

THE EFFECTIVENESS OF PRACTICAL WORK DONE BY PRE SERVICE TEACHERS

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ABSTRACT

The study investigated the effectiveness of practical work done by pre-service teachers in preparing to be science teachers. For this paper the phrase ‘pre-service teachers’ is replaced with the phrase ‘science student teachers’ sometimes used interchangeably. The study was guided by the following research questions: ☐ What type of practical work do science preservice teachers do?

- ☐ How do science student teachers relate practical work to the concepts being taught in lectures?
- ☐ To what extent do the practical tasks enable the science student teachers to do/ learn the things the lecturer intended them to do/learn?
- ☐ To what extent do the practical tasks done by science student teachers align with practical work specified in the CAPS document?

This is a case study employing both qualitative and quantitative research. The researcher interviewed participants in order to obtain qualitative data. He used a questionnaire to obtain quantitative data. The type of sampling employed in this study is called comprehensive sampling because the participants were chosen based on a set of criteria. This study uses the constructivism theory as a conceptual framework.

The study provided evidence that the type of practical work done by science student teachers is limited to rediscovering what is already known. It was shown that the other types of practical work (investigate phenomena, solve problems etc.) were not entirely covered by science student teachers. The study provided evidence that practical work done by science student teachers is related to the content taught in lectures. It shows that practicals done at the university relates to what CAPS advocates; however not all the aspects that the CAPS document advocates are covered by science student teachers during practical tasks. The study recommends that practical work done by science student teachers should be designed to cater for specific aims. Also, institutions should provide more resources and support for science student teachers.

Key words: Pre-service teachers, inquiry based practical work, nature of scientific inquiry.

DECLARATION

I Thabo Mkalipi, declare that the research report, which I hereby submit for the degree Masters of Science in Science Education at the University of the Witwatersrand, is my own work and has not been previously submitted by me for a degree at this or any other tertiary institution.

SIGNATURE: _____

DATE: 31 October 2017

DEDICATION

This work is dedicated to my fiancée Fezeka Daile for the strength and encouragement she provided from the beginning to the end of this journey. It is also dedicated to my mother Mrs Popi MkhaliPhi, my father Mr V. F MkhaliPhi and my children, Lwandle and Skhulile MkhaliPhi. My brother Vusi MkhaliPhi, my late brother Moosa MkhaliPhi (RIP), my sisters Sphiwe and Nondumiso MkhaliPhi. Thank you all for your support.

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Chapter One

Introduction to the Study

1.0 Introduction

Science teaching involves the facilitation of scientific knowledge from the teacher to the learner. There are many theories discussing ways in which scientific knowledge is generated and ways it can be constructed by learners with the facilitation of teachers. The focus of the study was on practical work in science education. I believe that social reality and knowledge is constructed by stakeholders and it is subjectively experienced. This is not an empirical study or an evaluative study but it is subjective to the participants. I firmly believe that perception influence behavior so it is important to find out the perception of participants regarding the effectiveness of practical work. I hold the belief mentioned by Jussim (1991) that social perception is a major force in the creation (construction) of social reality. I believe the perceptions of science preservice teachers will influence their behavior and the way they will teach science in the near future. I therefore think it is important to collect accounts and perceptions that explain how practical work is experienced by preservice teachers, lecturers and laboratory demonstrators. Preservice teachers in this study refers to students who intend to be teachers who will teach physical sciences at Senior Phase(grade 7-9) and Further Education and Training(FET) (grade 10-12),in the South African context. Laboratory demonstrators refer to senior students (honors and masters level) who assist preservice teachers in setting up and marking practical activities. The research seek to find perceptions of preservice teachers about the effectiveness of practical work that they do as part of their preparation to be science teachers. The aim is to check how useful practical work to preservice teachers is. The approach to be used is that of a case study. Opie (2004) view a case study as an in-depth study of interactions of a single instance in an enclosed system. In this case the interaction is between the preservice teachers, the lectures and the laboratory demonstrators while the enclosed system is the University of Witwatersrand, Johannesburg. Unfortunate personal experiences with practical work at high school were the motivation for choosing this study. Practical work was and still is part of the assessment criteria but learners were not given adequate opportunities to engage in practical tasks. Part of the reason for not doing practical tasks was lack of resources, but another reason seemed to be insufficient knowledge on the part of the teacher. As a result, we were merely told results and observations theoretically even though some apparatus was available. This raised questions

about the quality of the teacher education environment in South Africa. In particular, I was interested to know if institutions of higher education are producing science teachers who are well prepared to engage in meaningful practical work. It goes without saying that scientific knowledge cannot be separated from practical work. The study has a potential to contribute to the knowledge base for training teachers.

The current study is important for the teacher education environment because it sheds light on how preservice teachers perceive practical work and what is essential in order to achieve effective practical work. It illuminates challenges faced by preservice teachers in this particular case study. Of course, once problems are exposed possible solutions to those problems can be explored. The focus was on the perceptions of science preservice teachers because they represent the future. They are the ones who will improve the quality of teaching and learning science in South African schools. The study focused on one institution of higher learning with the aim to get the ideas of lecturers and science preservice teachers with regard to practical work that they were undertaking in that particular institution. The programme the research focused on is Bachelor of Education which is a four year degree; the focus was mainly in science education.

In this particular institution, science preservice teachers were required to do one practical task per week in both physics and chemistry. It was therefore ideal to use the preservice teachers as participants in the study in order to get detailed information about the nature and type of practical work they did as preparation to be science teachers. Third year and final year science preservice teachers were chosen for this research. The reason for choosing this group was that they have more teaching experience compared to first and second year students. Every year preservice teachers go for teaching experience in schools twice a year for duration of three weeks per teaching experience. During teaching experience they gained knowledge of the curriculum and the value of practical work in the teaching and learning of science. Final year and third year students would be qualified teachers in the near future; so the aim was to know if they would be well prepared to conduct effective and meaningful practical work when they began to teach.

This research was worth doing because it could be useful in improving the design of practical tasks in both institutions of higher learning and at high school levels. It is evident that there are problems in the teaching and learning of science which this research can contribute towards solving. A number of studies (e.g. Howie, 2005) highlighted a number of challenges in the teaching and learning of mathematics and science in South Africa. One example is a study conducted in 1995 by the Third International Mathematics and Science Study (TIMSS). In the study South Africa participated with 41 others. The study showed that South African mathematics learners came last with a mean score of 351 (ibid.). South Africa has participated in four other TIMSS (1999, 2003, 2011 & 2015) after 1995 and South African pupils performed poorly compared to other countries. Of course several factors can contribute to this poor performance. However, a focus on the contribution made by practical work to the problem might yield some solutions.

Before proceeding it is important to define physical science for the purposes of this study. Physical Sciences deal largely with physical and chemical phenomena. Physical sciences uses scientific inquiry, scientific models, theories and laws in order to explain and predict events in the physical environment (CAPS) (DBE,2011).It should be noted that part of the definition involves words like “investigate” and “scientific inquiry” which are very important in the development of scientific knowledge. In science, practical activity involves experimentation. In fact, scientific theories are derived from the experience acquired by observation and experiment. Before a scientific theory can be developed, there must be observations from the natural world, or experiments done in the laboratory. The National Research Council (NRC) mentions that scientific inquiry involves,

... making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of 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 and logical thinking, and consideration of alternative explanations. (NRC, 1996, p. 23)

Kask and Rannikmäe (2006: 6) indicate that “inquiry based experimental work develops students’ process skills”. This notion is also held by Ottander and Grelsson (2006) and White (1996). It is vital to note that inquiry based practical work is not a new concept in science education. Hurd (1969) stated the importance of using practical work which is inquiry based:

If education is to serve the future, there is likely to be more educational value from laboratory experiments with the objective of developing cognitive skills than there is in collecting data . . . the purpose of these [laboratory] problems need to be identified in terms of inquiry processes rather than on the more fragile bases of obtaining information and acquiring technical skills (Hurd, 1969, p. 115).

