn through it, the inefficient approach of teaching, lack of adequate knowledge on pedagogy, absence of knowledge of the subject matter, lack of adequate laboratory resources, inadequate time for effective teaching, a curriculum that is based on content, and the absence of robust teacher development programmes among others (Hodson, 1990; Ramanarain, 2014; Cook & Taylor, 1994; Halai, 2008). Some of these challenges are discussed below:

2.7.1. INEFFICIENT TEACHING APPROACH

In the curriculum of the South African education system, teachers are expected to teach Physical Sciences by means of practical work that is inquiry oriented. Although the practical work that is based on inquiry offers the learners the opportunity to discover knowledge by themselves through the support of the teachers, most of the teachers of Physical Sciences find it difficult to comprehend the practical work that is based on inquiry, and how it can be used by the learners during the acquisition of knowledge and skills. Consequently, students are being subjected to the ancient ways of learning science, whereby teachers transmit knowledge through giving notes to the learners. Whenever the practical work that is based on inquiry is used, teachers do not utilize it in ways that will benefit learners (Ramnarain, 2014).

The downside of it is that such practical work fails to give the learners the opportunity to discover scientific knowledge by themselves without the guidance of the teachers. Focussing on the manipulation of the materials deprives them of the chance for critical engagement in their individual thinking and perception (Millar, 2004), leading to meaningless learning in the classroom. Ooyo (2009) argues that several teachers in secondary schools who were interviewed at six schools in Tshwane South district of Gauteng, South Africa, said that learners lack the connection between theory and practical work that is of an inquiry nature. As a result, there is a lack of conceptual comprehension of the Physical Sciences. They also argued that the focus of the learners is on using experiments during the execution of given tasks without focusing on the achievement of the formulated goals (Bulunuz & Bulunuz, 2016; Verhoef et al., 2013).

According to Millar (2008), inquiry-based practical work is very effective in the promotion of learning, only if it challenges learners to think about what they are carrying out. Duckworth (1990), and Millar (2004.p. 12) argue that the tasks which are effective are the ones in which the learners do not only become the ‘hands on, but the minds on'. In addition, the study has also shown that, when the learners carry out an activity without involving their minds, they end up being observers who attach no value to the task. Due to this, they are not able to develop the skills of processing, and the conceptual knowledge, which is acquired through the practical work that is based on inquiry (Abrahams & Millar, 2009).

The teachers of Physical Sciences are of the perception that the practical work that is based on inquiry is indeed effective in helping the learners to comprehend the skills and concepts of scientific knowledge (Yagger & Akcay, 2010). Hence, for the learning process by means of an inquiry to be efficient and effective, the teachers are supposed to make sure that there is adequate time for introducing the new concepts during the lessons and full discussion of the new ideas and scientific concepts (Abrahams, 2009).

Hofstein (2004) argues that the learners are supposed to be helped to take charge of the learning of scientific knowledge. Thus, acting as facilitators, teachers of Physical Sciences are supposed to give the learners an opportunity that will motivate them to formulate questions and make reflections on their individual scientific knowledge. This approach will promote the advancement of sensible science theories and ideas from the learners' prior knowledge.

The researcher is of the view that teachers' understanding of practical work that is based on inquiry, and how the learners learn through inquiry have a huge influence in aiding scientific knowledge development and skills that are imperative in learning Physical Sciences. Millar (2004) argues that the effective engagement of teachers and learners in the Physical Sciences lesson, can be possible if the teachers of Physical Sciences know that for the learners to connect between the observation and the explanatory ideas, their intervention is highly required.

2.7.2. LACK OF TEACHERS' ADEQUATE PEDAGOGICAL CONTENT KNOWLEDGE

Teachers who are aware of what to teach and how to teach can positively influence how learners construct their own science knowledge (Baxter & Lederman, 1999). Knowledgeable teachers always understand that learners learn differently, so they always devise means for their learners to learn better. Even in schools where learning resources like a fully equipped laboratory are a scarce commodity, knowledgeable teachers always improvise for the benefit of their learners (Baxter & Lederman, 1999). Most knowledgeable teachers apply different teaching approaches that engage their learners because they can handle any scientific questions their learners might pose within the lesson. On the other hand, teachers who lack knowledge of teaching always avoid teaching approaches that will allow their learners to pose questions or discuss among themselves (Baxter & Lederman, 1999). Inquiry as an approach that allows learners to construct their own knowledge is always avoided by teachers who lack science teaching knowledge (Baxter & Lederman, 1999). The Department of Basic Education policy advocates that all teachers should teach Physical Sciences by means of an inquiry approach. However, only those who have vast knowledge of how to teach through inquiry have the confidence to engage learners in the learning process (DBE, 2011).

In Physical Sciences classes, the expectation by the revised National Curriculum Statement (NCS) is that teachers should be confident to integrate both the practical work that is inquiry oriented and the theory within their lessons (DBE, 2011). The teachers of Physical Sciences should take the responsibility to help the learners to make a connection between what they do in a laboratory and what they do in Physical Sciences class. Learners should be assisted to construct their own science knowledge in all lessons and the context should not be a barrier to learning (Baxter & Lederman, 1999). Unfortunately, not all teachers can promote learning in all contexts because, without knowing what to teach and how to teach, they leave learners confused. Consequently, the meaning of learning is lost. The content knowledge of the teachers of Physical Sciences is used to determine the approach of teaching to be applied during the interaction in the classroom (Baxter & Lederman, 1999). Therefore, content knowledge of the teachers of Physical Sciences is important when it comes to the construction of knowledge in an inquiry lesson (Callaghan & Akuma, 2017; Mokiwa, 2015; Ituma & Twoli, 2015).

Callaghan and Akuna (2017) assert that strong content knowledge gives teachers confidence to try new teaching approaches such as an inquiry approach for the benefit of learners. Ramnarain et al. (2016) argue that the teachers who have inadequate content knowledge on the Physical Sciences do not have confidence to teach their learners by means of inquiry. This disadvantages the learners who lose out on meaningful construction of science knowledge, resulting in a drop to their academic achievement. Crawford (2000) argues that the inquiry approach to imparting science knowledge to Physical Sciences learners, requires Physical Sciences teachers to possess some advanced concepts and principles that are taught in Physical Sciences. These include but are not limited to a greater level of understanding of the attributes of discipline and good understanding of mentoring, coaching, and interacting with the learners. Despite the great benefit that an inquiry approach brings, such as triggering the construction of scientific conceptualisation, a vast number of the teachers of Physical Sciences who have a limited content knowledge on Physical Sciences, find it hard to implement practical work that is based on inquiry during the lessons. As a result of this, they continue to employ the ancient approaches of teaching while achieving the same poor results (Crawford, 2000).

Motlhabane (2013) argues that several teachers of Physical Sciences, who have inadequate content knowledge on sciences fail to understand the importance of using practical work that is based on inquiry as an approach. The only confidence they have is teaching Physical Sciences using the textbooks and other materials that are related with the curriculum. Hence, they do not give the learners the opportunity to develop scientific knowledge by themselves.

Even though the Curriculum Assessment Policy Statement (CAPS) argues that teachers should teach the Physical Sciences by means of the approach that involves learners in the construction of their science knowledge such as an inquiry, the insufficient content knowledge that these teachers have makes it difficult to draw the connection between practical work and the theory during the lessons (DBE, 2011).

The poor approach of teaching the Physical Sciences is being influenced negatively by the poor content knowledge of the teachers (Motlhabane, 2013; Callaghan & Akuma, 2017; Dudu, 2014). As reported by the research conducted by Lewis, Dema, & Harshbarger (2014) at a large university in Southwestern U.S. urban centre, concerning the pre-service teachers' understanding of concept of inquiry, they noted that because of poor content knowledge of science, the pre-service teacher fails to acknowledge the practical work that is based on inquiry as the most effective method of teaching and learning during the lessons.

Lederman, AbD-El-Khalick (2013); Kapenda, Kasanda, & Naweseb (2015) alluded to the fact that for the teachers to effectively teach the Physical Sciences, their knowledge on concepts, theories, and principles that are taught and learned in science, should be above the content that is supposed to be taught in the classroom situations. According to Kapenda et al., (2015), teachers cannot be in a position of teaching the science content that they do not understand. In the rural and Township schools where resources are lacking and teachers are still stuck in ancient methods of teaching, the learners are performing poorly in the Physical Sciences (Ramnarain et al., 2017). The academic achievement of science learners is mainly dependent upon what they themselves have done to construct science knowledge. However, teachers seem not to create the environment in which a creative learning process is possible for the new science knowledge to be constructed by the learners (Helliar & Harrison, 2011).

According to the research that was executed by Ramnarain et al., (2017), most of the teachers of Physical Sciences in the rural and Township schools in South Africa had no knowledge of pedagogical content in science and the knowledge of subject matter. This discredits teachers in developing an in-depth content knowledge, which in turn directly affects learners' performers in Physical Sciences (Sadruddin, Khawaja, & Zafar, 2017).

Physical Sciences teachers' poor content knowledge seems to compel them to choose poor teaching approaches that produce the learners with poor knowledge of concept and poor knowledge of the content (Lederman & Abd-El-Khalick, 2013; Kapenda et al., 2015; Katchevich, Hofstein & Mamlok-Naaman,2013; Ayub, Siddiqqui & Lodhi, 2017). The end result is unpleasant academic performance.

The difficulties of learning that are faced by the learners can only be comprehended and dealt with by the teachers who have sufficient knowledge on the subject matter. This is because teachers are responsible for choosing the approach of instruction that can change learners' comprehension of concepts (Mokiwa & Msila, 2013; Lederman & Abd-El-Khalick, 2015; Mokiwa & Nkopodi, 2014). In addition, Windschitl (2001) argues that teachers with less in -depth knowledge on the inquiry approach of teaching and learning are not in a position to use practical work that is based on inquiry which is recommended as being one of the effective pedagogies to teaching and learning.

2.7.3. LACK OF ADEQUATE LABORATORY EQUIPMENT.

The reform of the curriculum in South Africa from 1994 was aimed at having an education system that is inclusive. The democratic education system views all schools to be the same ─ real or imagined. They are expected to teach Physical Sciences according to Physical Sciences policy, which is to teach through inquiry-based practical work (Ramnarain, 2018).

On the contrary, there are inequalities in the schools. The schools located in the affluent places have many resources compared to rural and Township schools (Ramnarain, 2018). In the previously advantaged schools, the laboratories have adequate resources, which are fully used since they have the required capital and material resources to utilize them. On the other hand, the schools in rural and Township areas do not have adequate resources hence, they get their resources from the Department of Basic Education (Ramnarain, 2018).

When the curriculum was being reformed, the Department of Basic Education did not close the gap that was existing in schools between those that were previously advantaged and those which had been previously disadvantaged. Notwithstanding this glaring anomaly, all the teachers in the two polarized contexts are expected to teach the Physical Sciences by employing inquiry approach to imparting science knowledge and producing the learners who have similar scientific knowledge (Maringe et al., 2015).

Although the practical work that is based on inquiry is viewed as the most effective in the development of learners' conceptual understanding of Physical Sciences and scientific skills (Ramnarain, 2018), the teachers from rural and Township schools find it hard to teach the Physical Sciences using practical work that is based on inquiry because laboratories do not have the required resources. On the other hand, the schools from the affluent places teach the Physical Sciences with ease through practical work that is based on inquiry.

According to the research by Ramnarain (2016), that was dealing with two schools from

Malawi ─ one less privileged while the other was privileged ─ it was realized that the teachers of science in the schools which had been privileged were greatly employing the teaching approach that is inquiry oriented compared to the other group of teachers. At less privileged schools, the teachers were not able to help their students in the discovery of their knowledge using the inquiry approach of teaching and learning due to inadequate resources.

From the existing literature, it is true that teaching and learning resources greatly influence the approach of teaching used by teachers in Physical Sciences in the classrooms (Ramnarain, 2016).
At schools previously advantaged, the teachers of Physical Sciences were comfortable when employing the teaching approach that is inquiry oriented, while the teachers from disadvantaged schools were using the ancient methods of teaching, which failed to promote meaningful and effective learning of Physical Sciences (Ooyo, 2013; Schuster & Ramnarain, 2014; Ramnarain, 2016).

Copriady (2015) alludes to the fact that learners can effectively discover their own knowledge on Chemistry if they have laboratories that are fully equipped. Copriady (2015) argues further that to give lessons that are productive in Physical Sciences, there should be adequate resources in the laboratory, complemented by teachers who have the required skills as well as a positive attitude towards the inquiry approach.

2.7.4. INEFFECTIVE TEACHER DEVELOPMENT.

Whenever the education system is being reformed in South Africa, teachers are taken through a three-day staff development training. Even though all the curriculum reforms are supposed to be implemented effectively by the teachers, the discussion groups provided by the Department of Basic Education do not equip the teachers fully to enable them to implement the new curriculum changes. According to Whitworth and Chiu (2014), some of the programs that are meant to develop teachers do not lead to the required change in the approaches of teaching and learning.

Borko (2004); Cohen and Hill (2000) argue that continuous teacher training is most effective because it gives teachers an opportunity to be involved in active learning. Teachers' active learning in the teacher development programme gives them the opportunity to reflect on everything they have learnt. It equips them to put all what they have learnt into practice, during the lessons. Longer duration teacher development programmes also assist teachers on how they can address the challenges, which emerge during learning by changing their teaching approaches (Crawford, 2012).

The research argued that teacher development programmes, whenever curriculum is being changed in South Africa, do not adequately prepare teachers to make use of the inquiry approach of teaching and learning during the lessons (Crawford 2012). Several teacher development programmes are not effective because they emphasize theory and not practice. They do not consider the approach of teaching, but are mainly focussed on the curriculum concepts (Nichols, Burgh & Kennedy, 2017). The effective development of teachers should help the teachers learn practical ways of integrating their knowledge on sciences, pedagogy and learning and not just the development of content knowledge, (Hodson, 1990; NSES 1996, 1996; Luft, 2001).

Objectively, an effective teacher development programme is supposed to develop teachers' scientific knowledge through inquiry approach of teaching and learning (NSES, 1996). In South Africa, however, teachers in their teacher development programmes were not actively involved in interpreting data, investigating phenomena, and making sense of the outcome. The Department of Basic Education offered a teacher development programme, which was not effective in fostering the inquiry-based approach of teaching. It did not develop teachers on the skills that are needed for effective teaching of Physical Sciences using practical work that is based on inquiry. Teachers should be adequately trained so that they can implement the inquiry approach of teaching in the classroom situations (Turner, 2000; Tseng, Tuan & Chin, 2012).

According to Harlen (2014), the teachers can only learn inquiry teaching approaches if they themselves were subjected to learning. In addition, it has been claimed that teachers effectively involve learners in the inquiry approach of teaching and learning, if they have gone through the learning experiences, which engage them in effective content knowledge of the inquiry method (Kennedy, 1998; Tobin, 1990 in Hofstein &

Lunetta, 2003). Supovitz and Turner (2000) argue that a continued engagement in the effective teacher development programme, increases the possibility of a positive modification in the way they give lessons to their students.

Although continuous and long-term development of teachers enhances the professional understanding of teachers on science, content knowledge of science, as well as the confidence and skills for teaching the Physical Sciences through inquiry-based practical work (Gess-Newsome, 1999; Shulman, 1986; Tobin, 1999), in South Africa, every time when change is made on the curriculum, the teachers of Physical Sciences do not have enough time for training and practicing their acquired skills (Maringe et al., 2017). Yet, they are supposed to effectively implement the changes that have been made. When Physical Sciences teachers lack confidence on how they are supposed to teach Physical Sciences through inquiry, the negative energy cascades down to the learners who do not effectively learn (Lederman, 2009). The lack of effective lessons translates to poor science knowledge development, leading to poor retention of content knowledge and poor process skills (Ali khalfan & Tairab, 2005 in Elhassen Hamad, 2015). Similarly, lack of content knowledge and poor process skills lead to poor retention, which negatively affect learners' academic performance.

The research has shown that teachers who were adequately trained and had undergone the required programme for their development, were able to develop adequate content knowledge (Laksmanan et al., 2011). The adequate content knowledge gives teachers the confidence to apply the inquiry approach in their lessons (Lakshmanan et al., 2011). The cause-and-effect principle says that the quality of teachers' in-service training should be equivalent to the students' scholastic achievement (Yoon, Duncan, Wen-Yu-Lee, Scaloss & Sharpley, 2007). The Department of Basic Education always expects good performance by learners in Physical Sciences. For this to be possible, teachers need an effective training programme that will prepare them to teach Physical Sciences through inquiry (Ramnarain, 2018).

Furtak, Seidel, Iverson, and Briggs (2012); Schroeder, Prins, Rietbergen, Fencher, Vaesen and Jael (2007); Savelsbergh, Prins, Rietbergen, Fechner, Vaessen & Jael (2016); Nichols, Burgh & Kennedy (2017); Luft (2001); Wilson (2013) concur that inquiry-based learning generally improves learners' academic performance. Therefore, alternatively to workshops, the Department of Basic Education should implement a long duration teacher training programme. The long-term teacher training programme provides necessary skills for teachers to apply inquiry-based method (Wilson, 2013). An effective teacher development programme leads to a change in teaching approaches, which stands to benefit learners. Hofstein and Lunetta (2003) argue that a good teacher development programme can equip teachers in such a way that they are able to take responsibility for their learners' progress in class.