Practical work plays an important role in science teaching and learning. According to Wellington (1998), it seems practical work might include all experimental activities used in science teaching at school. These activities might include students’ experimental or laboratory work which is hands on activities done in small groups. Demonstrations done by a teacher also fall in this category. This research is a case study focused on practical work done by science preservice teachers in preparation for being science teachers. The current South African Curriculum and Assessment Policy Statement (CAPS) advocates practical work as an essential aspect of science teacher training so the focus on practical teaching is relevant in this context.

The question that might arise is: why is scientific knowledge important? According to Millar (2004), it seems scientific knowledge attempts to provide explanations for the behavior of the material world. ‘Material world’ in this context, means matter in terms of physical and chemical properties. Millar argued that the scientific community has built up a body of knowledge which is accepted by that community (Millar, 2004). The knowledge claims undergo a certain level of testing and scrutiny. The community over centuries has gained a much better understanding of the universe and enjoyed the benefits that came with technology, which is the application of science. For scientific knowledge to be passed on to future generations, sound science education is essential. Science teachers, therefore, need to be trained effectively. Part of their training involves doing practical work. This approach to science education involves a certain degree of inquiry-based education. The quotation above from the NRC explains exactly what inquiry entails. This research seeks to examine the perspectives of preservice teachers about the effectiveness of practical work they do as part of their teacher training. An explanation of what is meant by ‘effectiveness’ will follow.

In the University where the research was conducted, science preservice teachers do practical tasks as a form of continuous assessment. Each practical task will have unique aims and unique objectives. According to Abrahams and Reiss (2012), the focus seems to be on the effectiveness of specific practical tasks instead of the effectiveness of practical work in general. The next question might be: what does the South African curriculum say about practical work in science?

The Curriculum and Assessment Policy Statement (CAPS) (DBE, 2011a) highlights what teaching science in the schools entails. CAPS focuses on scientific enquiry; how it is conducted, of the different kinds of knowledge claims that scientists make, the forms of reasoning that scientists use to link data and explanations and the role of the scientific community in checking and scrutinizing knowledge claims (DBE, 2011a, p. 8). Therefore, physical science teachers in South African schools have to be involved in scientific inquiry which involves a great deal of practical work.

It is evident that practical work is important for science education in the South African context. General research has shown that South African schools are performing relatively poorly in Physical Sciences. The Trends in International Mathematics and Science Study (TIMSS) for 2003 provides evidence of poor trends in learner performance in science in South Africa (Reddy, 2006). Similar results were observed in TIMSS (2011 & 2015). Of course there can be many factors that contributed to the poor performance. Makgato (2007) conducted a study in the secondary schools in the Soshanguve Township in South Africa. The study investigated the factors that contributed to the poor performance of learners in Physical Sciences and Mathematics. The findings of the research suggested several factors that contribute to the poor performances. They have been described by Makgato as,

...the lack of adequate practical experiments in the laboratories, the lack of teacher knowledge in Physical Sciences and Mathematics, inadequate parent involvement, lack of proper teaching and learning methods in Physical Sciences and Mathematics and the lack of motivation and interest of teachers and learners in the subjects. Makgato (2007, p. 100)

Ajaja (2009) asserted that poor teacher training could be a contributing factor for the low teacher performance in the teaching of science. Ajaja (2009) also adds that there is a minimal use of practical work however textbooks were preferred in the teaching of science. Thus, the lack of resources in some South African schools can be the reason for poor performance in Physical Sciences. In a study done by Makgato (2007) focusing on factors that contribute to poor performance in mathematics and science, one of the findings included the use of practical work. In the study, teachers and learners were interviewed in District 3 Tshwane North. Most of them reported that they did not have enough equipment to do practical work. Laboratory usage helps in improving learners' higher order thinking skills such as analysis, problem solving, and evaluating. However according Makgato (2007), it seems learners complained about was the lack of laboratory equipment .Other factors (inadequate parent involvement, etc.) that might have contributed to the poor performance in Physical Sciences in South African schools do not fall into the scope of this study.

1.1 Focus and Purpose of the research

This study focused on the perspectives about the effectiveness of practical work done by science preservice teachers in preparing to be science teachers. The element of effectiveness of the practical work depends on the nature of the practical work being done by the science preservice teachers. The study thus looked at how the lecturers compiled the practical tasks booklet by examining the practical book manual for in both Physics and Chemistry for third year and final year preservice teachers. The comparison of the course outline, course content (topics to be taught in class) and the contents of practical tasks were made in order to establish relationships. The other element was the role played by the laboratory demonstrators in giving support to the preservice teachers while doing the practical tasks. Most important was the way in which science preservice teachers perceived they were being trained to be science teachers.

The main purpose of the study was to get the perspectives about the effectiveness of the practical tasks done by the science preservice teachers. To achieve this goal the study interviewed preservice teachers, a lecturer and a laboratory demonstrator. Further the study examined whether there is a relationship between what preservice teachers do as practical tasks and what they actually learn in the lecture rooms. This was done examining weekly practical scripts comparing them with the course content. Lectures were attended by the researcher and a journal was used to record what was observed. Practical work can be used in

class to “enhancing the mastery of subject matter” (Perking-Gough, 2007, p. 93). The study enquired if this role of practical work is achieved by preservice teachers when doing their own practical tasks as preparation to be science teachers. The study wanted to ascertain whether the preservice teachers can see relevance between what the lecturers intends them to learn through practical activities and what is being taught in class. Thus, the prime purpose of the study was to see whether the participants perceive practical work done by science preservice teachers as a way of enhancing the mastery of subject matter. Of course the views of the participants are subjective and cannot be generalized.

A secondary purpose of the study was to check views of preservice teachers if the practical work they do is relevant to the current Curriculum and Assessment Policy Statement (CAPS). CAPS document was examined focusing on the kind of practical work that should be done at schools. A comparison was made between CAPS and the practical manuals in order to determine the relationship. As is mentioned above, the CAPS advocate the use of practical work that is inquiry based as part of the learning and teaching of science. The nature of science is part of what CAPS advocates, as mentioned in the Curriculum and Assessment Policy Statement (CAPS) (DBE, 2011a). Finally, the study checked the views of preservice teachers about the types of practical work they think they do.

1.2 Rationale for the Research

Practical work plays an important role in science education. One way of differentiating science from other bodies of knowledge according to Popper (2005) is that scientific knowledge must be testable and scientific theories must be falsifiable, capable of being tested (verified or falsified) by experiment or observation. It is important to research the effectiveness of practical work since science cannot survive without practical work. Abrahams and Millar (2008) argue that practical work plays an important part of science education. Through practical work, students develop their understanding of science, appreciate that science is based on evidence and acquire hands-on skills that are essential if students are to progress in science (Abraham & Millar, 2008). When discussing the nature of experiments, students learn to examine the double roles of practical work at school; on the one hand helping students to learn content and on the other hand helping them to obtain ideas and skills about the process of scientific inquiry (e.g., Woolnough 2001; Leach 1999). It is important to know if pre-service teachers are well orientated in respect of these different roles of practical science before they begin to teach physical sciences.

Practical work is important for science education; not only in developing understanding of science but also in understanding the nature of science (NOS) and the nature of scientific inquiry (NOSI). Achieving scientific literacy is commonly referred to as the main goal of science teaching (AAAS, 1989, 1993; NRC, 1996). Practical work plays an important role in achieving this goal of science teaching. If preservice teachers are exposed to meaningful and effective practical work; they will understand the tenets of scientific inquiry, thus achieving scientific literacy. Of course, understanding the tenets of scientific enquiry does not alone amount to scientific literacy; however, it is a good place to start when one aims to achieve scientific literacy. An understanding of NOSI is a constitutive component of scientific literacy (Laugksch, 2000). Laboratory work is considered to play a central and distinctive role in science teaching and some science educators believe that good benefits in learning arise from using laboratory activities (Hofstein et al., 2005; Hofstein & Lunetta, 2004).

Practical work in science, as mentioned above, is part of the definition of science. Donnelly (1998) has suggested that many science teachers see the frequent use of practical work as an essential part of what it means to be “a science teacher.” For effective teaching and learning of science, practical work must be done effectively. For practical work to be effective the teacher needs to be competent and have enough knowledge about how practical work ought to be conducted. The study focused on the effectiveness of the practical work that preservice teachers are exposed to before completing their training. Finding out the effectiveness or ineffectiveness of practical work will enable the designers of the teacher training curriculum to explore ways of improving the quality and strategies to be employed when doing and designing practical work as part of science teacher education.

As noted in the introduction of the study, the Curriculum and Assessment Policy Statement (CAPS) advocates practical work. In the CAPS document, part of formal assessment practical work is broken down into three units: 1) “Practical activities” which refer to practical demonstrations, experiments or projects used to strengthen the concepts being taught; 2) “Experiments” will refer to a set of outlined instructions for learners to follow in order to obtain results to verify established theory; and 3) “Practical investigations” will require learners to go through the scientific process (CAPS) (DBE, 2011a). Researching the effectiveness of practical work for science student teachers is essential because they are the

ones who will implement the curriculum in schools. The assessment weighting of physical sciences in grades 10 to grade 12 includes practical work. For grade 10 and 11 two prescribed experiments are done per year, one physics experiment chemistry experiment as formal assessment. For grade 12 three prescribed experiments are done per year, one or two physics experiment and one or two chemistry experiments as formal assessment. In grade 10 and 11 one practical investigation can be used as formal assessment. It is important to know if science preservice teachers are getting proper training in doing practical work. This is because their training will determine whether the CAPS is implemented effectively in South African schools. According to Abrahams and Reiss (2012) students see practical work as being both affective and effective in terms of their enjoyment and learning of science. Therefore, knowing how effective the practical work done by science student teachers is will inevitably affect the enjoyment and learning of science by learners in the science classroom:

“Much more must be done to assist teachers in engaging their students in school science laboratory experiences in ways that optimize the potential of laboratory activities as a unique and crucial medium that promotes the learning of science concepts and procedures, the nature of science, and other important goals in science education”. (Lunetta, Hofstein& Clough, 2007, p. 433).

It is clear that practical work promotes learning of science concepts and procedures. It is important to know if science preservice teachers are getting these benefits of practical work when doing practical work as part of their training. If practical work done by science preservice teachers is not effective; then improvement in designing practical work can be done to ensure that practical work is effective.

1.3 Problem Statement

As a junior lecturer I was observing preservice teachers during their teaching experience. I observed a total of twenty preservice teachers. The aim of the observations was to provide support to the preservice teachers. Teaching experience is part of assessment and a criteria was used to check preservice teachers' performance. I observed from my school visits (twice per preservice teacher in a period of three weeks, twice a year) that most science preservice teachers do not engage learners in practical activities as part of their teaching experience. I conducted informal interviews with the preservice teachers with the aim to find out if they were comfortable (competent) doing practical work during teaching experience. Most of the preservice teachers indicated that they were not confident enough to do practical work in

schools. Part of the problem was that schools did not have functioning laboratories. That was a problem because of the importance of practical work in science teaching and learning. A personal opinion was that tertiary institutions were not preparing science preservice teachers sufficiently with regard to practical work. Therefore, I decided to focus the research, on the effectiveness of practical work done by science student teachers.

As quoted above, Ajaja (2009) argues that teachers are not trained adequately, as a result there is no use of practical work but teachers rely on textbooks for teaching science. In South Africa, most teachers who I met continue to ignore practical laboratory activities and only engage in them for purposes of continuous assessment. Thus, learners only get to grapple with the complex manipulative, organizational and cognitive skills involved in practical work, when they are being assessed. This of course can affect their continuous assessment marks (since practical work is part of formal assessment) and lowers the national performance level in physical science. This problem needs to be addressed.

1.4.1 Research Questions

The research focused on the effectiveness of practical work done by preservice teachers as part of their training. The study classified practical work as a measure of impact. To arrive at the measure of effectiveness, the study focused on; a) The connection between practical work and content knowledge taught (relevance criteria); b) the design of practical activities, so that they test specific skills (validity criteria) and c) the mapping out of such skills so that they represent the full domain of skills required to be a competent science teacher and to be aligned with the CAPS document. To better satisfy these requirements the study was guided by the following sub-questions

- ☐ What type of practical work do science preservice teachers do?
- ☐ How do science student teachers relate practical work to the concepts being taught in lectures?
- ☐ To what extent do the practical tasks enable the science student teachers to do/ learn the things the lecturer intended them to do/learn?
- ☐ To what extent do the practical tasks done by science student teachers align with practical work specified in the CAPS document?

In order to answer the above questions, it was necessary to review literature related to this study. The next chapter, therefore, reviews the relevant literature.

Chapter Two

Literature Review

2.0 Introduction

This chapter reviews literature that is significant to this study. The chapter starts by reviewing literature on: 1) historical use of practical work, 2) definitions of practical work, its role in teaching and learning, 3) the effectiveness and purpose of practical work, 4) how practical work should be used, 5) types of practical work, and 6) challenges in using practical work in teaching science. Finally, the chapter presents the conceptual and analytical framework of the study, arising out of the literature review.

2.1 Historical use of Practical Work

Practical work is not a new thing in science classroom. Hofstein & Lunetta (1982) mention that science classroom laboratories have been a tool by teachers for a long time in teaching learners concrete aspects of science. In this context concrete mean not abstract. Therefore, the idea of practical work in the teaching and learning of science is not a new idea. South African curriculum advocates for the use of practical work. Hodson (1990) indicates that, since 1883, science instruction has been delivered with experimentation by the Education Departments in New Zealand, the UK and Australia. Practical work has, thus, long been part of science classroom teaching in many countries. Teacher education for science preservice teachers in South Africa still include a component of practical work.

Research shows that practical work was not used effectively in the past. Hodson (1990) argues that most teachers used practical work without thinking; this was because teachers did not understand the main purposes of practical work in learning and teaching. Hence teachers did not use it effectively. Studies have shown that this problem persists to this day (Stoffels, 2005; Abrahams & Millar, 2008). Some South African schools do not use practical work in the learning of science as it was argued by Ajaja (2009) that teachers are not trained adequately, as a result there is no use of practical work but teachers rely on textbooks for teaching science. The next section looks at how practical work is defined by different authors.

2.2 What is Practical Work?

Different authors have different ways of defining practical work. According to Tsai (2003, p. 847) practical work in school science means laboratory based experiences. For this definition laboratory equipment (apparatus, chemicals, etc.) is needed in order for practical work to happen. Millar (2004) defined practical work as learning and teaching activity which at some point involves learners manipulating or observing materials. Clough, Lunetta and Hofstein (2007) define practical work as “...learning experiences in which students interact with materials or with secondary source of data to understand the natural world” (p.394). Both definitions point out that learners interact or manipulate materials. Stoffels (2005) argues that practical work is those teaching and learning situations that offer learners opportunities to practice the process of investigating. This definition assumes that the process of investigation is already known by students, and that practical work is merely practice. CAPS as mentioned before require investigation to be part of learner assessment tasks. According to Stoffels (2005), it seems practical work involves hands-on and ‘minds-on’ practical learning opportunities where learners practice and develop various process skills including hypothesizing, observation, interpreting, predicting, problem solving, communicating, and drawing and evaluating conclusions (Stoffels, 2005). Such skills need to be communicated to learners and preservice teachers as outcomes of a practical activity.