2.8. SUMMARY TO CHAPTER TWO

Chapter Two reviewed related literature on the teaching of Grade 12 Physical Sciences through inquiry-based practical work. To facilitate and unpack the review process, the following key themes were looked at in relation to the study objectives: the concept of scientific inquiry, the types and forms of scientific inquiry, the implementation of scientific inquiry in teaching science, the importance of scientific inquiry in science, the effects of scientific inquiry in learning science, and the challenges associated with the implementation of scientific inquiry in teaching science. The cited challenges included inefficient teaching approach, lack of teachers' adequate pedagogical content knowledge, lack of adequate laboratory equipment and inefficient teacher development programmes. The following chapter outlines in detail the research methodologies followed to generate data.

CHAPTER THREE: METHODS AND METHODOLOGY OF THE STUDY

3.1. INTRODUCTION TO CHAPTER THREE

This chapter explains the research methodology followed in undertaking the study. These among others include research approach, population sampling of participants, data collection, in which the qualitative data tools such as semi-structured interviews and lesson observation are discussed. Quantitative data collection, trustworthiness of the instruments, validity, and reliability of the research instrument in which triangulation, thick description and low inferences are also discussed. Ethical issues considered in the study such as informed consents, deceptions and mechanically recorded data are clearly delineated.

3.2. RESEARCH APPROACH

A mixed method research approach also known as convergent parallel mixed method research design was used to explore the grade 12 Physical Sciences teachers' teaching through scientific inquiry. According to Creswell (2013), a convergent parallel mixed method is a research method in which qualitative and quantitative data are collected/generated concurrently, analysed separately, and merged. Thus, the quantitative data was collected from an existing data source, which was learners' academic performance mark sheet. The quantitative data assisted in answering research questions five and six. The qualitative data was generated from semi-structured interviews and lesson observation. The qualitative data was able to answer research questions one to four. The rationale for using the mixed method in collecting data was to answer all the research questions because some of the research questions could not be answered by qualitative or quantitative data separately. To answer all the research questions, the following procedures were followed:

3.3. POPULATION AND SAMPLING OF PARTICIPANTS

Cohen, Mannion and Morrison, (2013) argue that the sampling method of data collection is very important because it is not possible to study the entire population. According to Inan and Inan (2013), sampling refers to the technique or the process of choosing participants that are appropriate and recognized to be part of the whole inhabitants, from where the information is gathered. Inan and Inan (2013) define inhabitants as a grouping of persons, singles, items, or things from where the data is gathered for the calculation. The main aim of sampling is drawing inferences concerning the population under study from the selected samples. In addition, Inan and Inan (2013) indicate that it is cheaper and can save time to work with the sample, as opposed to working with the whole population. Thus, the purpose and technique of sampling is used as a way of gaining access to the studied people, for instance, people who have a clear comprehension of given issues. This can result from the professional responsibility and access to experience and networks (Cohen et al., 2013).

The study was conducted with the assumption that all teachers currently teaching Physical Sciences in grade 12 are fully qualified, have gone through teacher development programmes to implement CAPS, and are teaching in schools with fully functional laboratories. The participants were systematically randomly selected from 16 schools, in District 10, in Soweto Township. The systematic random sampling technique found in literature was used to randomly select the participants (Acharya et al., 2013). Due to lack of time and budget to conduct the study, the researcher chose four participants, two for the pilot study, and two for the main study. The four participants were chosen through systematic random sampling, in which every kth item is selected, to avoid bias, increase validity, and minimize cost (Acharya et al., 2013). The four participants were selected from 16 secondary schools in District 10, in Soweto Township using the formula, k= N/n, in which, N= 16 and n= 4 (Acharya et al., 2013). The 16 secondary schools were given numbers from 1 to 16. The total number of schools was divided by the required number of participants, which was four, hence 16 was divided by 4 to produce 4, which is the sampling interval. The next step was for the researcher to choose one number between 1 and 4. The researcher randomly picked number 2, which became a participant number 1. Then, 4 was added to 2 to give 6, which made number 6 the second participant. 4 was then added to 6 to give 10, making 10 the third participant, and finally, 4 to 10 to give 14 as the fourth participant. The subsequent participants were 2,6,10 and 14. Due to a small number of learners who enrol in Physical Sciences, all schools have a small number of Physical Sciences teachers. Notably, there was one Physical Sciences teacher in each school. In order to identify the participants who could take part in a pilot study, the researcher used the same systematic random sampling technique. As two schools out of four are required for a pilot and two for the main study, the researcher had to allocate the four schools, numbers from 1 to 4. As in the first instance, the total number was divided by two to get two. A number between one and two was chosen, which happened to be number one, then two was added to one to give three. Therefore, participants one and three took part in a pilot study, while two and four remained for the main study.

3.4. DATA COLLECTION PROCEDURE

A letter seeking permission to conduct a study was given out to the authorities of the sampled schools, teachers, learners, and parents. Data was generated from different sources including the interviews, using the interview protocol; lesson observations, using observation schedule; and existing data from learners' academic mark score sheet. Interviews and lesson observation can give a more precise account of the situation than any of them used alone (Maxwell, 1996 in Onwuegbuzie & Leech, 2007). In the study, the researcher collected/generated both qualitative and quantitative data to enable answering all the research questions.

3.5. QUALITATIVE DATA COLLECTION

The researcher utilized two data collection tools, namely, the interview protocol and observation schedule. The two data collection tools were developed based on the research questions and its objectives. For validity and credibility of the research tools, interview protocol and observation schedule were refined during the ethics clearance application in line with the research questions. The tools were reviewed several times by UNISA professors. Comments were noted and changes were implemented for the tools to meet the research requirements. The tools were also peer reviewed by the University of the Witwatersrand Masters' students, who were also on inquiry studies. Their comments were used to make some changes that improved the research tools.

3.5.1 SEMI-STRUCTURED INTERVIEWS

An interview is a data-collection technique that involves oral questioning of respondents, either individually or as a group (Creswell, 2013). Interviews permit clarification of questions and have a higher response rate than written questionnaires. Semi-structured interviews were conducted in two phases during the study. The first phase of semi-structured interviews was done before the lesson observations. The main purpose for the pre-interviews was to get a deep understanding of Physical Sciences teacher participants, regarding scientific inquiry. The second phase of the interviews was conducted after the lesson observation, to understand why teacher participants conducted their lessons the way they did. Due consideration and caution were taken in the second phase of the interviews to avoid sounding judgemental and patronizing. Kvale (1996) cited in Cohen et al., (2013, p. 355) avers that the researcher can utilize the interviews to achieve the following:

- Accept that the interviews may provoke new insights and changes in the participants themselves.
- Adopt a deliberate openness to new data and phenomena, rather than being too structured.
- Elicit descriptions of specific situations and actions, rather than generalities.
- Be able to reveal and explore the nuanced descriptions of the life worlds of the participants.
- Focus on specific ideas and themes but avoid being too tightly structured.
- Engage, understand, and interpret the key features of the life worlds of the participants.
- Accept the ambiguity and contradictions of situations where they occur in participants.
- Regard interviews as interpersonal encounters, with all that this entails.

According to Rehmat and Bailey (2008), responses to questions asked during an interview can be recorded by writing them down or by a video recording, or by a combination of both. Both the pre-interviews and post interviews were video recorded by the videographer hired by the researcher. The interviews were recorded in order to capture each and every word that the participants said, so that transcription represents their own words. Video recording also assisted the researcher to observe the activities, which might have taken place during the interviews, without the researcher's notice, but might be useful for the study.

3.5.2. LESSON OBSERVATIONS

Observation is a technique that requires systematically choosing and paying attention to the behaviour and characteristics of objects or events (McMillan & Schumacher, 2006). The researcher observed one lesson from each teacher participant after the pre-interviews. The main purpose for the lesson observation was to explore the teacher participants in action and to observe the presence of inquiry in their teaching. According to McMillan and Schumacher (2006 cited in Dhlamini, 2008, p. 56), the observation process allows the researcher to be engaged in a careful, systematic experience and conscious recording of details regarding many aspects of the situation. For the researcher not to miss any activity, the lesson was video recorded. While acknowledging that the presence of a video camera is likely to create a platform for spectacle and theatricality for the participants, the video recording of a lesson also assisted in avoiding observer biasness. The researcher was a non-participant observer; the cameraman was also not involved in the lesson. The cameras were placed in the corners of the classroom, so that the situation observed was not influenced. Learners were grouped into four to five groups, four learners in each group**.** The observer took field notes during the lesson observation, regarding the teacher interaction with the learners. The field notes taken during the lesson observation and video analysis, were used to collect qualitative data, which were analysed together with the data generated during the interviews to answer the research questions 1 to 5.

3.6. QUANTITATIVE DATA COLLECTION

The researcher used existing quantitative data from learners' academic performance mark score sheets, emanating from the organic chemistry test and the organic chemistry practical experiment **(see appendix M).** It should be noted that organic chemistry is taught in the first term of the academic year in the South African curriculum, hence the research had to be done in term 1. The practical experiment was prescribed for the grade 12 Physical Sciences learners in South Africa, which had to be administered during the teaching of organic chemistry in term 1. The theoretical test was a District set term 1 test, which was written by all schools on the same day, at the same time in the District. Both the test and practical experiment were administered, marked, and recorded by the teacher participants. The researcher received learners' academic performance marks score sheets from teacher participants on request. The participant teachers retrieved the academic marks score sheets from the South African Schools Administration and Management System (SASAMS), which was a clear indication that they were submitted for term 1's reporting to parents, after they were moderated at the school and District level. The mark score sheets aided to answer the research questions, five and six, and to gather quantitative data. According to McMillan and Schumacher (2006, p. 343 in Ngozwana, 2018), document analysis is a non-interactive strategy with little or no reciprocity between the researcher and the participants. Learner academic performance marks score sheet will be discussed in full in Chapter Four.

3.7. DATA ANALYSIS

The qualitative data was generated from the semi-structured interviews and lesson observations, which were video recorded. The recorded videos were to be watched and listened to by the researcher several times to enable verbatim transcription by the researcher. According to Lester, Cho and Lochmiller (2020 in Lippart, 2020), video recording aims to capture every word said by the respondents, and it serves as an error-free record of the answered questions. The researcher has familiarized himself with the transcribed data by reading the transcripts several times. Familiarization with data sets enables the researcher to have a sense of the participants' standpoint, and as a result, it accelerates the data analysis at a later stage. According to Dudu (2014), unveiling common patterns from data sets is done by reading the transcripts several times. This is called analytic induction. The qualitative data was manually analysed. The researcher made notes on the margins of words that summarized all what the teacher participants have said, in answering the research questions. According to Burnard, Gill, Stewart, Treasure and Chadwick (2008), themes that emanate from data can be identified from the data by making notes in the margins of words in the text, which is called coding. The emerging patterns of the data set were utilized for category development (Dudu, 2014). In order to assess participant teachers' understanding of scientific inquiry, the researcher used Views About Scientific Inquiry (VASI) instrument from the literature (Dudu, 2014). By adopting Lederman et al.'s (2014) classification of Views About Scientific Inquiry, which falls into the multifaceted framework, the teacher participants' responses were classified as; 'informed', if the answer provided by the teacher participants were consistent with the aspects of scientific inquiry; 'mixed', if the teacher participants' responses were either/or partially in line with the scientific inquiry aspects; and 'naïve', if completely in contrast with the scientific inquiry aspects. According to Lederman et al., (2014, p.68), the following aspects of scientific inquiry are considered to be informed understanding of scientific inquiry:

- Scientific investigations all begin with a question and do not necessarily test a hypothesis.
- There is no single step followed in all investigations (i.e., there is no single scientific method).
- Inquiry procedures are guided by the question asked.
- All scientists performing the same procedures may not get the same results.
- Research conclusions must be consistent with the data generated.
- Scientific data are not the same as scientific evidence.
- Explanations are developed from a combination of generated data and what is already known.
- Scientific knowledge is socially and culturally embedded.
- Scientists use human creativity and imagination to create scientific knowledge.

Equipped with these aspects of scientific inquiry, the results were organized into categories in line with the objectives of the study. Classification of teachers' responses into categories gave meaning to the data set, and this data was analysed by interpretational analysis (Burnard et al., 2008; Dudu, 2014). The researcher revisited the research objectives and tried to identify the research questions that could be answered by the generated data set.

The quantitative data was presented in the form of tables to give a reader a visible portrayal of what is being unpacked. According to Neuman (2014), the outcome from quantitative data should be presented in a table form for the reader to have a visual representation. The quantitative data was checked for errors before it was analysed. The researcher used statistical techniques to analyse the quantitative data. The quantitative data in this study was used to complement the qualitative data. Therefore, the researcher used descriptive statistics analyses to describe data, and inferential statistics analyses for data comparison. In order to showcase the average learners' academic performance in both practical experiments and a test in organic chemistry, the mean and standard deviation was calculated for both schools participating in the study. The mean scores above 60% and more were regarded as a high achievement level.

3.8. TRUSTWORTHINESS OF THE INSTRUMENTS

Before the interview protocol and observation schedule were used in the main study, they were piloted to the two systematically sampled schools for a piloting study. Punch (2009) in Morris (2018) argues that the researcher should ensure that there is trustworthiness and rigour on the methods of data collection during the study. Punch (2009) in Morris (2018) argues further that an instrument is said to be valid if it can measure what it should measure in a certain context and the research has trust in it.

Meriwether (2001) in Hanson & Seheri-Jele (2018) argues that the vagueness of the research instruments is reduced by piloting, which also increases its reliability. Elsewhere, Dikko (2016) contends that piloting research helps the researcher in ascertaining the ability of the instrument to work in actual research through identifying the possible challenges, as well as the areas which may need adaptation. Dikko (2016, p.522) adds that if the interview is well used as the instruments of the research, the piloting of research is good because:

- It highlights the questions which are ambiguous, unnecessary, and difficult thus allowing for modification to suit the research.
- It records the time which has been taken to finish the interview so that one can determine if it was reasonable.
- It determines if every question can elicit sufficient answers from the participants.
- It establishes if the responses from the participants are in line with the information which is required.
- It determines if the researcher formulated all the questions which are required to test all the concepts.
- It also allows the researcher to be in a position of practicing and perfecting the techniques of interviews.
- Makes some changes on the interview questions, and an observation schedule design in order to answer the research questions.
- Gains interview skills and confidence to probe further in order to gain deeper responses from the participants.
- Improves strategies before beginning the main study.
- Increases the utility of interview questions in comprehending the participants' lived experiences, and to observe the lesson in the participants' context.

3.9 VALIDITY AND RELIABILITY

Dhlamini (2008, p. 56) defines validity as the extent to which independent researchers could discover the same phenomena between the researcher and the participants. To improve the validity and the reliability of the study, the researcher used the following strategies:

3.9.1. TRIANGULATION

In this study, the researcher generated data from different sources namely, semi-structured interviews, observation schedules and existing data from learners' academic marks score sheets. The generation of data using multiple resources is called triangulation. According to Leedy and Armrod (2005, p.155), triangulation improves the credibility of the data if more than one data source converges onto consistent conclusions. In any material differences the participants and the research might have, triangulation gives the researcher a chance to resolve the differences.

3.9.2. THICK DESCRIPTIONS

For the readers to draw their own conclusions from the data presented in the study, the presentation of the data was adequately presented in 'rich and thick' details (Leedy & Ormrod, 2005, p. 100). McMillan and Schumacher (2006) refer to the idea of presenting data in a rich and thick manner as verbatim accounts. The interviews were presented word for word, transcripts and direct quotations from the documents recorded to demonstrate teacher participants' meaning (Dhlamini, 2008).

3.9.3. LOW INFERENCE DESCRIPTORS

Low inference descriptors entail videotaping, specifically a comprehensive descriptor of participants and set of circumstances. According to Dhlamini (2008), low inference descriptors assist the reader in making some well-informed judgements about the findings of the study in relation to their usefulness in comprehending other circumstances (Dhlamini, 2008).

3.10 ETHICAL ISSUES CONSIDERED IN THE STUDY

In any research, the researcher should take into consideration the ethical issues to enhance credibility. In this study, semi-structured interviews and lesson observation were used to gather qualitative data, and by doing so, the researcher invaded the participants' space. In support of these views, McMillan and Schumacher (2006, p. 333 in Ngozwana, 2018) assert that qualitative research is more likely to be personally intrusive than quantitative research. Therefore, to avoid this ethical issue from happening, the researcher obtained informed consent, assured confidentiality, and anonymity by using pseudonyms, and making sure that there was no form of deception administered to the participants.