According to Hodson (1998), practical work means laboratory based work that involves experimentation. This suggests that experiments are viewed as a kind of practical work. Preservice teachers must be involved in this kind laboratory based work in order to develop other process skills as measuring, controlling variables, inferring and formulating models. Practical work is considered as learning and teaching tool in science that involves learners handling objects and tools they are studying (Millar et al., 1999). So this supports what Stoffels (2005) said about practical work being a hands-on practical learning. Therefore, when engaged in practical work, learners should be handling apparatus or real objects as part of their learning of science. Preservice teachers need to be able to handle apparatus themselves before they can teach learners such skill.

According to Pekmez *et al.* (2005) practical work can be defined from the perspective of the movements influencing it. The discovery learning movement depicts practical work as the means for discovery learning wherein learners develop their thinking. Through investigations, CAPS aim to promote discovery learning. It is important for preservice teachers to be introduced to discovery

learning as part of their training. The process approach movement depicts practical work as the way of teaching that will give opportunities to learners to practice what scientists do when they are acting as scientists. From this perspective practical work is not directed by the content. In addition to content the learners are initiated to the scientific community. From the perspective of the investigation movement practical work is seen in a more holistic light. As Pekmez *et al.* (2005:11) note, “learners have to be thinking about what lies behind what they are doing rather than simply applying a practiced process”. So giving preservice teachers set of instructions to follow when doing practical activity without focusing on what lies behind what they are doing will not develop their investigative skills. It is important to focus beyond the aim of a specific experiment. Rather the purpose of the experiment must be clearly stated for preservice teachers.

The type of practical work advocated by CAPS should include “experiments”, “practical activities” and “practical investigations”, as explained in Chapter 1. “Experiments” are similar to the process approach movement. The investigation movement practical work is similar to what CAPS call “practical investigation”. The discovery learning movement is similar to what CAPS calls “practical activities”.

2.3 Roles and Purpose of Practical Work

The role of practical work in science teaching is, “to encourage accurate observation and description, making phenomenon more real, arousing and maintaining interest and promoting a logical and reasoning method of thought” (Science Community Representing Education [SCORE], 2008, p. 5). It is agreed that learners enjoy doing practical activities compared to theory. Thus to maintain their interest in science practical work can be used. Practical work can also be used with the purpose of “enhancing the mastery of subject matter” (Perking-Gough, 2007, p. 93). In this sense practical work can be used to ensure that learners understand and master the subject matter of science. This kind of view was also expressed by Lunetta (1988) who stated that participating in laboratory and practical activities can play a very important role in developing scientific concepts and problem solving skills. Also Colin (1995) argued that science is concerned with increasing learners’ understanding of the natural world by observation and investigation through experiments. One of the research questions focuses on how do science student teachers relate practical work to the concepts being taught in lectures. It is important that practical activities relate to what is being taught in class. The seek to examine if this relationship exist.

The other use of practical work is for observation purposes. For example, when teaching the difference between series and parallel connections in electricity, practical work can be used to demonstrate the phenomenon so that it can be observed directly by learners. Furthermore,

CAPS says that practical work plays a big role in developing skills in scientific inquiry and problem solving. The skills include, “observation, data collection, analysis and drawing conclusions” (DBE, 2011a, p. 8). It is important for preservice teachers to have these skills for effective teaching and learning of science.

The other function of practical work in the curriculum is to help students to understand the nature of science (NOS) and to adopt new scientific concepts, principles, and models (Nivalainen, Asikainen, Sormunen & Hirvonen, 2010). Practical work can help students learn about science—develop an understanding of the nature and methods of science and an awareness of the complex interactions among science, technology, society and the environment (Hodson, 1996). The construct “nature of science” has been advocated as an important goal for student studying science for approximately 100 years (Central Association of Science and Mathematics Teachers, 1907). Nature of science according to Schwartz and Lederman (2006) scientific knowledge is tentative (subject to change), empirically based (based on and/ or derived from observations of the natural world), and subjective (involves personal background, biases, and/ or is theory-laden); necessarily involves human inference, imagination, and creativity (involves the invention of explanations); is socially and culturally embedded. Through practical work preservice teachers, students and learners can understand nature of science since practical work is empirically based. The central idea about the aims of doing practical work is that learners get involved in the learning process by observing, manipulating materials to verify theory and enhancing their conceptual understanding.

Kask and Rannikmäe (2006) indicate that the purpose of practical work is to enable students to acquire and practice process skills. In this context process skills might include manipulative skills. This view of the purpose of practical work is shared by a number of authors including: Ottander and Grelsson (2006), Kapenda *et al.* (2002), Pekmez *et al.* (2005), Perking-Gough (2007), Gott and Duggan (1996) and Hodson (1990). It is therefore evident that practical work can be done with the purpose of enabling students to acquire and practice process skills.

Perking-Gough (2007) also indicates that practical work can be intended for the development of teamwork abilities. Students usually work in pairs or as part of a small group when doing practical work. Each member of the group can have a specific role within the group for the practical task to be successful. Therefore, students develop teamwork abilities whilst doing the practical work.

Practical work is not limited only to the science laboratory. Practical activities can be done outside the laboratory. Preservice teachers and learners can be involved in field work. The

above section verifies that the teaching and learning of science requires a great deal of practical work. The next section looks at the effectiveness of such practical work.

2.4 The Effectiveness of Practical Work

It is important to have a set of standards that we can use to know if practical work is effective. The literature below focuses on what different authors consider to be effective practical work. The ontology and epistemology of the teacher plays a key role in the effectiveness of practical work. The nature in which scientific knowledge is developed plays a key role in the effectiveness of practical work. Understanding the Nature of Science (NOS) and the Nature of Scientific Inquiry (NOSI) can also be a key aspect of making practical work effective. “Scientific inquiry” refers to the methods and activities that lead to the development of scientific knowledge. (Schwartz, Lederman & Crawford, 2004). For example, if the teacher does not understand the difference between *data* and *evidence* it is then likely that the practical work he/she will conduct will not be effective. However, if the teacher understands NOS and NOSI (hence the nature of practical work), he/she will be able to make practical work more effective for learners.

Abraham & Millar (2008) argue that practical work is effective in helping learners remember ideas existing behind the phenomena and the practical aspects of experiments. As a tool to assist learners to remember, practical work is effective in illustrating theories or concepts that need to be understood by learners. If learners do an experiment, they must at least in the end remember ideas behind the phenomena of the experiments. If that happens, the experiment may be regarded as having been effective.

Usually when practical work is not well planned it will not be effective in the learning of science. Abrahams and Millar (2008) argue that further problems regarding practical work may arise due to learners not understanding the instructions and procedures in situations where apparatus is inadequate, resulting in them not being able to do what the teacher intended (Abrahams & Millar, 2008). This can also be a result of teacher’s lack of content knowledge or lack of preparation by the teacher. The design of the practical manual can also contribute to learners’ misunderstandings of what ought to be done in a particular practical activity. According to Abrahams and Millar (2008), most learners fail to relate what they do in practical work to other aspects of their learning. Again, proper preparation and availability of equipment can minimize these difficulties. Practical work can only be effective if the above problems are addressed.

The next section will focus on how practical work should be used.

2.5 How should practical work be used?

It is important to know ways of using practical work so that it is effective. Millar (2004) mentions that practical work is likely to be effective “when learning objectives are clear and relatively few in number for a given task” (Millar, 2004) It is important for teachers and students to observe this because learners who have clear objectives in a practical/experiment will perform well. For example, if, a teacher provides apparatus to learners without clearly explaining the objectives of the experiment, it is likely that the experiment will not be effective in enhancing theory. Therefore, the task designed should assist learners to make links between the science theory/concepts and what is observed in the laboratory. It is also important to have few, though clearly defined objectives. The study will examine the practical manuals to check if learning objectives are clearly stated for practical activities.

“In order to implement science teaching successfully, teachers need to have a good knowledge base of the subject as well as the use of different skills to convey knowledge to learners” (Mere & Kwayisi, 2009).

This notion can also be associated with preparation from the teacher. In my experience as a lab demonstrator I noted that before a teacher conducts a practical task with students/learners, it is important to do a trial run to ensure that the experiment works. It is embarrassing for a teacher to be in the laboratory and fail to do the practical due to the lack of preparation.

It is also important for learners to make predictions and hypotheses before they do the actual practical. Sutton (1998) mentions the importance of conversation in practical work.

“...meaningful practical work, whether by scientists or by children, is always embedded in conversation, – a discussion of ideas that makes it necessary to check those ideas against experience”. (Sutton, 1998, p. 174)

Good arguments in science classrooms are important. The “*dialogical*” interpretation of argument is involved when different perspectives are being examined and the purpose is to reach agreement on acceptable claims or course of action. (Driver, Newton and Osborne, 2000). Preservice teachers need to engaged in practical activities that promotes arguments. Such practical activities involve investigations, were hypotheses will be argued and proved or disproved by conducting the investigation. Practical work can be done effectively if the learners are engaged in constructive arguments about what they predict and what they actually observe. Constructive arguments components are identified by Toulmin (1958) as:

- *Data*: these are facts that those involved in the argument appeal to in support of their claim.
- *Claim*: this is the conclusion whose merits are to be established.
- *Warrants*: these are reasons (rules, principles, etc.) that are proposed to justify the connections between the data and the knowledge claim, or conclusion.
- *Backing*: these are basic assumptions, usually taken to be commonly agreed that provide the justification for particular warrants.

Practical work done by preservice teachers need to ensure that arguments that take place in the laboratory, or during practical activities should have the components mentioned above.

The teacher should first assess learners’ prior knowledge and, if there are misconceptions, practical work can help to address those misconceptions. For example, in physics, the teacher might ask learners the relationship between current and resistance in parallel connections. Learners might predict for example that more current will flow in the branch with higher resistance. Doing a practical by connecting and measuring the current in different branches with different resistances can help the learner to realize the misconception. In that process learners will learn the concept of resistance in a circuit through practical work and their misconception will be addressed.

Ramnarain (2011) notes that in South Africa, the lack of learner autonomy results in practical work being dominated by teacher demonstrations and a ‘cookbook’ approach where learners merely follow the teacher’s direction. By creating a good learning environment, teachers can shift from the “cookbook” approach and let learners explore phenomena and original notions. Preservice teachers need to be given freedom to be involved in open-ended inquiry to increase autonomy and be involved in discovery learning. The table below provides different levels of inquiry as summarized by Bell, Smetana and Binns (2005):

Inquiry level	Description and examples
1	Confirmation —Students confirm a principle through an activity in which the <i>results are known in advance</i> . "In this investigation you will confirm that the rate of a chemical reaction increases as the temperature of the reacting materials increases. You will use effervescent antacid tablets to verify this principle. Using the following procedure, record the results as indicated, and answer the questions at the end of the activity."
2	Structured inquiry —Students investigate a teacher-presented question through a <i>prescribed procedure</i> . "In this investigation you will determine the relationship between temperature and the reaction rate of effervescent antacid tablets and water. You will use effervescent antacid tablets and water of varying temperatures. Using the following procedure, record the results as indicated, and answer the questions at the end of the activity."
3	Guided inquiry —Students investigate a teacher-presented question using <i>student designed/selected procedures</i> . "Design an investigation to answer the question: What effect will water temperature have on the rate at which an effervescent antacid tablet will react? Develop each component of the investigation including a hypothesis, procedures, data analysis, and conclusions. Implement your procedure only <i>when it has been approved by your teacher</i> ."
4	Open inquiry —Students investigate topic-related questions that are <i>student formulated through student designed/selected procedures</i> . "Design an investigation to explore and research a chemistry topic related to the concepts we have been studying during the current unit on chemical reactions. Implement your procedure only <i>when it has been approved by your teacher</i> ."

Inquiry level 3 and level 4 can assist preservice teachers to be involved in constructive argumentation and discovery learning in higher order. Preservice teachers should gradually progress from lower to higher level of inquiry over the course of the year. The design of practical manuals should consider the gradual progress of inquiry levels.

2.6 Types of practical work

Pekmez *et al.* (2005: 6) identified and described the following types of practical work for physical science:

1. Demonstrations that verify facts and principles
2. Repetition by pupils of standard qualitative experiments, e.g., ‘to show that...’
3. Repetition by pupils of standard quantitative experiments, e.g., measurement of physical constants
4. Fundamental classical experiments repeated to show crucial stages in the logical development of a principle or topic
5. Problem-solving or discovery experiments (by teacher or pupil) designed to answer a question raised in the development of the theoretical work

6. Investigation projects- problems worked out by the pupil(s); not necessarily connected in a direct way with theoretical course

7. Practical work set primarily to develop skills and techniques.” (Pekmez et al, 2005)

Brown (1995), in Kapenda *et al.* (2002:54) identifies five types of practical work which are:

1. Exercises to develop specific skills
2. Investigations including hypothesis testing or problem solving
3. Experiments to introduce students to particular phenomena
4. Demonstrations to allow the teacher to develop a scientific argument or create a dramatic impression
5. Fieldwork.

This study was mostly interested in practical work outlined by the South African curriculum; ascertaining whether preservice teachers are initiated to what CAPS advocates. CAPS mentioned four types of practical work. They are demonstrations, experiments, investigations and projects. (CAPS) (DBE, 2011a). ‘Demonstrations’ are activities done by the teacher with the aim to help in explaining certain concepts. ‘Experiments’ are a set of outlined instructions for learners to follow in order to obtain results and verify existing theories. ‘Practical investigations’ require learners to go through a scientific process. (CAPS) (DBE, 2011a).

“The scientific process requires learners to write down the aim of the investigation, formulate a hypothesis, identify the variables, design the experiment, observe and record data, analyse and interpret data and write a conclusion. A project is an integrated task that focuses on process skills, critical thinking and scientific reasoning as well as strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts. This requires learners to follow a scientific method to produce a poster, a device, a model or conduct a practical investigation (DBE, 2011a, p. 144).

The type of practical work advocated by CAPS constitutes inquiry based education. Aspects involved in inquiry based education discussed already above. Just like the use of practical work in science education, inquiry based education is an old notion. Learning by *inquiry* (NRC, 2000) is a challenge for teachers and learners (Krajcik, Mamlok, & Hug, 2001). *Inquiry* refers to different ways in which *scientists* explore the natural world, propose ideas, and explain and justify hypotheses based upon evidence derived from scientific work. It also refers to ways in which *learners* can investigate the natural world, propose ideas, and explain and justify assertions based upon evidence and, in the process, sense the spirit of science (Hofstein&Lunetta,2004).

Hodson (1993) emphasised that the focus of laboratory activities should not be limited to learning specific scientific methods or particular laboratory techniques; however, learners should use the methods and procedures of science to investigate phenomena, solve problems, and pursue inquiry and interests. To achieve this goal there must be a certain level of inquiry, which is open-ended.

2.7 Challenges in using practical work in teaching science

There are many challenges associated with using practical work in teaching. Africa is made up of developing countries, including South Africa. Developing countries have inherited a problem with resources generally. Gray (1999) argues that the lack of adequate resources in developing countries greatly affects the quality of the delivery of the science curriculum. Most schools in South Africa, especially schools in rural areas have no equipment for practical work.

Oyoo (2013) noted several factors impacted on the successful implementation of effective science education in Kenya. Among these factors is the issue of teaching resources.

It was noted that in many secondary schools, science laboratories, workshops and equipment are inadequate and the curriculum materials are in short supply. In some well-resourced schools, teachers do very few science demonstrations and almost no classroom experiments which results in learners not attaining the skills necessary for learning science.