3.10.1. INFORMED CONSENTS

The researcher fully disclosed the nature of the study to the participants who were given a chance to choose if they would like to participate or not to participate. To seek consent, a letter was addressed to the participants containing the information (included as annexure A, C, E, G) as follows:

- A short explanation of the study
- An explanation of what would be the participants' roles in the study.
- An assurance that the participants' involvement in the study is voluntary and may withdraw anytime they so wish.
- An assurance statement that the study would not interfere or disturb the smooth running of the school.
- An assurance that the names of the participants and their schools would be anonymous, only pseudonyms would be used instead.
- A statement that any findings would be kept confidential at all times.
- An assurance that on completion, the report would be made available, mostly to the Department of Basic Education.
- A space for participants to sign if they agree to take part in the study, the date of agreement also to be indicated.

3.10.2. DECEPTION OF PARTICIPANTS

For a researcher to hide information from participants as a way of influencing the participants to be involved in a study is unethical. Thus, to avoid deception to take place, a researcher must always check with the participants if they are still at ease with the research process (Leedy & Ormrod, 2005).

3.10.3. MECHANICALLY RECORDED DATA

In collecting qualitative data, the researcher utilized interviews and lesson observations. To capture every activity during the semi-structured interviews and lesson observation, the researcher used a video-recorder. For this activity to be ethical, the researcher sought permission to use the video-recorder during the in-depth semi-structured interviews and lesson observation. According to Bogdan and Biklen (2007, p.112), any recorder can be considered as a third party who cannot see.

3.11. SUMMARY TO CHAPTER THREE

The focus of this chapter was to explain the procedure that the researcher followed to answer the investigative question, and to have a better understanding of the topic. The following was discussed in details; the research approach, population and sampling of participants, data collection in which the data collection instruments used in collecting data such as interviews and lesson observations have been discussed, trustworthiness of the instrument, validity and reliability of the instruments in which, triangulation, thick description and low inferences were discussed, and ethical issues considered in the study in which, informed consents, deception of participants and mechanically recorded data were discussed. The following chapter is an analysis of the findings obtained during data generation.

CHAPTER FOUR: FINDINGS

4.1. INTRODUCTION TO CHAPTER 4

Chapter three considered the methods and the methodology followed for the study. In this chapter, the analysis and interpretation of findings is drawn from the generated data acquired through semi-structured interviews with two teachers from the different schools and lesson observations from the same two schools. This chapter is divided into three sections, namely: 1.) Section One: Data generated from semi-structured interviews. 2.) Section Two: Data generated from lesson observations. 3.) Section Three: Presentation of data from learners' academic scores. Data generation is framed on the concepts of Views About Scientific Inquiry (VASI) instrument as *informed*, *naïve,* or *mixed*.

Data generation for semi-structured interviews and lesson observations
was informed by the following questions:

- To what extent do the Physical Sciences teachers understand the meaning of scientific inquiry?
- How do teachers use scientific inquiry in their Physical Sciences lessons?
- When is the practical work that is based on inquiry implemented by the Physical Sciences teachers in their lessons?
- What hinders the Physical Sciences teachers from implementing the practical work that is based on inquiry?
- What effect does the understanding of inquiry in Physical Sciences have on learners' academic performance?
- To what extent do learners' academic performance on a test and inquiry-based practical work differ in Organic Chemistry?

4.2 SECTION ONE: DATA GENERATED FROM SEMI-STRUCTURED INTERVIEWS

The teacher participants were asked questions to share their insight on inquiry-based practical work in the teaching of Physical Sciences. To elicit information about the participant teachers' understanding of scientific inquiry, interview protocol was used.

The interviews followed the verbatim transcription of the discussion (see Appendix L); only the interpretation and the discussion of results are presented in this chapter, with only relevant parts of the interviews. Table 4.2 depicts the findings and discussion of the questions, analysis, and interpretation of the results and VASI.

Table 4.2: Analysis and interpretation of the findings

Questions	**Analysis and interpretation of findings**	**Views About Scientific Inquiry**
1. To what extent do the Physical Sciences teachers understand the meaning of scientific inquiry?	Learners build scientific knowledge from the world around them. They learn from applying all their five senses – hearing, seeing, tasting, smelling, and touching everything in their environment. This is specifically because learning scientific knowledge is not and should not be confined to the classroom or laboratory. Science knowledge is everywhere because science is a way of life.	Informed view
1.1 Please explain, what is the essence of scientific enquiry?	Learners build scientific knowledge from the world around them. They learn from applying all their senses – hearing, seeing, tasting, smelling, and touching in their environment.	Informed View
1.2 Do you think scientific inquiry is important in	Without creativity and imagination, scientific problems	Informed view

teaching Physical Sciences? Why is it so important?	that always evolve with time will not be solved. Solutions to new science challenges always come from Scientists' imagination and creativity.	
1.3 Which forms of scientific inquiry do you know?	Both teacher participants listed experiments, tutorials, practical investigation, and research projects.	Informed
1.4 From the types of inquiry you just mentioned, which one do you integrate in teaching Physical Sciences?	Scientists do not follow any prescribed way of doing any investigation. Each investigation is based on the research question that needs to be answered.	Naïve
1.5 Please elaborate on your choice of scientific inquiry in learning Physical Sciences.	Scientists always review what is already known in order to make an improvement and develop new knowledge through experimental evidence.	Informed view
1.6 Why is practical work as an inquiry integral in teaching Physical Sciences?	Scientists always have a question in mind that needs to be answered through discoveries. Scientists use their creativity and critical thinking to construct new scientific knowledge that will be embedded in	Informed view

	one's mind for a long duration.	
1.7 May you kindly comment on the rationale that practical work as an inquiry can be used to explain laws and theories of Physical Sciences?	Through creative thinking and innovation by scientists – both of which are key tenets of scientific inquiry –, laws and theories that explain phenomena are established. In a constructivist classroom, there is no knowledge or truth to be discovered. Rather, learning is through interaction with the environment and those around you.	Naïve view
1.8 May you kindly comment on the rationale that practical work that is based on inquiry can be used in process skills development	Scientists use different methods to solve different problems. There is no rigid and fixed way of solving problems. In a constructivist classroom, creativity and teamwork are at the centre of promoting learning by discovery. Hence, there are no specific procedures to develop new scientific knowledge that responds to ever mutating scientific challenges. Through robust engagement with each other or with the teacher, learners	Naïve view

	can develop new scientific knowledge.	
1.9 According to your understanding, is practical experiment the same as an inquiry? Please explain.	Whether scientists do an experiment in a dedicated space such as a laboratory, or conduct research outside of the classroom environment, new science knowledge is constructed. Whenever there is a problem to be solved, scientists will embark on an investigation without following any procedure. And through their creative thinking and interaction with the environment, their ultimate goal is to get a solution to the problem.	Naïve view
1.10 The esterification experiment you are about to do with your learners; is it an inquiry?	The investigative part is in line with the aspects of Views About Scientific Inquiry. However, the explanation about following the methodology contrasts sharply with the aspect of Views About Scientific Inquiry, which states that there is no single method to be followed in doing an inquiry.	Teacher responded O provided a Mixed view, while Teacher respondent D gave a Naïve view.

	Teacher participant D is excluding an experiment from inquiry when scientific fact shows that the experiment is within which the inquiry is embedded. What is needed though, are thought provoking questions that will excite learners' creative impulse. In constructivist views, knowledge construction can take place anywhere, provided the teacher creates an environment conducive for it to develop	
2. How do teachers implement scientific inquiry in their Physical Sciences lessons?	Enquiry does not have to be used in a practical or prescribed by authorities. Scientists always try to deal with a problem at hand and not wait for any prescription of how and when to resolve it.	Naïve view
2.1 Would you link the purpose of inquiry with the type of experiment in your lesson?	The purpose of any activity leads into a specific procedure to be followed, and the scientific methods to be used in performing an activity. In a constructivist classroom, a scientist does not follow any procedure or specific method, they just use their creativity and critical thinking to design an investigation to	Naïve view

	study some phenomena.	
2.2 How would you explain the objectives and purpose of the practical activity to your learners?	In both classes, learners were instructed to follow the procedures and methodology in order to obtain the desired results. In a constructivist classroom, there are specific procedures or methodology to be followed. Scientists use their creative thinking and imagination to get to a solution to scientific problem. The use of the enquiry-based practical work in the teacher participant's physical sciences lessons lacked the features of a classroom inquiry.	Naïve view
2.3 Do you mean that you guide them through?	The objectives, purpose and methodology are in total contrast with the Views About Scientific Inquiry. In investigating phenomena, scientists do not follow specific procedures or methodology. They use their critical thinking to come-up with innovative ways of solving the problem.	Naïve view

4.3 SUMMARY

The findings suggest that both teacher participants, when teaching Physical Sciences, are guided by the Naïve view. The results mean that the teacher participants' understanding of inquiry-based practical work and how it is used in teaching Physical Sciences for learners' benefit is uninformed. This might have influenced teacher participants' choice of teaching strategy while using inquiry-based practical work. The teacher participants' choice of teaching strategy might have deprived learners a chance to develop their scientific knowledge, resulting in them achieving poor results in their assessments. The teacher participants' poor understanding of inquiry and how it can be used for learners' benefit negatively affect learners' academic achievement.

4.4 SECTION TWO: DATA GENERATED FROM LESSON OBSERVATIONS

As part of explicit exploration of how the lesson was enacted, the lessons of the two teacher participants were observed. The aim was to observe the existence of inquiry aspects during classroom interaction. Hence, the focus was mainly on five features of classroom inquiry described by the National Research Council (NRC, 2000, p. 29):

- Learner engages in scientifically oriented questions
- Learner gives priority to evidence in responding to questions
- Learner formulates explanations to scientific knowledge
- Learners connect explanations to scientific knowledge
- Learner communicates and justifies explanations

Looking for these classroom inquiry features in the teacher participants' lessons, the researcher focused on three phases of the lesson namely, introduction of a lesson, learners performing the experiment and teachers and learners' interaction.

Place: Diepkloof and Orlando

Date: 01/02/2019

Time: 12:00-15:00

Setting: Classrooms

Role of an observer: Non-participant observer

Table 4.4: Observation schedule

Category	School O	School D
Number of learners		
Are learners working as a group?	Yes	Yes
Size of the group.	22	35
Prior to the activity, the teacher clarifies the purpose and the purpose and the objectives of practical work to the learners.	No	No
Before the commencement of the activity, the teacher asks a question.	Yes, but before learners answer the question, he provided the definition of esterification.	No
The class discussion is facilitated by the teacher prior to the practical activity (pre-practical discussion evident).	No pre-practical discussion.	No pre-practical discussion.
During the discussion, learners ask questions both to the teacher and among themselves.	One learner asked about the smell of Sulphuric acid, but the teacher ignored the question.	No questions asked, the focus was on performing the experiment do a write-up.
Learners are doing practical work and the teacher moves among the groups to provide guidance to the learners but allow them to develop their own knowledge.	Only moved around to two groups who called for assistance. Never bothered to engage learners in a	He left learners on their own and came to check if they were done with the experiment.

	learning process.	
Learners observe a demonstration done by the teacher.	Done a demonstration.	Never carried out any demonstration.
Learners discuss in groups during practical work for collaborative learning.	There was no concentration, they were discussing general staff, and some even continue taking pictures.	There was no teacher to facilitator any discussion because he was in and out of the laboratory. He had no interest whatsoever.
The teacher facilitates class discussion after practical work through questioning.	Did not facilitate any learning. The only thing he did was quickly draw a table they should use to tabulate the results. And emphasised that the submission should be on Monday morning.	He only told them that the write-up must be submitted after two days, because marks will be required for term one SBA.
Discussions between the learners take place regarding the activity (This is relevant for effective teaching and learning that encourages knowledge development thus improving conceptual development and academic achievement).	There was no meaningful learning that promotes knowledge development.	No learning took place because the teacher was not part of learning and teaching. He wanted only the results and the write- up.

Learners engage in scientifically oriented questions.	No scientific questions were asked to provoke critical thinking or for knowledge development.	Learners were left alone for the duration of two hours.
The teacher answers learners' questions.	Ignored questions from the learners.	Learners had no chance to ask or answer questions.
Learners connect explanations to scientific knowledge.	There was no discussion to build scientific knowledge.	There was no discussion that could lead to learning.

Introduction of a lesson: Teacher participant O reminded the learners that they would be performing the experiment in esterification. He asked learners if they still remembered what an esterification is, but before any learner could answer the question, he defined esterification himself facing away from the learners. He told learners to be in groups. Learners grouped themselves, and in the process, they were taking selfies, disregarding what the teacher was saying. The teacher explained how they would perform an experiment while moving around the groups distributing apparatus instead of letting the learners collect them. Experiment instruction sheets were distributed by the teacher. One learner was asked to read the methodology and safety precautions. But because many of them were making noise, moving about in the laboratory taking pictures during the experiment, they were in complete disregard of safety measures in the laboratory.

As far as the methodology was concerned, the teacher participants emphasized that learners must follow instructions step-by-step in order to get the correct results. The participant teacher demonstrated the experiment by making one of the esters. But when he was about to open one of the bottles containing methanol, the bottle could not open. It was observed that it had not been used for a long time. Hence, the teacher had to force-open another one. When putting specific drops of carboxylic acid, alcohol, and sulphuric acid in the test tube, it was observed that one medicinal drop was used, which was contaminating other chemicals in the process. Notably, this was one of the precautions read aloud by a learner at the teachers' request. When preparing a water bath for the experiment, an electric kettle was used to boil the water. The collection of water from the kettle posed some safety risk because it was spilling on the floor and the glass beakers became hot. The teacher instructed learners not to move the kettle, but to collect from it. This was also affecting the temperature at which the reaction could take place. Through the video recording, the researcher could observe that the teacher participant never demonstrated how the formation of ester could be detected. He never moved around the groups for them to detect a smell, by wafting. From his demonstration, he did not explain the effects of sulphuric acid and heat on esterification and relating this to the rate and extent of chemical reaction or the kinetic molecular theory of matter.

Learners performing the experiment: After the teacher participant's demonstration, learners were instructed to have group representatives to collect the chemicals from the main desk using a single medicinal drop for all chemicals. As an observer, the researcher could not understand why only one medicinal drop was used when there were five of them on the table. The teacher was not controlling the amount of chemicals learners were collecting; this is something that could affect the school in the long run. Additionally, Sulphuric acid is a strong acid with some corrosive characteristics and should be handled with care. Nevertheless, learners were allowed to collect it on their own, which was putting everyone's safety at risk. It was observed that some learners had to be reminded by their teacher to change their water bath during the experiment because they were not paying attention.

Teacher and learners' interaction: One learner asked the participant teacher if sulphuric has a smell; instead of taking advantage of the question to explain the corrosive nature of sulphuric acid and why it is used as a catalyst or dehydrating agent, the teacher reprimanded the learner not to ask funny questions. Another learner also asked if it is possible to react to the specimen under investigation and get a different result from the one expected, like a different smell. This was also another opportunity for the teacher to start a discussion with the whole group; but the teacher participant said, it is not possible not to get exactly what they said you will get, thereby shutting down the discussion. The Teacher participant was observed in the video recording spending most of his time on one group, ignoring the other four groups. It was also observed that the teacher participant was pushing learners to get the results for a scientific report. He jumped forward and stopped everyone in order to stress the point that after the experiment, the most important thing is the scientific report. Learners were asked if they still remembered how to write a scientific report, and they responded affirmatively. The participant teacher was observed drawing learners' attention to the white board, where he drew an expected table of results. He insisted that learners must submit the report the following day for SBA, which meant that reporting was not supposed to be done immediately after the experiment.

Table 4.4.1: Post observation interviews

Questions	**Analysis and interpretation of findings**	**Views About Scientific Inquiry**
3. When is the practical work that is based on inquiry implemented by the Physical Sciences teachers in their lessons?	Their responses always associate inquiry with experiment, which, according to them, needs time and equipment to implement. In a constructivist classroom, science knowledge develops in any environment where learners live. Inquiry can be done within a classroom or outside, as long as the teacher creates an environment in which knowledge can be developed. Within the lesson, the teacher and learners can engage through questioning to find the solution to the problem. Thinking that an inquiry learning and teaching needs equipment or time, is contrary to	Naïve view

	the understanding of the Views About Scientific Inquiry. Inquiry teaching and learning can be implemented in any lesson, provided, the teacher is knowledgeable on how to implement it. Resources cannot impede the teacher from being creative and innovative to improvise in situations where there are no resources.	
3.1 What hinders the Physical Sciences teachers from implementing the practical work that is based on inquiry?	Originating out of the teacher participants answers, the study has discovered that the teaching of Physical Sciences through practical work, that is based on inquiry on their everyday lessons is hindered by factors such as curriculum overload, insufficient time allocated for Physical Sciences, lack of inquiry-oriented teacher development programmes, content focus curriculum, exam focused authorities and lack of sufficient laboratory resources. The construction of new scientific knowledge in a classroom can be made possible by the teacher. In a constructivist classroom, a teacher promotes critical thinking through posing questions to students and involving learners in their	Naïve view

	own learning. Inquiry based technique would ne enactment in environment if the teacher has knowledge of inquiry base approach. Except for the lack of enquiry-oriented teacher programme, the factors are identified by the respondents as hindering the execution of practical work that is based on enquiry are considered naïve	
3.2 What was the training all about?	In a constructivist classroom, a teacher should know that knowledge development does not depend on a method followed. The environment let learners build their own method and knowledge.	Naïve view
3.3 If you could be asked by the Department of Basic Education to suggest ways in which practical work that is based on inquiry could be done effectively, what would be your suggestions?	Inquiry does not need equipment or laboratory to be used in teaching Physical Sciences. Scientists always depend on their critical thinking and imagination to solve daily challenges.	Mixed view
4. What effects does the understanding of inquiry by Physical Sciences teachers have on learners' academic performance?	In a constructivist classroom, a teacher should know that knowledge development does not depend on the method followed. The environment allows learners to	Naïve view

	construct their new scientific knowledge through their interaction with it.	
4.1 But asking learners some questions provoke their thinking and they become creative; did you not think that not asking questions deprived your learners a chance to explore a lot of scientific knowledge?	In a constructivist classroom, where knowledge needs to be constructed by learners through their teacher's guidance, a thought-provoking question must be asked. Asking questions provokes thinking and creativity. During the implementation of the inquiry based practical work in this study, asking questions could have challenged their thinking, and assisted learners to develop new knowledge and understanding organic chemistry with much ease. Also, the respondents should have known that knowledge construction does not need any methodology.	Naïve view
4.2 Why were you only focusing on the completion of the experiment and not using the experiment as a tool to make	Learning and teaching in constructivist classroom should be done for knowledge development and not, for assessment. In a constructivist	Naïve view

learners develop more knowledge?	perspective, reality is subjective, and its construction could be through interaction with other people. A teacher participant unclear understating of enquiry could have influenced their teaching approach. Similarly, the choice of teaching approach enacted could have influenced learners' conceptual development, which could be evident in their academic achievement	
4.3 But what about an effective learning and teaching of Physical Sciences through inquiry based practical work, which ensures that, what is learnt is retained for a long time. And if retained for a long time, learners can pass the exam with ease?	The responses to the question run contrary to the Views About Scientific Inquiry. Learning and teaching in a constructivist classroom should be done for knowledge development, and not for assessment. In a constructivist perspective, reality is subjective, and its construction could be through interaction with other people. The teacher participants' unclear understanding of inquiry could have influenced their teaching approach. Similarly, the choice of teaching approach	Naïve view

	enacted could have influenced learners' conceptual development, which could be evident in their academic performance.	
5. What effects does the understanding of inquiry by physical sciences teachers have on learners' academic performance?	In a constructivist classroom, a teacher should know that knowledge development does not depend on the method followed. The environment allows learners to construct their new scientific knowledge through their interaction with it	Naïve view
5.1 But asking learners some questions provoke their thinking and they become creative; did you not think that not asking questions deprived your learners a chance to explore a lot of scientific knowledge?	In a constructivist classroom, where knowledge needs to be constructed by learners through their teacher's guidance, a thought-provoking question must be asked. Asking questions provokes thinking and creativity. During the implementation of the inquiry based practical work in this study, asking questions could have challenged their thinking, and assisted learners to develop new knowledge and understanding organic chemistry with much ease. Also, the respondents should have known that knowledge construction does	Naïve view

	not need any methodology.	
5.2 But what about an effective learning and teaching of Physical Sciences through inquiry based practical work, which ensures that, what is learnt is retained for a long time. And if retained for a long time, learners can pass the exam with ease?	The responses to the question run contrary to the Views About Scientific Inquiry. Learning and teaching in a constructivist classroom should be done for knowledge development, and not for assessment. In a constructivist perspective, reality is subjective, and its construction could be through interaction with other people. The teacher participants' unclear understanding of inquiry could have influenced their teaching approach. Similarly, the choice of teaching approach enacted could have influenced learners' conceptual development, which could be evident in their academic performance.	Naïve view
6. To what extent do learners' academic achievement on a theoretical test and inquiry-based practical work	They do appreciate that inquiry-based practical work could improve knowledge development, but they do not expect the academic performance of the	Mixed view

differ in Organic Chemistry?	learners to improve that much. If the construction of scientific knowledge improves, conceptual development also increases, leading to improved learners' academic performance.	
6.2 Why do you think that there will be slight difference? Does it not make sense to you that an inquiry-based practical work can improve the way learners learn, and improve their academic performance?	The teacher participants were of the views that inquiry teaching is only possible if there are resources to perform the experiments. Knowledge construction can take place in any environment, as long as the teacher has an informed understanding of inquiry.	Naïve view

4.5 SUMMARY

The findings provided through post observations questions indicate that the two teacher participants' have a naïve views about inquiry-based practical work. This implies that they can use ineffective teaching strategies that do not benefit learners. As a results, learners' conceptual development cannot be enhanced, consequently affecting their academic achievement in Physical Sciences.

4.6 SECTION THREE: PRESENTATION OF DATA FROM LEARNERS' ACADEMIC SCORES

In order to explore how teachers' understanding of inquiry impacted learners' academic performance, the test results for both schools are presented on the table below:

Table 4.6: Means and standard deviations in achievement of the participant schools

Treatment Groups	Numbers	Mean	Standard Variation
School O	22	26.32	18.68
School D	35	34.19	17.22

The results on the table reveal that the mean score of school O is 26.32 and that of school D is 34.19. Even though the mean score of school D is higher than that of school O, learners on both schools have performed poorly in their Physical Sciences. Teachers' lack of informed understanding of inquiry had a negative effect on learners' academic performance.

Table: 4.6.1. Analysis of the test scores and experiment mark scores of school O**.**

Treatment group	Activities	Number	Mean	Standard deviation	Mean Difference
School O	**Formal Test**	22	26.32	18.68	9.08

	Formal experiment	22	35.4	26.89	

Table 2 analysis reveals that there is a mean difference of 9.08 between the test and the formal experiment in school O, which is significant. The results indicate that learners performed much better in the experiment than the test. During lesson observation, it was observed that learners were allowed to go and do their write up at home, giving them ample time to refer to other sources for answers, but they still underperformed. The teachers' lack of informed understanding of inquiry, which enhances learners' scientific knowledge, might have had a negative effect on learners' academic performance. If learners understood what they were doing and why they were doing it, they could have done much better in both their test and the experiment. Teachers' naïve understanding of inquiry has a negative impact on the enactment of inquiry teaching, which in turn has a negative impact on learners' academic performance.

Table: 4.6.2. Analysis of the test scores and experiment mark scores of school D.

Treatment group	Activities	Number	Mean	Standard deviation	Mean Difference
School D	**Formal Test**	35	34.19	17.22	21.45
	Formal experiment	35	55.64	22.07	

Table 3 analysis reveals that there is a mean difference of 21.45 between the test and the formal experiment, which is too significant. The results on the table indicate that learners in School D, performed 21.45 better in an experiment than in a test. It was observed that, learners had to write the experimental report at home, just like in school O. The mean score of 55.64 is considered low achievement, more so based on the context of the write up, learners were expected to perform much better. Teacher's understanding of inquiry influences teaching practice, and that influences learners' academic performance. In this study, teachers' lack of informed understanding of inquiry might have influenced their choice of teaching approach. Consequently, they chose a traditional way of teaching, which might have negatively affected learners' academic performance. Teacher D did not guide the learners in conducting the experiment. From a constructivist perspective, for teachers not to guide learners during the experiment frustrates learners. It can also contribute to poor understanding of concepts. On the other hand, teacher O posed a question on esterification, but did not create a platform in which they could engage one another as a group. He quickly answered the question instead. In a constructivist classroom, engagement enhances scientific knowledge development because learners learn from each other's reasoning.

4.2. SUMMARY TO CHAPTER FOUR

This chapter presented the results and analysis of both qualitative and quantitative data. The quantitative data was obtained from the existing learners' academic mark score sheets. The quantitative data were presented on the tables. Qualitative data were presented under the category in which they belong using the Views About Scientific Inquiry instrument. The findings from the semi-structured interviews and observations, were categorized in line with the research questions and the research objectives. The quantitative data was analysed by calculating the mean and standard deviation. The summary of the findings are as follows:

- Teacher participants always associate an inquiry with an experiment.
- Teacher participants think that an inquiry cannot be done without following specific methodology.
- Practical work implemented by teacher participants lacked most inquiry aspects.
- Learners' academic performance in both a test and practical work was significantly poor in both schools

- There is a significant difference between learners' academic performance in a test and practical work in organic chemistry.

The following chapter discusses in detail the findings obtained during data generation.

CHAPTER FIVE: DISCUSSIONS

5.1. INTRODUCTION

The findings of the study based on the six research questions that guided the study are discussed in this chapter.

5.2. DISCUSSION OF THE FINDINGS

Drawing on the constructivist theory, this research has investigated the construction of new knowledge in Grade 12 Physical Sciences by means of a practical experiment activity that is centred on the learners. The learners had the opportunity of constructing knowledge by themselves on the knowledge of Organic Chemistry from their daily experiences. In the process of learning, teachers assist learners to learn better, enhance their critical thinking skills, develop excellent comprehension of science, and perform better in their academic work.

The study revealed the teacher participants' understanding that an inquiry only exists if there is an experiment to be performed. According to their understanding, an inquiry requires equipment that can be manipulated. These findings are consistent with the results from the study conducted on South African Physical Sciences teachers, in Limpopo Province by Mokiwa and Nkopodi (2014). This researcher found that the teacher participants held beliefs about inquiry as a kind of pedagogy that focuses on activities involving practical work, experiments, problem solving and hands-on activities. The teacher participants' naïve views of inquiry might be due to teacher participants' lack of exposure to informed views about science inquiry. Informed views, for example, include statements like 'scientifically oriented questions that will engage learners.' Looking deeply into the teacher participants' responses, the researcher found out that teacher participants have never been offered training on how to teach Physical Sciences through inquiry-based practical work. The only training, they received from the Department of Basic Education was on how to perform the experiment, and not how to teach Physical Sciences through it. Yet, the curriculum expects them to teach Physical Sciences through inquiry-based practical work.

The study also revealed that the teacher participants harboured the naïve view that an inquiry can only be done by following specific methodology. The findings of the study are consistent with the results from the study conducted on South African grade 11 Physical Sciences teachers, from five metropolitan high schools in Johannesburg, in Gauteng Province by Dudu (2014). This researcher found that the teacher participants held one of the widely naïve ideas about science, "Scientific Method" (McComas et al., 1998, p. 513 in Dudu, 2014, p. 13). The teacher participants' naïve ideas about following a specific methodology might be emanating from the way school practical experiments are designed. The school's experiments designs, in which the methodology exists, might have been influenced by the format in which scientific reports and journals are presented (Dudu, 2014). The other cause of their naïve ideas might be lack of inquiry knowledge due to lack of inquiry immersed teacher training. They might not have been exposed to any informed views about scientific inquiry such as the fact that scientists do not depend on specific methodology to develop new science knowledge, but they depend on their imagination and creative thinking.

This study discovered that the practical work implemented by teacher participants generally did not have essential features of inquiry. This discovery is consistent with the studies conducted on South African teachers in Limpopo Province by Mokiwa & Nkopodi (2014). In their studies, they found that teachers did not create an environment for learners to develop scientific knowledge. In both studies, it was discovered that the teacher participants' lessons were mostly teacher centred. The teacher participants' failure to implement the inquiry-based practical work might be due to their lack of informed views about inquiry. Teacher participants' lack of clear understanding of inquiry, might have had a negative influence on the choice of teaching approach. The other factor that might have contributed to the teacher participants' failure to implement the inquiry-based practical work, could be, the lack of effective inquiry teacher development programmes. However, this study is also inconsistent with the study conducted on the South African teachers in KwaZulu Natal Province by Ramnarain (2011). In the study, it was discovered that, during a scientific investigation, learners were in total control of their scientific knowledge construction. In the process, teachers only posed thought provoking questions in order to support learners, and only intervened when it was necessary for them to do so. These are the expectations of a constructivist classroom.

This study revealed that the teacher participants' lack of informed understanding of inquiry-based practical work had a negative effect on learners' academic performance. These findings are consistent with the study by Borman, Gamoran and Bowdon (2008). In their study, they found that science achievement on learners exposed to inquiry teaching was reduced. These results, however, are inconsistent with findings of a considerable number of studies conducted by Furtak et al., (2012); Meyer (2004); Minner, Levvy and Century (2010 in Baker-Lawrence, 2013). In their studies, they found that inquiry-based teaching has a positive effect on learners' academic achievement. The outcome of this current study was expected, due to the teacher participants' naïve views about scientific inquiry. The teacher participants' uninformed views about scientific inquiry might have significantly affected their teaching approach (Lederman & Gess-Newsome, 1999) which, in turn, affected learners' conceptual development, resulting in learners' poor academic performance.

In analysing learners' academic performance scores in Tables 2 and 3, the study found that, in both schools, there is a mean difference of 9.08 and 21.45 between learners' academic performance on a test and inquiry-based practical work respectively, which is significant. The study revealed that learners scored higher marks in an inquiry-based practical work than in a test of the same subject matter. These findings are inconsistent with the study conducted by Ajayi and Omole (1999 in Galadanci & Mukhtar, 2017); Uwaifo (2012). In their studies, they found that there is a strong correlation between the practical examination and the theoretical examination of the same subject matter, which means that the learners' scores in a practical examination can be used to predict their scores in the theoretical examination. Learners in this study might have performed much better in the inquiry-based practical work because they did not perform their inquiry-based practical work in an examination setting. They were allowed to do the write-up at home, which might have given them a chance to copy from different sources, taking away their creative thinking, which could have assisted in permanent knowledge retention of the same concepts in the examination. Maybe, if learners were to do the write-up in a more controlled setting, like in an examination or a test, the results could have been different.

5.3 SUMMARY

This chapter focused on discussion of the research study findings obtained from different datasets. The following chapter outlines the conclusion of the study, educational implications of the findings, recommendations, limitations, and suggestions for further research

CHAPTER SIX: SUMMARY, CONCLUSION, EDUCATIONAL IMPLICATIONS OF THE FINDINGS, RECOMMENDATIONS, LIMITATIONS, SUGGESTIONS FOR FURTHER RESEARCH

6.1. INTRODUCTION

This chapter presents the summary of the study. The conclusion, educational implications of the findings to the education system, recommendations, the limitations of the study and suggestions for further research are also presented.

6.2. SUMMARY TO THE STUDY

This study explored the teaching of grade 12 Physical Sciences through inquiry-based approach. The inquiry-based approach is considered a teaching approach that can enhance learning in Physical Sciences worldwide. An effective teaching approach is required to reduce poor performance in Physical Sciences as a fundamental knowledge discipline. Within the broader South African context, meaningful improvement of science education quality depends on the Physical Sciences teachers' professional capability to accept a new teaching approach as an important stimulant to effective teaching and learning. Holistic and effective implementation of inquiry-based learning can be rendered useful to clarify the nature of practical work as a critical component of Physical Sciences as fundamental knowledge discipline. Responding to this critical imperative, this study provided exploratory insights into the implementation of inquiry-based approach as a tool to facilitate the performance of scientific investigations in grade 12 Physical Sciences teaching. These exploratory insights were anchored on six key research questions that guided the investigation. The research was based on constructivist theory. The literature review reflected variables in the diverse but interrelated study topics such as the concept of scientific inquiry, the types and forms of scientific inquiry, the implementation of scientific inquiry in teaching science, the importance of scientific inquiry in science, challenges associated with using the scientific inquiry in teaching science, ineffective teaching approaches, lack of teachers' adequate pedagogical content knowledge, lack of adequate laboratory equipment and ineffective teacher development programmes. The research applied a mixed method approach involving semi-structured interviews, lesson observations and the existing data from learners' academic performance mark scores. There were two systematically randomly selected sampled teacher participants in the study. The research instruments of the study were interview protocol and observation schedule. The qualitative data was analysed through interpretational analysis, while the quantitative data was analysed through descriptive statistics, and inferential statistics. Major findings of the study revealed that teacher participants have uninformed views about scientific inquiry, which in turn, might have influenced their choice of teaching approach. Their ineffective teaching approach might have negatively affected learners' conceptual development, and by extension, negatively affected learners' academic performance. It can, therefore, be deduced that if Physical Sciences teachers have a clear understanding of inquiry, they can effectively teach Physical Sciences lessons through inquiry for the benefit of learners. It is, thus, very important for Physical Sciences teachers to have an informed understanding of an inquiry-based teaching and learning approach.

6.3. CONCLUSION

In this study, it was discovered that the teacher participants do not have a clear comprehension of what teaching through inquiry-based practical work entails. Their uninformed views about scientific inquiry might have influenced their teaching approach, which in turn, might have had a negative effect on learners' conceptual development, resulting in poor academic performance by learners.