Oyoo (2013, p. 465)

According to Oyoo, (2013), large class sizes accompanied by the shortage of equipment make the development of scientific skills impossible. These findings are similar to the South African situation. Teachers in most township schools are facing large numbers of learners in a class. Moreover, most schools do not have laboratories. Jennings and Everett (1996) found that only 23% of Black schools had laboratories in the Eastern Cape, South Africa. According to a study by Muwanga-Zake (1998) a well-equipped laboratory would stimulate learners' interest in science and ultimately improve learners' results. The study also revealed that in Grade 7-12 schools in the Eastern Cape, teachers do not use practical work because of lack of knowledge of practical skills and lack of knowledge in science concepts. This sentiment was echoed by Stoffels (2005) who asserts that shortage of equipment forces teachers to do demonstrations and limit learners to fully engage in practical work. Teachers were also found not to conduct practical activities in natural Science due to lack of knowledge. For example,

teachers who are more competent in life sciences prefer to do practical work related to life sciences rather than physics or chemistry. As a result, grade 8 and grade 9 learners in such cases are disadvantaged in understanding physics and chemistry. This is a major challenge for effective practical work because it demotivates learners and teachers.

Hattingh, Aldous and Rogan (2007), used a large sample to explore factors which correlate with the quality of practical work being undertaken. In the study 117 science teachers of grades 8 and 9 in Mpumalanga completed the revised questionnaire. Teachers were asked to estimate what percentage of their teaching time was allocated to practical work and also what percentage of their practical work teaching time was allocated to each of the different levels of practical work practices. Findings of the study showed that a large number of teachers claim to do practical work. However, according to Hattingh et.al (2007) what may seem surprising is the lack of influence of the availability of physical resources on the level of practical work. The claim is often made by teachers that their ability to do practical work is hampered by the lack of laboratories and science equipment.

Teachers play an important role in the effectiveness of practical work. Teachers' attitudes towards practical work therefore can be a barrier or a contributing factor to the effectiveness of practical work. According to Hattingh et.al. (2007), for practical work to be conducted, and the types of practical work to be used, depends, not on intentions of policy documents, but on the decisions of science teachers. It is important to initiate science teachers to meaningful practical work while they are still training to be teachers (pre-service teachers). This will enable science student teachers to develop a positive attitude to practical work which will help them to be better science teachers.

It is interesting that even though lack of resources is usually claimed to be the main challenge in doing practical work; the study done by Hattingh et.al (2007) showed that doing practical work does not depend on whether teachers have physical resources (e.g. laboratories, science apparatus or portable laboratory stations) or not. It seems that those who are motivated to do practical work will improvise and do the practical activities even in the most poorly resourced of schools. However, resources can still be a barrier to most teachers. I think this motivation can be fostered within their training sessions at University level. This study investigates preservice teacher education, scrutinizing whether there is meaningful and effective practical work done by preservice teachers. The next section will discuss the conceptual framework to be used in this research project.

2.8 The Conceptual Framework

This study uses the constructivism theory as a conceptual framework. The constructivist theory of learning is where knowledge is constructed in the minds of the learners based on their experience. (Brooks & Brooks, 1999) In simple terms, the constructivist theory of learning sees knowledge construction as resulting from learners' minds based on what they know. According to Brooks and Brooks (1999) constructivism is a theory of how knowledge is constructed and how learning occurs – not necessarily a theory about teaching. In constructivism learners actively construct or create their knowledge based on their experiences and existing knowledge. Learners have to make sense of the experiences and discourse in the science classroom and use it to construct meaning. Thus, the social environment of the individual is crucial in the construction of knowledge.

All the aspects of practical work discussed on the review of literature are aligned with the view that knowledge is constructed. Through practical work, learners/preservice teachers/students are actively involved in the construction of scientific knowledge. It can be of different levels of construction but they are actively involved. The constructivists approach is in-line with the levels of inquiry discussed above.

The idea is that learners come to lessons with ideas about the world which makes sense to them. Teachers through practical work can show learners their misconceptions and address them effectively. It is through practical work that learners can construct new knowledge and understand scientific concepts better. According to Miller (2004) the role of the teacher would be to create a learning environment (practical work) such that it involves a range of activities to encourage and support students as they attempt to construct personal meaning.

The reason for choosing the constructivism theory as a conceptual framework is that science student teachers will be constructing their own knowledge and meaning as they engage with the practical tasks given to them during their teacher training course. Part of my strategy in conducting the research was to consider knowledge creation on the part of the preservice teachers as they engaged in practical work. I observed their practical tasks and examined their practical scripts. The aim was to see whether they made meaning of what they observed in a particular practical activity and to see if they related what they did in lectures to what they did in the practical activity. That is part of knowledge construction.

It is argued that “constructivist learning usually begins with a question, a case, or a problem”

(Cooperstein & Kocavar-Weidinger, 2004, p141). This suggests that there should be some kind of investigative question in the case of practical work. For effective practical work, science preservice teachers have to begin by identifying the purpose, or the investigative question of each particular practical work session. From observations, preservice teachers should be able to construct their own knowledge and meaning of what they observe, linking it to theory and therefore to learning. The following section will discuss the analytical framework used as part of the data analysis process.

2.9 The Analytical Framework

As part of the data analysis process, I used the model of designing and evaluating the effectiveness of practical task proposed by Abraham and Millar (2008) as my analytical framework (**Figure 1**). The model looks at the effectiveness of practical work i.e. Box A: Teachers' objectives (what teachers intend learners to do), Box B: Design features of tasks (what learners actually do, what is available for them), Box C: What learners actually do and Box D: What learners actually learn (Abraham & Millar, 2008). This model will form the basis of my data analysis process.

Figure1:

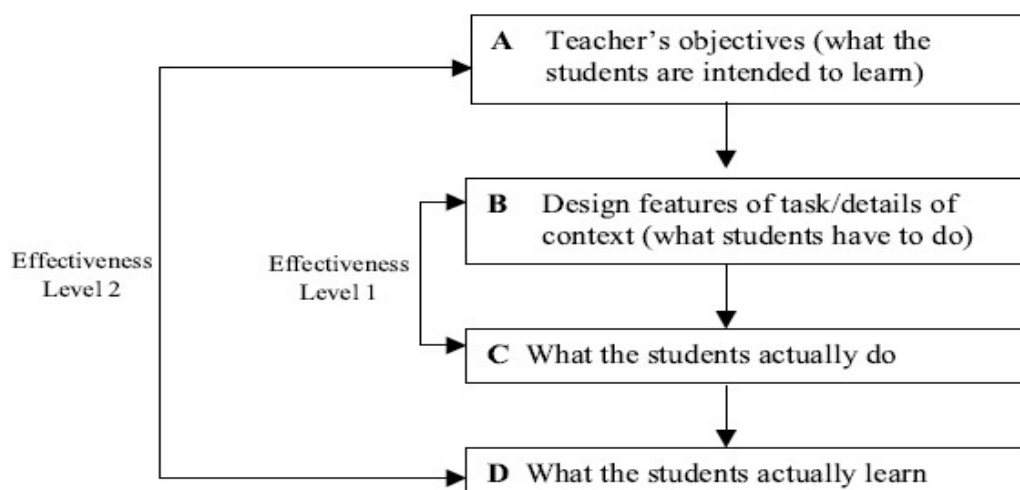


Figure 1. Model of the process of design and evaluation of a practical task

The starting point is the learning objectives that in this case the lecturer had in mind. (box A in figure 1). This will be examined by looking at the practical manuals and course packs. The learning objectives are statements of what the preservice teachers are intended to learn from that practical activity. It will be checked if they are stated explicitly in the practical manuals. The intentions of the lecturer are then translated into a practical activity: a statement of what the preservice teachers are to do in order to achieve this learning (box B).