6.4. EDUCATIONAL IMPLICATIONS OF THE FINDINGS

The findings of the study have some educational implications for the Department of Basic Education, curriculum developers, educational policy makers, Physical Sciences teachers, and the learners. The inquiry-based teaching approach has generally proven to be an effective teaching approach, which can improve learners' conceptual knowledge and academic performance. Physical Sciences teachers should be encouraged to teach content through inquiry-based approaches.

Since it has been established in this study that, Physical Sciences teacher participants have uninformed views about scientific inquiry, which might have negatively influenced their implementation of inquiry-based practical work, the Department of Basic Education, curriculum developers and policy makers should make available for Physical Sciences teachers, adequate and effective teacher training programmes on how to teach Physical Sciences through inquiry-based methods for the learners' benefit. These programmes should form part of the mandatory continuous training of Physical Sciences teachers for purposes of continuous improvement and knowledge development.

6.5. RECOMMENDATIONS

The following recommendations were made based on the findings of this study:

- The Department of Basic Education to make a collaborative effort to help Physical Sciences teachers develop a clear understanding of inquiry, which is in line with the constructivist views.
- The in-service teacher training by the Department of Basic Education must focus on how to teach Physical Sciences though inquiry-based practical work.
- The current workshops as a strategy to develop Physical Sciences teachers, must be replaced by an inquiry-independent teacher development programme, which will improve Physical Sciences teachers' knowledge of inquiry-based approach.
- Physical Sciences teachers need to be encouraged to improve their understanding of new effective teaching approaches through literature reading that is consistent with the constructivist views of scientific inquiry.
- Teacher training Universities to assist the Department of Basic Education in introducing teacher development programmes that focus on teachers' understanding of inquiry, so that Physical Sciences teachers shift from the traditional teaching approach to an inquiry teaching approach that supports effective learning.

6.6. LIMITATIONS TO THE STUDY

The limitations of the study include:

- To collect more conclusive data, the researcher should have included the questionnaire as a research instrument to elicit more data on teacher participants' understanding of scientific inquiry.
- To reach relatively more conclusive results, the researcher should have considered collecting data from more than one experiment in Physical Sciences.

6.7. SUGGESTIONS FOR FURTHER RESEARCH.

Drawing on the result of the findings and the limitations of this study, the following suggestions for further research are proposed:

- More studies to be conducted using the questionnaire, interview protocol and lesson observation to conclusively find out the extent to which Physical Sciences teachers understand scientific inquiry.
- Further research needs to be conducted in which data will be generated from more than one experiment in order to reach a relatively more conclusive result.

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APPENDICES

APPENDIX A: LETTER OF PERMISSION TO CONDUCT A STUDY IN YOUR SCHOOLS

Institute of Science and Technology Education
University of South Africa
P.O. Box 392
UNISA
0003

Dear Sir/ Madam

A LETTER OF PERMISSION TO CONDUCT A STUDY IN YOUR SCHOOLS

The researcher is a postgraduate student at the University of South Africa, and the study intended to **explore the teaching of Grade 12 Physical Sciences through inquiry-based practical work in District 10, Johannesburg, Gauteng Province, South Africa.**

Please, kindly give the researcher permission to interview the grade 12 Physical Sciences teachers, observe their Physical Sciences' lessons and video record both the interviews and lesson observations. The data generated will be treated with utmost confidentiality and will only be for the research purposes. On the report, only pseudonyms will be used.

Thanks for your anticipated cooperation.

Yours truly

S.R. RIVELE (The researcher)

Professor HI ATAGANA (Supervisor)

APPENDIX B: PRINCIPAL AND THE SCHOOL GOVERNING BODY CONSENT FORM

The following ethical considerations are outlined to inform your consent thereof:

Your participation is voluntary.

Pseudonyms will be used to keep data obtained confidential.

The data obtained is for the study purposes and will not be shared with a third party.

Your rights to asking questions concerning the study are protected, and the researcher can be contacted on the numbers below:

0725218628.

In participating in this study, you agree that:

I do comprehend what the study entails.

I do know that my participation is voluntary.

I was afforded enough time to consider my school's participation to the study.

No authority has forced my school's participation to the study.

I clearly understand that my school' participation in the study is voluntary.

I fully understand that relevant committees at UNISA and the Gauteng Department of Education relevant committees made approval of this study.

I ____ the Principal and I____ the School Governing Body chairperson of ____ school hereby give / do not give consent to Solie Richard Rivele to work with the Grade 12 Physical Sciences teacher and learners in his research study.

____

____

Signature of the Principal: Date

Signature of School Governing Body Chairperson Date

APPENDIX C: TEACHER CONSENT FORM

The following ethical considerations are outlined to inform your consent thereof:

- You are by no means forced to take part in this study. Should you be no longer interested in taking part, you are not obliged to continue.
- The data obtained will be treated with strict confidentiality.
- Assumed names will only be used to keep the participants anonymity.
- For any further inquiries regarding the study, you may directly contact the researcher at 0725218628.

In choosing to participate in this study, you consent that:

- You fully understand what the study requires.
- You understand that you can withdraw from taking part in the study at any time.
- You were given time to consider your involvement in the study.
- You are participating at your own free will; and you were not coerced to participate in the study.
- You fully comprehend that taking part in this study is completely voluntary.
- You fully understand that this research study has been approved by the relevant committees at the University of South Africa and the Gauteng Department of Education.

I_____________________________________ the teacher at________________________________ School hereby give/ do not give consent to Solie Richard Rivele to be part of his research project.

Signature Date…………………….

APPENDIX D: A LETTER TO THE PARENT

Institute of Science and Technology Education
University of South Africa
P.O. Box 392
UNISA
0003

Eka Vatswari va vana ya ntangha ya khume mbirhi.

PAPILA RO KOMBELA MPFUMELELO WO ENDLA VULAVISISI EKA MADYONDZISIWELO YA VANA VA N'WINA EKA DYONDZO YA PHYSICAL SCIENCES.

Mulavisisi I xitshudeni xa tidyondzo tale henhla eUnivesiti ya Africa Dzonga. Xikongomelo xa vulavisisi iku xopaxopa madyondziselo ya dyondzo ya Physical Sciences exikolweni hi vadyondzisi va vana va nwina.

Hikutitsongahata loku kulu, mulavisisi u kombela mpfumelelo wo endla vulavisisi laha vana va nwina va dyondzaka kona. Leswi swi nga vhumbhunuriwa hi vulavisisi swita tirhisiwa hi ndlela yo xiximeka swinene, naswona, mavito ya xikolo kumbe vana, aya nga paluxiwi.

Ndzi ta khensa ntirhisano wa nwina.

Wa nwina hi kutitsongohata

S.R. RIVELE Professor HI Atagana

(Muchudeni) (Mudyondzis)

APPENDIX E: A LETTER TO THE PARENT

Institute of Science and Technology Education
University of South Africa
P.O. Box 392
UNISA
0003

Dear Grade 12 Physical Sciences' Parent

RE: LETTER TO REQUEST A PERMISSION TO DO A RESEARCH ON HOW YOUR CHILDREN ARE TAUGHT PHYSICAL SCIENCES

The researcher is a student at the University of South Africa. The purpose of the study is to explore Physical Sciences Teachers' understanding of the use of inquiry-based practical work in teaching Physical Sciences.

The researcher humbly requests your permission to involve your learners in this study. The findings will be handles in a respective manner, and the names of the learners of the school will not be published, only pseudonyms will be used.

I will appreciate your cooperation.

Kinds regards,
Mr S.R. Rivele (Student)

Professor HI Atagana (Supervisor)

APPENDIX F: PARENT CONSENT FORM

Leswi landzelaka itifanelo leti muchudeni a faneleke ku tilandzela, ku kuma mpfumelelo wa n'wina:

Ami sindisiwanga ku va mi nika mpfumelelo wa leswaku vana va nwina vava xiave xa vulavisisi lebyi. Minga herisa mpfumelelo wa nwina nkarhi unwana na wunwana.

Vumbhoni bya vulavisisi byi ta tirhisiwa hi vutihlamuleri bya xiyimo xa le henhla.

Mavito ya vana kumbe ya swikolo awanga palushiwi, ktava xihundla. Filimi leyinga tava yi tekiwile yita sirhelela ku paluxiwa ka van ava nwina eka xichava.

Loko mirin a swivilelo kumbe swivutiso kuya hi vulavisisi, twanana mitshuxekile ku ba riqhingu eka nomboro leyi nga laha hansi.

0725218628

Loko ndzi nyika mpfumelelo, ni pfumela eka leswi landzelaka:

Ndzi twisisa vuxokoxo bya vulavisisi/dyondzo.

Ni nga hlawula ku tshika ndzi nga chavi nchumu.

Ndzi nyikiwe nkarhi wo enela kuti anakanya ninga se nyika mpfumelelo leswaku nwana ava xiave xa dyondzo leyi.

Ani sindisiwanga kuri ni nyika nwananga mpfumelelo wa ku va xiave xa dyondzo.

Ndza switwisisa kuri kuva xiave ahi xiboho.

Ndza switwisisa kuri dyondzo leyi yi kumile mpfumelelo eka tikomiti tate henhla ta Univesiti ya Afrika Dyonga.

Mina ____________________________________ mutswari wa ___________________

Eka ntangha 12 e_____________________________ xikolo xale henhla, ndzi nyika mpfumelelo leswaku/ andzi nyiki mpfumelelo leswaku ava xiave xa dyondzo leyi.

____

____

Nsayino Siku

APPENDIX G: LETTER TO THE LEARNER

Institute of Science and Technology Education

University of South Africa

P.O. Box 392

UNISA

0003

Dear Learners

A LETTER OF PERMISSION TO OBSERVE YOUR PHYSICAL SCIENCES LESSONS IN YOUR SCHOOLS.

The researcher is a postgraduate student at the University of South Africa, and the study is intended to **explore the teaching of Grade 12 Physical sciences through inquiry-based practical work in District 10, Johannesburg, Gauteng Province, South Africa**.

May you kindly give the researcher permission to observe, and video record your Physical Sciences lessons. The data generated will be treated with utmost confidentiality and will be used for the study purposes only.

Thanks for anticipated cooperation.

Yours truly

S.R. RIVELE (Researcher)

Professor HI Atagana (Project Supervisor)

APPENDIX H: LEARNER CONSENT FORM

The following ethical considerations are outlined to inform your consent thereof:

- You are not obliged to be part of the study, feel free to withdraw from the study, no penalties will be incurred.
- The data obtained will be kept confidential at all times.
- The participants will remain anonymous; pseudonyms will be used.
- You have the right to ask questions about this study. The researcher can be contacted on 0725218628.

In choosing to be part of this study, you consent that:

- You fully understand what the study requires.
- You understand that you can withdraw from taking part in the study at any time.
- You were given time to consider your involvement in the study.
- You are participating at your own free will; and you were not coerced to participate in the study.
- You fully comprehend that taking part in this study is voluntary.
- You fully understand that this research study has been approved by the relevant committees at the University of South Africa and the Gauteng Department of Education.

I ______________________________ a learner in grade 12 at ____________________________ school hereby give consent/ do not give consent to Solie Richard Rivele to be part of his research study.

____

____

Signature Date

APPENDIX I: (TEACHERS' INTERVIEW PROTOCOL)

Research Questions	**Interview questions**
1. To what extent do Physical Sciences teachers comprehend the meaning of scientific inquiry?	Please explain; what is the essence of scientific inquiry? Why is it so important? Which forms of scientific inquiry do you know? From the types of scientific inquiry, you have mentioned, which ones do you integrate into teaching Physical Sciences? Please substantiate on your scientific inquiry. Do you think scientific inquiry plays an important role in the teaching and learning of physical sciences? Why is practical work as an inquiry integral in teaching Physical Sciences? Comment on the rationale that practical work can be used to explain laws and theories of Physical Sciences. Comment on the rationale that inquiry can be used to develop process skills. According to your understanding, is practical experiment the same as inquiry? Please explain.

2. How is scientific inquiry implemented by teachers when teaching Physical Sciences?	Do you integrate inquiry based practical work into your PHYSICAL SCIENCES lessons? How do you do that? Please explain. Why do you implement inquiry the way you said you do? What rationale is postulated by assessment guidelines about the purpose of inquiry? Would you link the purpose of inquiry with the type of experiment in your lesson? Do you think it is necessary for the learners to know the purpose and objectives of the practical activity that is being conducted? Please elaborate. How would you explain the objectives and purpose of the practical activity to your learners?

POST- OBSERVATION INTERVIEW

Research Questions	Interview Questions
3. When is the practical work that is based on inquiry implemented by Physical Sciences teachers in their lessons?	When do you implement scientific inquiry into your lessons? How often do you implement practical work as an inquiry into your lessons? Do you find it easy to do practical work in most of your lessons? Please explain. Do your learners ask you to do practical work with them? Explain. According to CAPS, there are prescribed and recommended practical activities and esterification as one the prescribed activities. Against this background, would you have integrated it into teaching organic chemistry if it was not? Please explain? Do you think esterification experiment plays a major role in teaching organic chemistry? Please elaborate. If you were to be asked by education officials to suggest ways in which inquiry based practical experiments can be conducted effectively in your school, what suggestions would you submit?

4. What hinders the Physical Sciences teachers from implementing the practical work that is based on inquiry?	Do you think that the conceptualization/ understanding you have about inquiry based practical work has an influence in the way practical work was conducted during your lesson? Explain. Have you undergone adequate training to implement inquiry-based experiments in your classroom? If yes, when was it? And how long was the training? Is Your school equipped with the necessary resources to teach Physical Sciences through inquiry based practical experiments? Please elaborate. Do you receive adequate support from the Department of Basic Education or the SMT in order for you to integrate practical experiments in most or in all your Physical Sciences lessons? What do you think the Department of Basic Education should do in order for Physical Sciences teachers to implement inquiry based practical experiments regularly?

5. What effects do Physical Sciences teachers' understanding of inquiry based practical work has on learners' academic performance?	What is your perception of inquiry based practical work/experiments in teaching Physical Sciences? Do you believe that inquiry-based experiment is an integral aspect to teaching Physical Sciences? Please elaborate. According to your understanding, do learners learn better in inquiry teaching or through knowledge transmission? Please elaborate. Do you think your understanding and the way you implement practical work has an influence on your learners' academic performance in Physical Sciences? Please elaborate.
6. To what extent do learners' academic achievement on a theoretical test and inquiry-based practical work differ in Organic Chemistry?	From you own experience in teaching Physical Sciences, when you compare your learners' academic performance, in which one between the test and inquiry-based practical do your learners perform better? Can you please elaborate?

APPENDIX J: OBSERVATION SCHEDULE

Place: ______________________________

Date: _______________________________

Time: _______________________________

Setting: ____________________________

Role of an observer: ____

CLASSROOM OBSERVATION

Category	School O	School D
Number of learners		
Are learners working as a group?		
Size of the group		
Prior to the activity, the teacher clarifies the purpose and the objectives of practical work to the learners.		
Before the commencement of the activity, the teacher asks a question.		
The class discussion is facilitated by the teacher prior the practical activity (pre-practical discussion evident).		
During the discussion, learners ask questions both to the teacher and among themselves.		

Learners are doing practical work and the teacher move among the groups to provide guidance to the learners but allow them to develop their own knowledge.		
Learners observe a demonstration done by the teacher.		
Learners discuss in groups during the inquiry for collaborative learning.		
The teacher facilitates class discussion after practical work through questioning.		
Discussions between the learners take place regarding the activity (This is relevant for effective teaching and learning that encourages knowledge development thus improving conceptual development and academic achievement).		
Learners engage in scientifically oriented questions.		
The teacher answers learners' questions.		

Learners connect explanations to scientific knowledge.		

APPENDIX K: GDE APPROVAL LETTER

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	11 October 2018
Validity of Research Approval:	11 February 2019 – 30 September 2019 2017/324AA
Name of Researcher:	Rivele S.R
Address of Researcher:	3498 Nancy Street
	Greevillage
	Doornkop Ext 1, 1874
Telephone Number:	011 985 1037 072 521 8628
Email address:	srivele@yahoo.com
Research Topic:	An exploration of Grade 12 physical sciences teachers conceptions of practical work on esterification in D10, Johannesburg, Gauteng Province, South Africa
Type of qualification	
Number and type of schools:	Two Secondary Schools.
District/s/HO	Johannesburg North.

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

15/10/2018

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

1

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

1. *The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
4. *A letter / document that outline the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
5. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
6. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
7. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
8. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
9. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
10. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
11. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
12. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
13. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
14. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

....

Mr Gumani Mukatuni
Acting CES: Education Research and Knowledge Management

DATE: 15/10/2018

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

APPENDIX L: DATA GENERATED FROM SEMI-STRUCTURED INTERVIEWS

Teacher participants' responses from the semi-structured interviews

Question 1: To what extent do the teachers of Physical Sciences understand the meaning of scientific inquiry?

The teacher participants were asked questions to share their insight on inquiry-based practical work in the teaching of Physical Sciences. In order to elicit information about the participant teachers' understanding of scientific inquiry, interview protocol was used. The results were presented as follows:

Researcher: Please explain, what is the essence of scientific inquiry?

Teacher participant O: Scientific inquiry is about getting learners to explore knowledge than being told. Science is not narrative. Learners cannot learn science by being told only; they should sometimes experience it.

Teacher participant D: In my understanding, as stipulated in CAPS document, our learners must not just learn theoretically but must see and have a feeling of what science is all about; and it (scientific inquiry) is an application outside of the classroom.

Researcher: Do you think scientific inquiry is important in teaching Physical Sciences? Why is it so important?

Teacher participant O: It is important for creative thinking. It is important for our learners to keep up to date of what is happening in science. For example, in South Africa, we want to go somewhere in terms of Industrial Revolution.

Teacher participant D: It helps learners in solving day-to-day social problems. For example, if there is a pollution crisis in their community, they can do a research in order to solve the problem.

Researcher: Which forms of scientific inquiry do you know?

Teacher participant O: I know of experiments and tutorials.

Teacher participant D: I know of practical investigation, research project, to name a few.

Researcher: From the types of inquiry you just mentioned, which one do you integrate in teaching Physical Sciences?

Teacher participant O: On a weekly basis I interchange between experiment and tutorials. If I do an experiment this week, next week I will do tutorials. In tutorials, we use work sheet to answer questions. Experiment is used for scientific reports, and I teach them to differentiate between dependent and independent variables as asked in an exam.

Teacher participant D: Our syllabus in grade 12 expect us to do practical investigation. There are prescribed practical investigations that we must do. Some of these investigations are formal and some are informal. The formal investigations should be done for SBA and the informal investigations can be demonstrated in class.

Researcher: Please elaborate on your choice of scientific inquiry in learning Physical Sciences.

Teacher participant O: Experiment helps me to enforce theory taught during the week, and tutorials assist in dealing with questions.

Teacher participant D: The practical investigation is done in class by learners to prove or disapprove a theory. In other words, learners do the investigation in order to check if what is said in theory is true in a practical sense. I can give an example of Newton second law of motion; learners can prove if the object can accelerate in a direction of net force if the net force acts on it.

Researcher: Do you think scientific inquiry plays an important role in the teaching and learning of Physical Sciences?

Teacher participant O: Science needs no narrative; we need to investigate staff in order to promote creative thinking, so it plays a major role.

Researcher: How so?
It proves if what the theory is saying is right or wrong. Learners can prove the theory part by doing some investigations.

Teacher participant D: Investigation, as I said, it can prove or disprove the theory.

Researcher: So, are you saying that you implement practical investigation to confirm the theory?

Teacher O: I think theory can be proven by an investigation, so learners can see science in action.

Teacher D: For learners to believe if what scientists are saying is true, they should do the investigation.

Researcher: Why is practical work as an inquiry integral in teaching Physical Sciences?

Teacher participant O: Because Science is not a narrative subject. As I said before, in order to explore, we need to do experiments.

Teacher participant D: We have to integrate practical investigations in teaching our learners so that they can be able to answer the investigative questions in their examination.

Researcher: May you kindly comment on the rationale that practical work as an inquiry can be used to explain laws and theories of Physical Sciences.

Teacher participant O: A law should be in the experiment, where it can be explored, while a theory can be rejected. A law can be explored through the experiment to show that the law is obeyed. The theory is a general statement, cannot be proven.

Teacher participant D: As I mentioned before, a law's existence can be proven through the practical investigation, but the theory is just a claim a scientist has made.

Researcher: May you kindly comment on the rationale that practical work that is based on inquiry can be used in process skills development.

Teacher participant O: It should be done by following certain steps. It helps us to follow methodology when doing practical work. It assists us to follow steps in order to answer questions.

Teacher participant D: Our curriculum expects learners to develop process skills, and learners must follow the methodology to the latter, but in actual practice, we as teachers do not do practical investigation for the development of process skills.

Researcher: According to your understanding, is practical experiment the same as an inquiry? Please explain:

Teacher O: It depends on what you want to investigate. In inquiry, there should be a clear aim.

Teacher D: My understanding is that an inquiry is a broader perspective of science, while an experiment is smaller perspective of science that can be done in a classroom situation or laboratory.

Researcher: The esterification experiment you are about to do with your learners; is it an inquiry?

Teacher O: It is an inquiry because we have to investigate the physical properties of esters. I think an investigation allows learners to follow the methodology and steps in order to investigate phenomena.

Teacher D: I cannot say it is an inquiry because, in an inquiry, learners will have to go out of the classroom to collect information.

How do teachers implement scientific inquiry in their Physical Sciences lessons?

Researcher: What is the rationale postulated by assessment guidelines about the purpose of inquiry?

Teacher participant O: I am not sure about the assessment guidelines. But from where I was taught, science should be investigated and not narrated. What we do allows learners to explore the truth about what we tell them is true.

Teacher participant D: The assessment guidelines stipulate that, every Physical Sciences learner must design an investigation, come up with investigative questions, make hypothesis, investigate, collect data and make conclusions about the data generated.

Researcher: Would you link the purpose of inquiry with the type of experiment in your lesson?

Teacher O: I would say yes, because the activity without purpose has no meaning.

Teacher D: The CAPS document expects us to do so. In my Physical Sciences lesson, I do link the purpose with practical demonstrations.

Researcher: Do you think it is necessary for the learners to know the purpose and objectives of the practical activity that is conducted?

Teacher participant O: Yeah, so that learners can value what they do, and for them to gain skills in science, like process skills.

Teacher participant D: In my understanding, I think it is very important, so that they know as to what is expected of them from the investigation.

Researcher: How would you explain the objectives and purpose of the practical activity to your learners?

Teacher participant O: By explaining the methodology and by demonstrating to learners how to go about the activity.

Researcher: Do you mean that you guide them through?

Teacher O: Definitely, I do.

Teacher participant D: I would read through the assessment guidelines.

When is the practical work that is based on inquiry implemented by the physical sciences teachers in their lessons?

Teacher participant O: I have to do my experiments once per week because I have to cover a lot of content. The experiments in my physical sciences lessons are performed after the theory have been covered.

Teacher participant D: Due to the pressure to finish the syllabus, I push content first, then I come back and do the prescribed experiments.

Researcher probing Teacher participant O: Why do you wait to teach the theory before the practical work that is based on inquiry?

Teacher participant O: I feel like, if I do practical work before the theory on a particular topic, my learners will not be able to understand the concept, they will get lost. I prefer to teach them theory this week, do the experiment the other week.

Teacher participant D: Practical experiments need a lot of time, which we do not have. Researcher probing further: Are you saying that you cannot teach concept through a practical work that is based on inquiry?

Teacher participant O: To me, it will not make any sense to my learners.

Teacher participant D: In my understanding you can if you have enough time and easily accessible apparatus.

Researcher to teacher O: Have you ever tried it?

Teacher participant O: Not really.

Teacher participant D: I tried by doing demonstrations, and it made sense to the learners.
Researcher: Do you find it easy to perform practical work that is based on inquiry in your physical sciences' lessons daily?

Teacher participant O: It is difficult to conduct experiments in my physical sciences' lessons.

Teacher participant D: In our current situation it is difficult; we are pushed to finish the syllabus on time. Sometimes behind closed doors, our District officials emphasize on more content teaching, and how to teach learners for the examination.

Researcher probing Teacher participant O: What makes it difficult?

Teacher participant O: Because the school does not have adequate equipment for me to conduct experiments. If the experiment is prescribed or is a formal one, I have to go and borrow from other schools. In most cases, I found that they also do not have enough equipment. I usually take my learners to Sci-Bono laboratories for formal experiments.

Teacher participant D: Mister, our laboratories are not fully equipped to fulfil the CAPS requirements. Some of the experiments to be done in my lessons, I have to ask next door.

What hinders the Physical Sciences teachers from implementing the practical work that is based on inquiry?

Researcher: What hinders you the most in implementing practical work that is based on inquiry in your daily Physical Sciences' lessons?

Teacher participant O: I think running against the Annual Teaching Plan (ATP) is a major challenge. The syllabus is too long and should be completed before any learner seats for the final examination. The allocated time for teaching Physical Sciences is not adequate to juggle with theory and practical experiment that is based on inquiry. Therefore, some of us end up doing practical work that is based on inquiry if required for SBA. Another important constraint I need to mention is lack of training.

Teacher participant D: Our curriculum is focused mostly on preparing learners for the examination. For me to finish the syllabus, which is too long, I focus much on content. Our timetable is planned in such a way that, as a teacher, doing practical experiment in most of my lessons becomes impossible. There is no time allocated specifically for experiments, and I come to realize that the investigative questions in an exam do not carry a lot of marks. And in our Physical Sciences' workshops, emphasis is always on curriculum coverage and how our schools have performed on the tests, and nothing on teaching content through inquiry based practical work.

Researcher: How does lack of training hinder your implementation of inquiry-based practical work?

Teacher participant O: Most of us have never been to adequate training on how teach Physical Sciences through inquiry-based practical work. And without training, equipment will gather dust because we do not have skills and courage to utilize them. If I remember well, the last time I went for a practical work training was some years back, on a grade 11 intermolecular forces experiment.

Teacher participant D: If the effort put on teaching Physical Sciences content was the same as teaching through inquiry-based practical work, many of us could implement it with ease. According to my recollection, there was only one teacher training in which the focus was on the grade 11 experiment.

Researcher: What was the training all about?

Teacher participant O: The training was on performing practical work.

Teacher participant D: I remember being told to bring some apparatus from school in order to perform the experiment. In that training, we just performed the experiment following the methodology outlined on the teacher training manual.

Researcher: So, during training, were you taught about teaching intermolecular forces through the experiment?

Teacher participant O: Only on how to conduct the experiment for 2 hours.

Teacher participant D: As I said Sir, we just performed the experiment, do our observations and the facilitator dismissed us after 2 hours.

Researcher: If you could be asked by the Department of Basic Education to suggest ways in which practical work that is based on inquiry could be done effectively, what would be your suggestions?

Teacher participant O: I would suggest that schools should be well resourced, and teachers adequately trained to teach Physical Sciences through inquiry. The time allocation to be increased or the syllabus is trimmed. Stop content training workshops because Universities gave us enough content.

Teacher participant D: The issue of time allocation should be addressed; Physical Sciences should be given more hours per week. Our training should focus more on how to teach Physical Sciences through experiments, and our laboratories must be fully resourced. I would also propose that practical examination is introduced in all grades, so that teaching Physical Sciences through inquiry can be taken seriously.

What effects does the understanding of inquiry by Physical Sciences teachers have on learners' academic performance?

Researcher: Do you think the practical work you have just implemented helped learners to develop more scientific knowledge in organic chemistry? Please explain.

Teacher participant O: According to my understanding, they have learnt a lot about how to get the correct results by following the methodology. Now they know that by following procedures, there is no way that you cannot get the correct results.

Teacher participant D: By performing the experiment on their own following the methodology, they develop the knowledge of process skills.

Researcher: From my observations, you did not ask your learners any questions, which could have assisted them to build new scientific knowledge during the implementation of the inquiry-based practical work. Why did you not ask them questions?

Teacher participant O: I felt like asking questions will waste a lot of time, and I wanted them to finish the assignment for the SBA.

Teacher participant D: The practical work has questions in the end, that learners should answer for the submission of a report. I for one does not see it necessary to ask questions, it is not part of implementing the experiment.

Researcher: But asking learners some questions provoke their thinking and they become creative; did you not think that not asking questions deprived your learners a chance to explore a lot of scientific knowledge?

Teacher participant O: In a practical experiment, I do not think that I have to ask questions. Learners are the ones who have to answer the questions from the work sheet. In my understanding, as a teacher, I should guide them to perform the experiment according to the stipulated methodology so that they obtain the correct results.

Teacher participant D: As I said in the previous question, asking questions was not necessary because learners already have questions to answer within the experiment.

Researcher: Did you ever realize that you missed an opportunity to assist your learners to develop more scientific knowledge about concepts such as catalyst, dehydration, physical properties of other homologous series, acids and bases and all organic reactions within the practical experiment in esterification, by not asking questions?

Teacher participant O: I did not realize that, but now as you mention it, I do, my focus was in getting this formal experiment done?

Teacher participant D: This experiment is straight forward. Learners have to perform the experiment according to specific methodology and produce esters, and get it done.

Researcher: Why were you only focusing on the completion of the experiment and not using the experiment as a tool to make learners develop more knowledge?

Teacher participant O: There should be some evidence that shows that this experiment has been done and marks are recorded.

Teacher participant D: Ooh! I can see that you do not understand what the District expect from us; they need to see the experiment reports marked; that is the evidence they need. Whether learners learnt anything from it, no one cares.

Researcher: But what about an effective learning and teaching of Physical Sciences through inquiry based practical work, which ensures that, what is learnt is retained for a long time. And if retained for a long time, learners can pass the exam with ease?

Teacher participant O: In our department of education, evidence of learning and teaching is in learners' books and their files. So, as teachers, we make sure that there is evidence, like now, to show that this experiment was done, they have to submit the report tomorrow.

Teacher participant D: It might be, but I do not think at this level I have to bother much about that, as long as my learners have completed the experiment and evidence is there, no one will be on my case.

Is there any difference between learners' academic performance on a test and inquiry-based practical work?

Researcher: What were your expectations in terms of academic performance by your learners in both the test and the inquiry-based practical work?

Teacher participant O: Upon giving my learners practical work that is inquiry based, one of my expectations was that they should have acquired effective understanding of scientific information, and expertise at the conclusion of the practical work that is based on inquiry. We have carried out the experiment very well, following all the methods stipulated. Therefore, in my understanding and experience, I think this experiment assisted them to understand organic chemistry concepts. So, I am not expecting them to perform better in the theoretical test than in practical experiments. During the previous years, the performance in the two sets of activities was less than two percent different.

Teacher participant D: I always expect my students to greatly improve on the understanding of concept, and they should be in a position of linking the theory and practical experiment during esterification. According to their academic performance, the performance of students in both theoretical test and practical experiment can be slightly different, maybe 5 percent or less. Because over the years, my learners used to perform at the same level in both, so with this group I expect the same.

Researcher: Why do you think that there will be slight difference? Does it not make sense to you that an inquiry-based practical work can improve the way learners learn, and improve their academic performance?

Teacher participant O: The test was on organic chemistry, so was the experiment, one topic is examined twice, but differently. Maybe in a situation where the curriculum is centred around the experiments, and all required resources are provided, but in our case, I do not see it that way.

Teacher participant D: Learners are being tested on the same content, which is organic chemistry. In terms of inquiry based practical work as a tool to improve learners' knowledge, it could only happen in a well-resourced school.

APPENDIX M: DATA GENERATED FROM LESSON OBSRVATIONS

Researcher: What is the rationale postulated by assessment guidelines about the purpose of inquiry?

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Researcher: Do you think it is necessary for the learners to know the purpose and objectives of the practical activity that is conducted?

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Researcher probing teacher participant O: Why do you wait to teach the theory before the practical work that is based on inquiry?

Teacher participant O: I feel like, if I do practical work before the theory on a particular topic, my learners will not be able to understand the concept, they will get lost. I prefer to teach them theory this week, do the experiment the other week.

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Researcher: Do you find it easy to perform practical work that is based on inquiry in your Physical Sciences' lessons daily?

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APPENDIX N: ETHICS CLEARANCE CERTIFICATE

UNISA university of south africa

UNISA ISTE ETHICS REVIEW COMMITTEE

Date: 27 September 2018

ERC Reference # : 2018_CGS/ISTE+001
Name :Mr S R RIVELE
Student #:33823960
Staff #: 90119304

Dear Mr Rivele

Decision: Ethics Approval from 27 September 2018 to 27 September 2023

Researcher(s):	MR SR RIVELE
Address	3498 NANCY STREET GREEN VILLAGE DOORNKOP EXT 1
Postal Code	1874
Home Number	0768761713
Work Number	0119851037
Cell Number	+27725213628
Email Address	33823960@mylife.unisa.ac.za

Supervisor (s): Professor HI Atagana
Email address: atagahi@unisa.ac.za
Telephone #: 012 337 6129

Working title of research : Exploring the teaching of grade 12 Physical Sciences through inquiry based practical work in D10, Johannesburg, Gauteng Province, South Africa.

Qualification: MSC (Science Education)

Thank you for the application for research ethics clearance by the Unisa ISTE Ethics Review Committee for the above mentioned research. Ethics approval is granted for 5 Years.

*The **low risk application** was **reviewed** by the ISTE Ethics Review Committee on the 24th of August 2018 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
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Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the ISTE Ethics Review Committee.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
7. No field work activities may continue after the expiry date **27 September 2023**. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.
8. Field work activities may only commence from the date on this ethics certificate.
9. Permission to conduct this research should be obtained from the relevant gatekeepers prior to commencing field work.]