When preservice teachers are engaged in this activity, events that occur in the laboratory can be observed. We can see what the preservice teachers actually do during the practical (box C). The actions of preservice teachers may be close to what the lecturer had in mind, or may differ from it to a greater or lesser extent. It may become very clear when we observe the practical activity that its design needs to be improved in order for preservice teachers to do what the lecturer intended. This is the basic sense of effectiveness: the match between what the lecturer intended preservice teachers to do and see and what they actually do and see. That is the relationship between box B and box C in Figure 1 labelled as ‘effectiveness level 1’

The effectiveness of the practical task looks at the extent to which the practical activity helped preservice teachers learn what the lecturer wanted them to learn. This is about the relationship between box A and box D in Figure 1, labeled ‘effectiveness level 2’. It must be stated that it is not easy to assess or measure this effectiveness level. For this study, preservice teacher’s practical scripts and course packs will be examined to establish this relationship.

Furthermore, from the model, the study ascertained whether practical work done by preservice teachers is inquiry based. This was done by examining the practical manuals. For practical work to be effective it is important that the people involved in practical work have a proper view of the nature of science. To analyse the data therefore, aspects of the nature of science were included.

2.10 Conclusion

This chapter reviewed the literature on practical work and its aspects i.e., historical, definitions, roles, effectiveness and purpose of practical work. It also looked at ways in which practical work can be used, the types of practical work and the challenges of using practical work. The chapter also discussed the conceptual and analytical framework to be used in the data analysis. The next section will discuss the research design to be used in this study.

CHAPTER 3

Research Design and Procedure

3.0 Introduction

This chapter provides an outline of how the study was carried out. The chapter focuses on all the procedures followed in collecting data. To begin the methodology used in the study will be described briefly, followed by a sample, and then there will be discussion of the research instruments including the validity and reliability of the instruments used in the study. Finally, the chapter deals with data collection methods, data analysis methods, ethical issues, and the limitations and delimitations of the study.

3.1 Research Methodology

The study is a case study which employed qualitative research design. The data is analysed using qualitative methods. Preservice teachers' views and claims about the nature of practical work were also investigated, and so were the benefits of practical work as part of teacher training. This in-depth information required qualitative methods while the non-in-depth information were presented a form of graphs. Observations, interviews and questionnaires were the instruments used in the study.

The sample of the study, the paradigm (pragmatist) and the types of research instruments used in the study permitted the use of a mixed method approach in the collected data. For this study, a small section of data is quantitative while a large section of data is qualitative. Hitchcock and Hughes (1995: 324) indicate that using more than one form of data collection to obtain data is called methodological the triangulation. The questionnaire was used to enhance the validity of the study by triangulating the quantitative data with that from the interviews. Internal validity was necessary for the study to be trustworthy and credible (Opie, 2004). The questionnaires were used to generate part of the quantitative data while the interviews and observations generated the qualitative part. The purpose of gathering data which is qualitative and quantitative was to achieve complementarity, where results from one analysis are interpreted to clarify results from the other. As already mentioned, the study was a case study; hence a wide range of data was necessary due to the limited sample. (n=57).

Opie (2004: 74) indicates that a “case study is an in-depth study of interactions of a single instance in an enclosed system”. The tertiary institution was considered to be my enclosed system. The study focused on a single group with common goals. The group included mainly preservice teachers together with laboratory demonstrators and one lecturer (more details later). Opie (2004: 74) also indicates that “crucially the focus of a case study is on a real situation, with real people in an environment often familiar to the researcher”. This was an advantage for this study on account of familiarity with the environment. Yin, in Soy (1997: 1) defines a case study as “an empirical inquiry that investigates a contemporary phenomenon within its real life context...” and Stake (2006: 2) indicates that, “qualitative studies were developed to study the experience of real cases operating in real situations”. The intention, therefore, was not to manipulate the current ways of the institution but merely to report on the situation.

It is important to mention that the study was a descriptive case study. The focus was on a certain small group and the aim was to describe the events happening within that community of practice. Hitchcock and Hughes (1995: 321) indicate that “descriptive case studies have aimed at giving a narrative account of life as it is in a social situation”. In this case study the social situation is a laboratory. The aim, therefore, was not to generalize the findings but to generate in-depth information for a particular case.

Case study methodology has its disadvantages. Bassey (2003) mentions that the problem with a case study is the generalisation from the findings of the case study might seem like reinventing the wheel. It was not the aim of this study to apply its generalised findings to other situations. Hitchcock and Hughes (1995) indicate that it is possible to generalise from case studies if one designs the research with the purpose of generalising from its findings. This study was not designed for that purpose. Bassey (2003: 36) also indicates that “one of the advantages cited for case study research is its uniqueness, its capacity for understanding complexity in particular contexts”. This advantage outweighs the criticism of generalisation.

The study is unique and it is aimed at understanding what preservice teachers do in the laboratories. Recommendations made in chapter five, however, might be useful to teacher education programs in other higher education institutions.

3.2 The research sample

The sample was influenced by the purpose and size of the study. Since it is a case study, the sample consisted of thirty (30) third year preservice science teachers and twenty-five (25) final year preservice science teachers. The sample also included one (1) lecturer and one (1) laboratory demonstrator. The total participants on the study were fifty seven (n=57). The sample consisted of mixed gender in the preservice teachers and a male lecturer. All the preservice teachers completed the questionnaires but only six (6) were interviewed (four from third year and two from final year group). The lecturer and the laboratory demonstrator did not complete the questionnaire but participated only in the interviews. The laboratories were observed and observations were recorded in a journal.

Physical science students were used for this study because the researcher was part of the laboratory demonstrators for physical sciences. It was then convenient to use physical science students. The entire third year class was used (30 preservice teachers) and entire final year class (25 fourth year students) in order not to exclude a certain group of preservice teachers. There are two lectures, one for physics and the other for chemistry. The chemistry lecturer was chosen for the study based on experience on the job. The laboratory demonstrator was also chosen due to experience in the job. The six preservice teachers who were interviewed were chosen randomly.

The following information was obtained from interviews. Lecturer (L) has been in teacher education for more than twenty years. He lectures chemistry and teaching methodology from first year students up to final year students. Lecturer (L) is also involved with post graduate students from honours up to Ph.D level students. Lecturer (L) has a Ph.D as his highest qualification and he is now a full professor at the university. The laboratory demonstrator has a B.Ed. degree and a B.Sc. (hon) in science education. He has been involved in laboratory demonstration for two years. Science student teachers include third year and final year students having physical sciences as the first major and maths/ life sciences as second major.

The researcher chose this sample because he was one of the laboratory demonstrators; hence there was no additional cost to me for travelling to collect data or to secure participation from

the participants. Of course the sample was also chosen because the participants are directly involved in what the researcher is trying to explore. The type of sampling employed in this study is called comprehensive sampling according to McMillan and Schumacher (2006). They indicate that a sample that is chosen based on a set of criteria is a product of comprehensive sampling.

3.3 Pilot study

Research instruments were constructed first-hand. The researcher could not find instruments suitable for the purpose of the study. Validated instruments were taken out of their purpose. Therefore, it was necessary to pilot them before collecting the actual data. When designing and piloting my instruments I went through the stages stated below: a) designing of questionnaire items and interview schedule, b) testing them out on peers, c) receiving feedback and d) modifying the items to accommodate feedback from peers.