Note:

*The reference number **2018_CGS/ISTE+001** should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

Signature *Padayachee*
Chair of ISTE ERC : Prof K Padayachee
E-mail: padayk@unisa.ac.za
Tel: (012) 429-6191

Signature *BB Mamba*
Executive Dean : Prof B Mamba
E-mail: mambabb@unisa.ac.za
Tel: (011) 670 9230

URERC 25.04.17 - Decision template (V2) - Approve

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APPENDIX O: FORMAL ORGANIC CHEMISTRY TEST AND ESTERIFICATION EXPERIMENT

GRADE 12

PHYSICAL SCIENCES: CONTROL TEST (P2)

MARCH 2018

MARKS: 50

TIME: 1 hour

THIS QUESTION PAPER CONSISTS OF 7 PAGES AND 2 DATA SHEETS

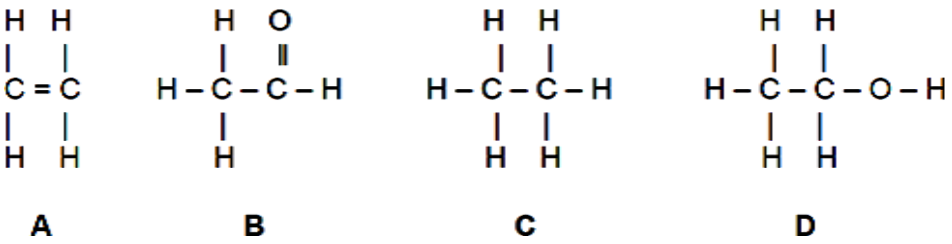
INSTRUCTIONS AND INFORMATION

1. This question paper consists of FOUR questions. Answer ALL the questionsin the ANSWER SHEET.
2. Start EACH question on a NEW page in the ANSWER SHEET
3. Number the answers correctly according to the numbering system used in this question paper.
4. Leave ONE line between two sub questions, for example betweenQUESTION 2.1 and QUESTION 2.2.
5. You may use a non-programmable calculator.
6. You may use appropriate mathematical instruments.
7. You are advised to use the attached DATA SHEETS.
8. Show ALL formulae and substitutions in ALL calculations.
9. Round off your final numerical answers to a minimum of TWO decimal places.
10. Give brief motivations, discussions, et cetera where required.
11. Write neatly and legibly.

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write only the letter (A–D) next to the question number (1.1–1.3) in the ANSWER SHEET, for example 1.4 E.

1.1 Which ONE of the following compounds will decolourise bromine water the fastest under normal conditions?



(2)

1.2 The melting points of four straight chain hydrocarbons (**A**, **B**, **C** and **D**) are shown in the table below.

Hydrocarbon	Melting point (°C)
A	-182,5
B	-95
C	28
D	-56,5

Which ONE of the above hydrocarbons has the strongest intermolecularforces?

A ABC

B D

C

D (2)

1.3 The addition of hydrogen to an alkene is known as ...

A hydration. cracking. hydrogenation.

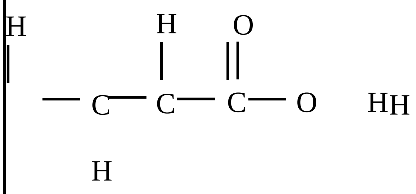
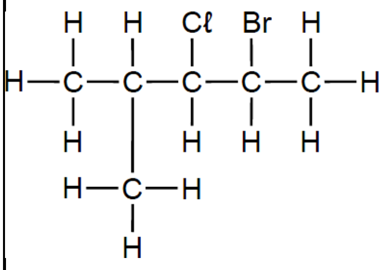
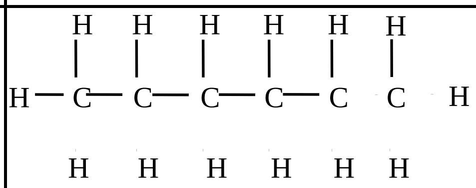
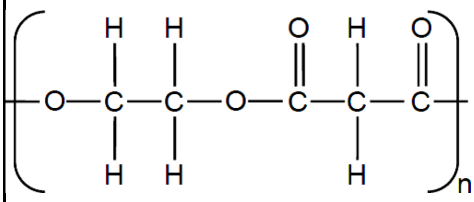
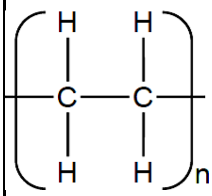
B hydrohalogenation.

C

D (2)

QUESTION 2 (Start on a new page.)

The letters **A** to **H** in the table below represent eight organic compounds.

A		**B**	
C	C_4H_8	**D**	$CH_3CH_2COCH_3$
E	$CH_3CH(CH_3)CH_2OH$	**F**	
G		**H**	

Use the information in the table (where applicable) to answer the questions that follow.

2.1 Write down the LETTER that represents a compound that:
(A compound may be used more than once.)

2.1.1 Is a haloalkane (1)

2.1.2 Has a hydroxyl group as functional group (1)

2.1.3 Belongs to the same homologous series as ethanoic acid (1)

2.1.4 Is a condensation polymer (1)

2.2 Write down the:

2.2.1 IUPAC name of compound **B** (3)

2.2.2 IUPAC name of compound **E** (2)

2.2.3 Structural formula of the *functional group* of compound **D** (1)

2.3 Compound **C** has CHAIN and POSITIONAL isomers.

2.3.1 Define the term *positional isomer*. (2)

2.3.2 Write down the structural formula of a chain isomer of compound **C**. (2)

2.4 Compound **A** reacts with pentan-1-ol in the presence of an acid catalyst

2.4.1 Write down the TYPE of reaction taking place (1)

2.4.2 Write down the IUPAC name of the organic product formed (2)

[17]

QUESTION 3 (Start on a new page.)

The boiling points of compounds **A**, **B** and **C** were determined during a practicalinvestigation and recorded in the table below

COMPOUND	CONDENSED STRUCTURAL FORMULA	BOILING POINT (°C)
A	CH_3OH	78
B	$CH_3CH_2CH_2OH$	97
C	$CH_3C\ell$	39,6

3.1 Define the term *boiling point* (2)

3.2 Write down the type of intermolecular force that is responsible for the difference in the boiling points of compound **A** and **B** (1)

3.3 Explain the difference in the boiling points of compound **A** and **C** by referring to the TYPE and STRENGTH of the intermolecular forces (3)

3.4 Compound **C** is prepared under standard conditions (STP) by the reactionbetween methane and chlorine as shown by the equation:

$$CH_4(g) + C\ell_2(g) \rightarrow CH_3C\ell(g) + HC\ell$$

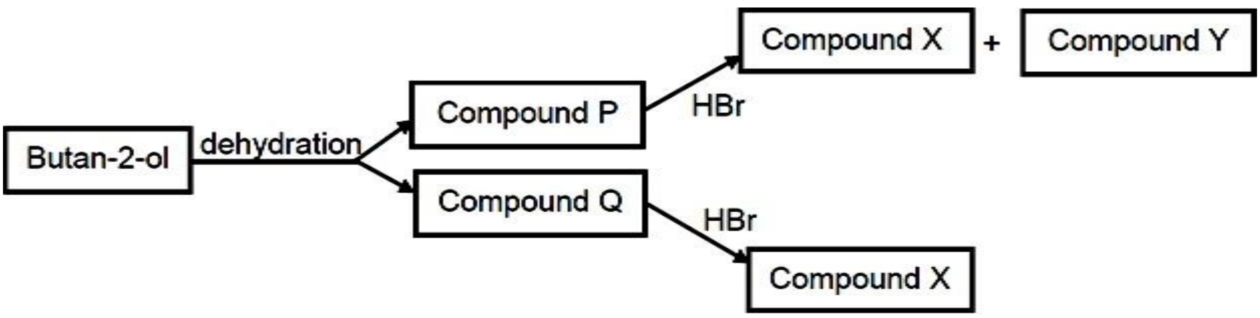
In the reaction, 12,8 g of CH_4 produces 0,035 kg CH_3Cl . Calculate thepercentage yield in the reaction (5)

[11]

QUESTION 4 (Start on a new page.)

The flow diagram below shows the conversion of an alcohol into haloalkanes.

Compound Q is the major product



4.1 Name the type of organic reaction of which dehydration is an example (1)

4.2 To which homologous series do compounds **P** and **Q** belong? (1)

4.3 What type of reaction takes place when compound P is converted to compounds **X** and **Y** as illustrated above? (1)

4.4 Use structural formulae to write a balanced equation for the preparation of compound **Q** as illustrated above. (4)

4.5 Write down the structural formula and the IUPAC name for compound **X**. (3)

4.6 A learner indicates that he can convert butan-2-ol directly into compound **X**. Name the type of reaction that will take place during a direct conversion. (1)

Petroleum companies use an elimination reaction to break longer hydrocarbons intoshorter, more useable hydrocarbons.

An example of such a reaction is given:

$$C\ H \xrightarrow{\text{Heat/catalyst}} C\ H + \text{compound R}$$

10 22 8 18

4.7 Name the TYPE of elimination reaction referred to above. (1)

Molecules of compound R can bond to each other to form a polymer

4.8 What is this TYPE of POLYMERISATION called? (1)

4.9 Using STRUCTURAL FORMULAE, write down a balanced equation for this polymerisation reaction.

(3)

[16]

GRAND TOTAL= 50 marks

“You are not a failure if you don’t make it. You’re a success because you tried”(Susan Jeffers)

GOOD LUCK!!! GOOD LUCK!!! GOOD LUCK!!!

DATA FOR PHYSICAL SCIENCES GRADE 12
PAPER 2 (CHEMISTRY)

GEGEWENS VIR FISIESE WETENSKAPPE GRAAD 12
VRAESTEL 2 (CHEMIE)

TABLE 1: PHYSICAL CONSTANTS/*TABEL 1: FISIESE KONSTANTES*

NAME/*NAAM*	SYMBOL/*SIMBOOL*	VALUE/*WAARDE*
Standard pressure *Standaarddruk*	p^{θ}	$1,013 \times 10^{5}$ Pa
Molar gas volume at STP *Molêre gasvolume by STD*	V_m	$22,4\ dm^{3}\cdot mol^{-1}$
Standard temperature *Standaardtemperatuur*	T^{θ}	273 K
Charge on electron *Lading op elektron*	e	$-1,6 \times 10^{-19}$ C
Avogadro's constant *Avogadro-konstante*	N_A	$6,02 \times 10^{23}\ mol^{-1}$

TABLE 2: FORMULAE/*TABEL 2: FORMULES*

$n = \frac{m}{M}$	$n = \frac{N}{N_A}$
$c = \frac{n}{V}$ or/*of* $c = \frac{m}{MV}$	$n = \frac{V}{V_m}$
$\frac{c_a V_a}{c_b V_b} = \frac{n_a}{n_b}$	$pH = -\log[H_3O^+]$
$K_w = [H_3O^+][OH^-] = 1 \times 10^{-14}$ at/*by* 298 K	
$E^{\theta}_{cell} = E^{\theta}_{cathode} - E^{\theta}_{anode} / E^{\theta}_{sel} = E^{\theta}_{katode} - E^{\theta}_{anode}$ or/*of* $E^{\theta}_{cell} = E^{\theta}_{reduction} - E^{\theta}_{oxidation} / E^{\theta}_{sel} = E^{\theta}_{reduksie} - E^{\theta}_{oksidasie}$ or/*of* $E^{\theta}_{cell} = E^{\theta}_{oxidisingagent} - E^{\theta}_{reducingagent} / E^{\theta}_{sel} = E^{\theta}_{oksideermiddel} - E^{\theta}_{reduseermiddel}$	

TABLE 3: THE PERIODIC TABLE OF ELEMENTS

KEY/*SLEUTEL*

Electronegativity / *Elektronegatiwiteit*	Atomic number / *Atoomgetal*	Symbol / *Simbool*	Approximate relative atomic mass / *Benaderde relatiewe atoommassa*
1,9	29	Cu	63,5

Each cell: atomic number, symbol, approximate relative atomic mass, (electronegativity).

1 (I)	2 (II)	3	4	5	6	7	8	9	10	11	12	13 (III)	14 (IV)	15 (V)	16 (VI)	17 (VII)	18 (VIII)
1 **H** 1 (2,1)																	2 **He** 4
3 **Li** 7 (1,0)	4 **Be** 9 (1,5)											5 **B** 11 (2,0)	6 **C** 12 (2,5)	7 **N** 14 (3,0)	8 **O** 16 (3,5)	9 **F** 19 (4,0)	10 **Ne** 20
11 **Na** 23 (0,9)	12 **Mg** 24 (1,2)											13 **Aℓ** 27 (1,5)	14 **Si** 28 (1,8)	15 **P** 31 (2,1)	16 **S** 32 (2,5)	17 **Cℓ** 35,5 (3,0)	18 **Ar** 40
19 **K** 39 (0,8)	20 **Ca** 40 (1,0)	21 **Sc** 45 (1,3)	22 **Ti** 48 (1,5)	23 **V** 51 (1,6)	24 **Cr** 52 (1,6)	25 **Mn** 55 (1,5)	26 **Fe** 56 (1,8)	27 **Co** 59 (1,8)	28 **Ni** 59 (1,8)	29 **Cu** 63,5 (1,9)	30 **Zn** 65 (1,6)	31 **Ga** 70 (1,6)	32 **Ge** 73 (1,8)	33 **As** 75 (2,0)	34 **Se** 79 (2,4)	35 **Br** 80 (2,8)	36 **Kr** 84
37 **Rb** 86 (0,8)	38 **Sr** 88 (1,0)	39 **Y** 89 (1,2)	40 **Zr** 91 (1,4)	41 **Nb** 92	42 **Mo** 96 (1,8)	43 **Tc** (1,9)	44 **Ru** 101 (2,2)	45 **Rh** 103 (2,2)	46 **Pd** 106 (2,2)	47 **Ag** 108 (1,9)	48 **Cd** 112 (1,7)	49 **In** 115 (1,7)	50 **Sn** 119 (1,8)	51 **Sb** 122 (1,9)	52 **Te** 128 (2,1)	53 **I** 127 (2,5)	54 **Xe** 131
55 **Cs** 133 (0,7)	56 **Ba** 137 (0,9)	57 **La** 139	72 **Hf** 179 (1,6)	73 **Ta** 181	74 **W** 184	75 **Re** 186	76 **Os** 190	77 **Ir** 192	78 **Pt** 195	79 **Au** 197	80 **Hg** 201	81 **Tℓ** 204 (1,8)	82 **Pb** 207 (1,8)	83 **Bi** 209 (1,9)	84 **Po** (2,0)	85 **At** (2,5)	86 **Rn**
87 **Fr** (0,7)	88 **Ra** 226 (0,9)	89 **Ac**															

58 **Ce** 140	59 **Pr** 141	60 **Nd** 144	61 **Pm**	62 **Sm** 150	63 **Eu** 152	64 **Gd** 157	65 **Tb** 159	66 **Dy** 163	67 **Ho** 165	68 **Er** 167	69 **Tm** 169	70 **Yb** 173	71 **Lu** 175
90 **Th** 232	91 **Pa**	92 **U** 238	93 **Np**	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	100 **Fm**	101 **Md**	102 **No**	103 **Lr**

GRADE 12

PHYSICAL SCIENCES: CONTROL TEST (P2)

MARCH 2018

MEMORANDUM

THIS MEMORANDUM CONSISTS OF 6 PAGES

QUESTION 1

1.1 A ✓✓ (2)

1.2 C ✓✓ (2)

1.3 C✓✓ (2)

[6]

QUESTION 2

2.1

2.1.1 B ✓ (1)

2.1.2 E ✓ (1)

2.1.3 A ✓ (1)

2.1.4 G ✓ (1)

2.2

2.2.1 2-bromo-3-chloro-4-methylpentane

Marking criteria:
Correct stem i.e. pentane.✓
All substituents (chloro, bromo and methyl) correctly identified. ✓
Substituents correctly numbered, in alphabetical order, hyphens and commascorrectly used. ✓ (3)

2.2.2 2-methyl✓propan-1-ol ✓

NotesIF:
2 methylpropan 1 ol 1 2 (2)

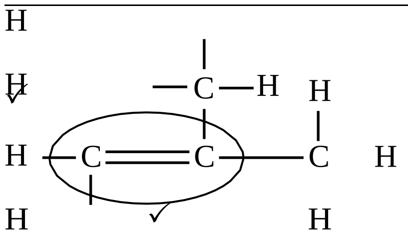
2.2.3 **ANY ONE:**

O — C C C ✓	O C	O R C R

(1)

2.3

2.3.1 Compounds with the <u>same molecular formula</u>✓ but <u>different positions of the functional groups</u> /side chain/substituents on parent chain. ✓ (2)

2.3.2		**Marking criteria:** □ Whole structure correct: $\frac{2}{2}$ □ Only functional group correct $\frac{1}{2}$

Notes:

If two or more functional groups $\frac{0}{2}$

Condensed or semi-structural formula: Max $\frac{1}{2}$

Molecular formula: $\frac{0}{2}$

(2)

2.4.1 Esterification (reaction) ✓ (1)

2.4.2 pentyl✓propanoate ✓ (2)

[17]

QUESTION 3

3.1 The temperature at which the vapour pressure of a substance equals atmospheric pressure ✓✓ (2)

3.2 London forces /Dispersion forces /Induced dipole forces ✓ (1)

3.3 Between molecules of compound **A** are <u>hydrogen bonds</u>✓ and Londonforces /Dispersion forces / induced dipole forces

Between molecules of compound **B** are <u>dipole-dipole</u>✓ forces andLondon forces

<u>Intermolecular forces in compound **A** are stronger</u>✓ than in **B**

OR

Intermolecular forces in compound **B** are weaker than in **A**

(3)

3.4

	Marking criteria
$n = \frac{m}{M}$ ✓ $= \frac{12,8}{16}$ $= 0,8 mol$ ✓ $n_{CH_4} : n_{CH_3Cl} = 1:1 \therefore n_{CH_3Cl} = 0,8 mol$ $m_{Cu} = n \times M$ ✓ $= 0,8 \times 50,5$ $= 40,4 g$ $\% yield = \frac{35}{40,4} \times 100$ ✓ $= 86,63\%$ ✓	Formula- $n = \frac{m}{M}$ ✓ 0,8 mol✓ Substitution of 50,5g✓ Percentage calculation✓ Answer: 86,63 %✓ (5) **[11]**

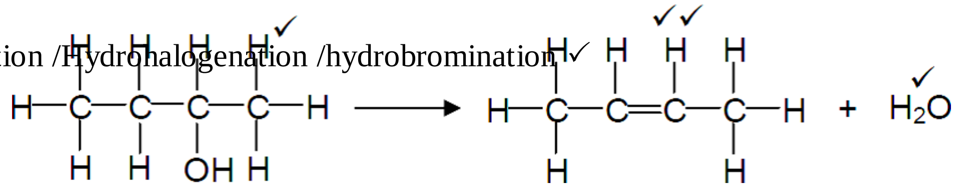
QUESTION 4

4.1 Elimination ✓ (1)

4.2 Alkenes ✓ (1)

4.3 Addition /Hydrohalogenation /hydrobromination ✓ (1)

4.4



Notes

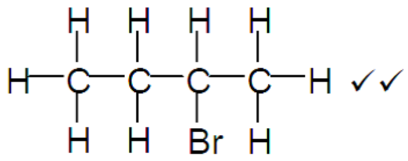
Condensed/semi-structural formulae or mixture of both: -1 mark

All bonds shown, one or more H-atoms omitted: -1 mark per structure

Everything correct, wrong balancing: -1 mark

Any other reactants or products: -1 mark

4.5



2-bromobutane ✓

Notes
Condensed/semi-structural formulae or mixture of both: -1 mark
All bonds shown, one or more H-atoms omitted: -1 mark per structure
No hypen in the name: -1 mark

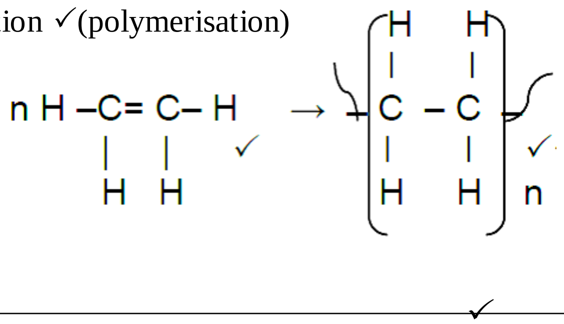
(3)

4.6 Substitution ✓ (1)

4.7 Cracking ✓
Accept: elimination (1)

4.8 Addition ✓(polymerisation) (1)

4.9



Notes
Condensed/semi-structural formulae or mixture of both: -1 mark
All bonds shown, one or more H-atoms omitted: -1 mark per structure
Letter n omitted per structure: -1 mark
(3)

[16]

TOTAL: 50

ANALYSIS GRID

Question No.	**Content**	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Total**
1.1	Organic reaction		2			
1.2	Physical properties		2			
1.3	Organic reaction		2			
Total			6			6
2.1.1	Homologous series	1				
2.1.2	Functional groups	1				
2.1.3	Homologous series	1				
2.1.4	Homologous series	1				
2.2.1	IUPAC naming			3		
2.2.2	IUPAC naming		2			
2.2.3	Functional groups		1			
2.3.1	Isomerism	2				
2.3.2	Isomerism		2			
2.4.1	Application of organic chemistry	1				
2.4.2	IUPAC naming			2		
Total		7	5	5		17
3.1	Physical properties	2				
3.2	Physical properties		1			
3.3	Physical properties			3		
3.4	Stoichiometry				5	
Total		2	1	3	5	11
4.1.	Organic reactions		1			
4.2.	Organic reactions		1			
4.3	Organic reactions		1			
4.4	Organic reactions				4	
4.5	Organic reactions			3		
4.6	Organic reactions		1			
4.7	Organic reactions	1				
4.8	Plastics and polymers		1			
4.9	Plastics and polymers			3		
Total		1	5	6	4	16
Grand .Total		10	17	14	9	50
Expected marks(policy)		**10**	**17.5**	**15**	**7.5**	**50**
Actual %		20%	34%	28%	18%	100

						%
Expected(policy) %		**2 0 %**	**3 5 %**	**3 0 %**	**1 5 %**	**1 0 0 %**

/15

PHYSICAL SCIENCES Grade 12
Formal ExperimentESTERS
Instruction sheet

%

Name:

You will be expected to write a full Scientific Report on this practical so take note of your procedure and findings.

Safety Precautions

- Safety eyewear must be worn at all times while you are in the laboratory.
- Most of the organic compounds used or produced in this experiment are highly flammable.All heating will be done using a kettle or hotplate and no flames will be permitted in the laboratory.
- Sulfuric acid is used as the catalyst for the esterification reactions. Sulfuric acid is dangerous and can burn skin, eyes, and clothing very badly. If it is spilled, wash immediately before the acid has a chance to cause a burn, and inform the instructor.
- The vapors of the esters produced in this experiment may be harmful. When determiningthe odors of the esters produced in the experiment, do not deeply inhale the vapors. Merely waft a small amount of vapor from the ester toward your nose.

You are required to follow the following method and prepare 3 different Esters and identify thesmell of each one.

Method:

Boil some water in a kettle for preparing a heat bath before commencing the experiment.

1. Take 3 test tubes and in each put 20 drops of ethanol, 20 drops of pentan-1-ol, and 20drops of 3-methylbutan-2-ol.
2. In each test tube add 20 drops of ethanoic acid or propanoic acid.
3. Add 1 drop of conc.H_2SO_4 in each test tube.
4. Place all the test tubes in the beaker with hot water for about 15 -20 minutes, replace thewater if it cools

down too much.

5. Gently shake the test tubes often.
6. Take a beaker and put about 20 mℓ of cold water into it, now add the contents of one ofyour small test tubes into it, cover the opening with the palm of your hand and shake it gently.
7. Try now to identify the smell.
8. If the smell is very acidic, add 1mℓ $CaCO_3$ to the mixture to neutralise the remaining acid.

Write a scientific report after performing this experiment. (15)

mett>yt I carbon 2carbons 3carbons propy

e<f-¥1 propyl 2-methyl butyl 4carbons pentyl Scarbons hexyt 6carbons bmzy4 rirag heptyt]carbons octyl &carbons nonyt 9carbons

m..-,
I carbon

.. hanoat,
2carbons

propano,te3carbons

2-methyl propanoate
4 carbons, branched

bulanoate
c arbons

penuinoate

2 Scatbons

i- ......
6carbons

ben-•
benn,nering

heptanoate

7carbons

salicylate
fromsalicylic add

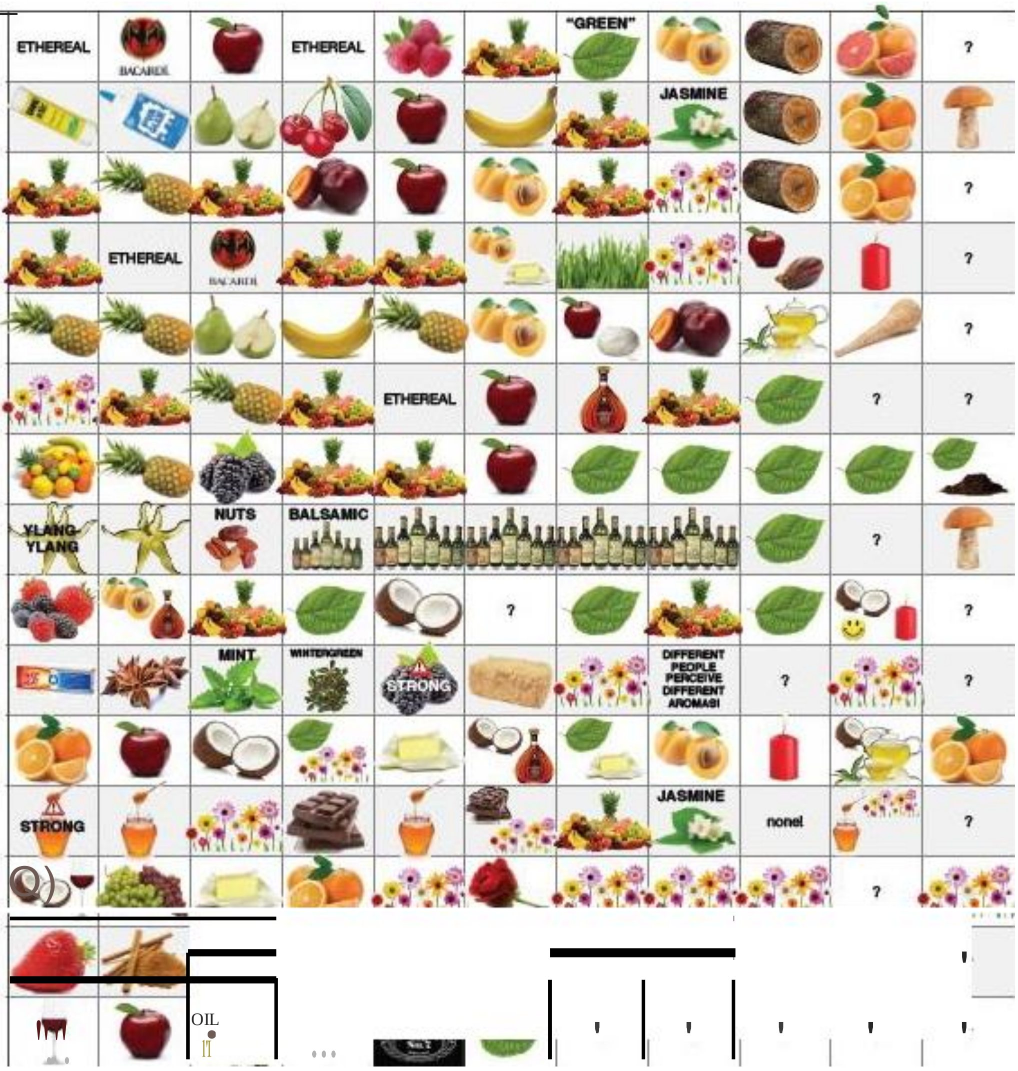
O<tanoa'2
8carbons

l)Mf¥iK.e-tilte
benzenerll'lg+ 2calbons

nonanoa te
9carbons

dnnamate benzeneting+propenol

deano;ite
10carbons



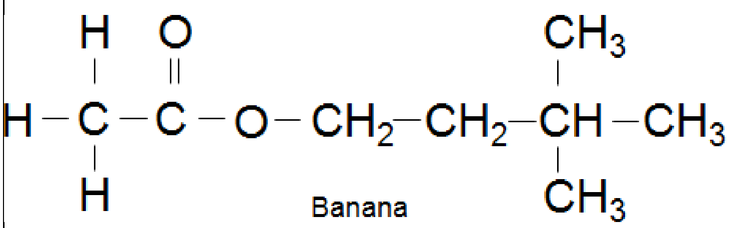
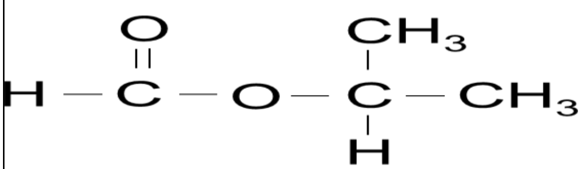
PHYSICAL SCIENCES Grade 12

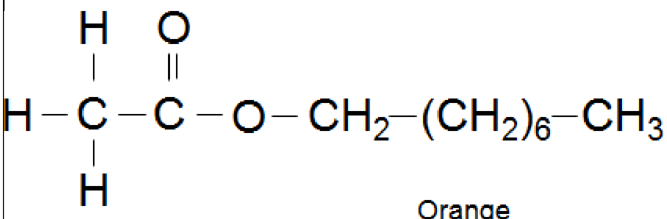
/35

Formal ExperimentESTERS

Name

Answer the following questions related to the experiment.

1	What is the function of the conc.H_2SO_4?	(2)
2	Why were the reactants of each test tube heated in a water bath and not directlyover a flame?	(2)
3	Is the organic **product** soluble in water?	(1)
4	For each of the following structures below, identify the acid and alcohol used to prepare these esters. Also give the name of the ester.	
4.1	 Name of the acid used: Name of the alcohol used:Name of the Ester:	(6)
4.2	 Name of the acid used: Name of the alcohol used: Name of the Ester:	(6)

4.3	 Orange Name of the acid used:	

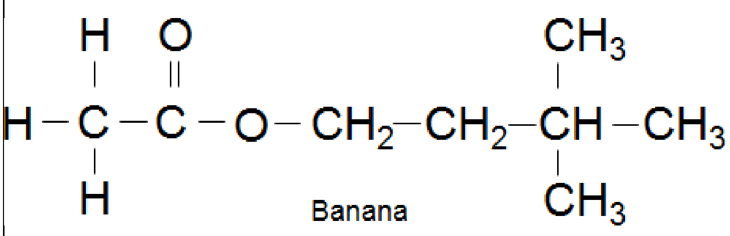
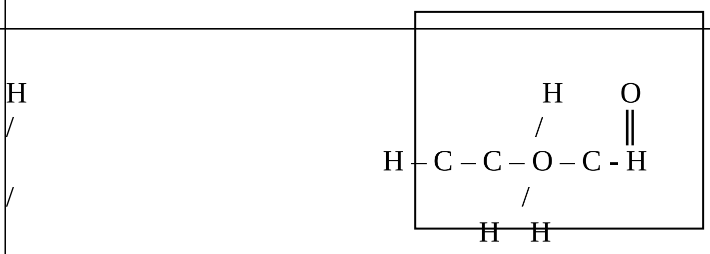
	Name of the alcohol used:Name of the Ester:	(6)
5	Give the structural formula of the ester formed from the following.	
5.1	Ethanol and ethanoic acid.	(4)
5.2	Pentan-1-ol and Propanoic acid.	(4)
5.3	Propan-1-ol and Ethanoic acid	(4)
		[35]

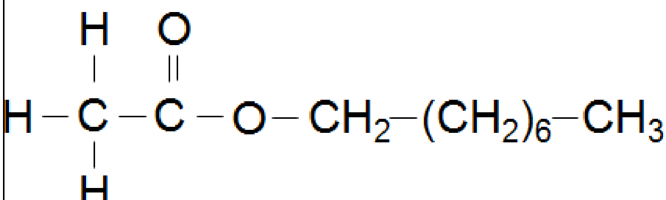
PHYSICAL SCIENCES Grade 12 /35

Formal ExperimentESTERS

MARKING GUIDELINE

Answer the following questions related to the experiment.

1	What is the function of the conc.H_2SO_4? Catalyst ✓✓	(2)
2	Why were the reactants of each test tube heated in a water bath and not directlyover a flame? The alcohol in the mixture is highly flammable ✓✓	(2)
3	Is the organic **product** soluble in water? Not soluble ✓ (ester is produced which is an oil that floats on the water.)	(1)
4	For each of the following structures below, identify the acid and alcohol used to prepare these esters. Also give the name of the ester.	
4.1	 Name of the acid used: ethanoic acid ✓✓ Name of the alcohol used: 3,3-dimethyl butanol ✓✓ Name of the Ester: 3,3-dimethyl butyl ethanoate ✓✓	(6)
4.2	 Name of the acid used: methanoic acid ✓✓ Name of the alcohol used: ethanol ✓✓ Name of the Ester: ethylmethanoate ✓✓	(6)

4.3	 Orange Name of the acid used: ethanoic acid ✓✓Name of the alcohol used: octanol ✓✓ Name of the Ester: octyl ethanoate	(6)
5	Give the structural formula of the ester formed from the following.	
5.1	Ethanol and ethanoic acid. O ‖ C – C –O – C – C BASIC STRUCTURE ONLY (Learners must show a full correct structure)	(4)
5.2	Pentan-1-ol and Propanoic acid. O ‖ C – C – C – C – C – O - C – C - C BASIC STRUCTURE ONLY (Learners must show a full correct structure)	(4)
5.3	Propan-1-ol and Ethanoic acid O ‖ C – C – C – O – C - C BASIC STRUCTURE ONLY (Learners must show a full correct structure)	(4)
		[35]