- a) *Designing the questionnaire items and interview schedule:* Initially I used the research questions and literature reviewed to formulate questions. Most questions were extracted from the book called “Review of indicators and Instruments in the context of Inquiry-Based Science Teaching (Heinz, Lipowaski, Groschner and Seidel, 2011). Questions were modified to suit the current study. The questionnaire had ten sections including questions which required participants to write short paragraphs when responding. I wanted to get a general perception about practical work from science student teachers. The interview schedules were designed to capture the ideas of participants about practical work. The questions asked participants to relate to the key aspects of the research questions.
- b) *Testing them out on peers:* The questionnaire was administered to a group of third year and final year students to check if they were easy to fill and they provide relevant data. The students responded to the questionnaire but not all questions were answered. Questions to be answered required short answers and ticking appropriate boxes. (Generally, participants ignored questions requiring long answers.) Most questions provided a “yes” or “no” answer which was not ideal for analysis. I asked participants for feedback after answering the questionnaire. The results of the testing did not satisfy the aims of the study because they were not providing details as required in a case study. My supervisor was asked to comment on how the instruments might be

improved. The number of questions and the type of questions was decided after reviewing feedback from the trial participants and consultation with my supervisor.

c) *Receiving feedback:* My supervisor assisted with the refinement of the instruments after the pilot process. Some of the feedback given by the supervisor was that: 1) The questionnaires were too long and required too much writing; 2) The questions in the interview schedules were vague and 3) most questions required a “yes” or “no” answers which was going to limit responses from respondents. The group of trial student told me that they could not understand some of the question because they were too long.

d) *Modifying the items to accommodate feedback from peers:* The questions that required writing in the questionnaire were restructured so that respondents could tick an appropriate answer. The questionnaire was reduced to accommodate only six sections. Questions from the interview schedule were modified so that they required details rather than a “yes” or “no” answer. Questions were shortened and restructured so that they were clear and provides participants scope to express their views. Below is an example of altered questions:

From: Do you give your students freedom to investigate problems of their own choosing?
Which requires “yes” or “no”, to: How much freedom would you give your students to investigate problems of their own choosing?

The main reason for piloting the instruments was for the validity of my findings. Wellington, cited in Opie (2004: 68), indicates that, “validity refers to the degree to which a method, a test or a research tool actually measures what it is supposed to measure”. Piloting the study was undertaken to validate the instruments since they were newly constructed. White (2002:69) indicates that:

In all cases it is essential that newly constructed instruments, i.e. in their semi-final form, be thoroughly pilot-tested before being utilised in the main investigation. That ensures that errors of whatever nature can be rectified immediately at little cost. It does not matter how effective the sampling or analysis of the results is, it remains a fact that ambiguous questions lead to non-comparable responses; leading questions lead to biased responses; and vague questions lead to vague answers.

The pilot study was done when the instruments were on their semi-final form. The pilot study also presented an opportunity to deal with contextual factors like the power relationship (Opie, 2004) between the researcher and the interviewee. I got a chance to rectify the

instruments with the help of my supervisor and was able to establish relationships with potential participants.

3.4 Research procedures

The study employed two data collection instruments, i.e. interview schedules and questionnaires. Structured interviews were used to collect data from laboratory demonstrators and a lecturer. Interview schedule was used to collect data during the interviews with the lecturer. I interviewed four third year students and two final year students. Both closed and open ended questions were used during interviews. The closed questions used on the interview schedule (biographic) focused on the personal details (e.g. Age, qualifications, etc.) of the lecturer while open ended questions focused on practical work designed by the lecturer. Finally, I administered a questionnaire to the whole sample in order to obtain their general views of practical work. Thus, I obtained the quantitative data from the questionnaire.

3.4.1 Interviews

Opie (2004: 111) indicates that:

Interviews encourage respondents to develop their own ideas, feelings, insights, expectations or attitudes and in so doing allowing the respondents to say what they think and so to do so with greater richness and spontaneity.

The interview technique was used in this research because it encourages participants to develop their own ideas, feelings and also allows them to speak their mind without being limited. Interviews give the opportunity to ask follow-up questions to get rich information. The other methods – for example observation – do not allow the liberty to obtain rich information of causality of something. An interviewer observes something and uses his subjective interpretation of why something is done but there is the possibility that an interpretation could be wrong. Moreover, different people can have different interpretation of the same observed phenomena. The disadvantage of the use of interviews is, therefore, that they are prone to subjectivity and bias on the part of the interviewer.

Interviews can be divided into three main types: structured, semi-structured and unstructured interviews. In this study, the researcher used structured interviews.

4.2 Questionnaires

The other research instrument used in this study was a questionnaire. According to Opie (2004)

“the questionnaire is the most widely used procedure for obtaining information. It is relatively economical, respondents in distant locations can be reached, the questions are standardised, anonymity can be assured, and questions can be written for specific purposes.” Opie (2004, p.95)

For this study, the respondents were not at a distance from the researcher; however the semi-structured questionnaires were helpful in ensuring anonymity and eliciting relevant responses.

The main aim of using a questionnaire for this study was to get the general view of participants on the use of practical work as opposed to teacher centred approach in their teaching of science. The questionnaire for this study was also used to get biographical information of the respondents.

The use of the above mentioned research instruments assisted in getting all the relevant information with the aim of answering the research questions. The questionnaire which was administered at the beginning of the research measured pre-service teachers' attitudes towards practical work. The interviews provided deeper insights into what pre-service teachers actually get as support when doing their laboratory practical tasks. The interviews also provided information on what pre-service teachers actually learn from the practical tasks compared to what they have been taught in the lectures. There was a separate interview schedule which aimed to get information from the lecturer. This interview aimed to find deeper insights into how the practical manuals were designed by the lecturer. This interview schedule was also designed to discover the relevance of the practical manual to the content being taught and to the CAPS document.

3.5 Validity and Reliability of the Instruments

Different authors have different definitions of validity and reliability. According to Wellington (2000), validity refers to the degree to which a method, a test or a research tool actually measures what it is supposed to measure. Reliability and validity have been discussed as indicators of effectiveness, respectively, of data-gathering processes and of the relationship between claims and data-gathering processes (Opie, 2004). The research tools for this study are all instruments designed for the purpose of ascertaining from respondents the effectiveness of practical work.

As mentioned above; to achieve a high degree of reliability a ‘test-retest’ procedure was employed. Therefore, each instrument was piloted and then used again with the same preservice teachers, after which the sets of results were compared. The decision to use two methods of data collection was motivated by the need to increase the validity and reliability of the instruments. The questionnaire was used after the interviews to test the consistency of the results obtained from the interviews.

The second reason for using two methods of collecting data was to increase trustworthiness and credibility of the study. The responses from the interviews were triangulated with the responses from the questionnaire. Similar questions appeared in both instruments and the responses compared for consistency, for the purpose of triangulation and in order to establish the credibility of the study.

3.6 Data Collection

Interviews were conducted in different venues at the university, depending on the availability of the interviewee. Letters of informed consent (Appendix A, Appendix B and Appendix C) were sent to relevant people (Lecturer, lab demonstrator and pre-service teachers) to inform them about the study and to invite them to participate. A tape recorder was used to record the interviews. In addition, as McMillan and Schumacher (2006) recommend, notes, which were also used in the data analysis, were taken during the interviews. The recorded interviews were then transcribed from spoken to written English. Grammatical errors, conversational fillers ellipses and linguistic aberrations were represented in written form as accurately as possible for the purposes of this investigation. (Appendix H up to Appendix N). Letters of informed consent were given to science student teachers who agreed to participate in answering the

questionnaire. Instructions of the questionnaire were written but the terms and conditions of answering the questionnaire were explained. Participants answered the questionnaire individually after a science class with assistance available.

Permission to conduct research

An application was made online to the University of the Witwatersrand Ethics Committee. The application was rejected on the first attempt because of ethical concerns. The committee advised changes on the following points:

Information Letter

- ☐ The length of time each of the research instruments was expected to take
- ☐ Stating that the participants could withdraw without any disadvantage
- ☐ State what kind of participation participants were consenting to.

Instrumentation

- ☐ Reduce the length of the interview
- ☐ Provide the questionnaire.

Clearance was granted by the University of Witwatersrand Ethics Committee after the above points were addressed. The head of the science department was approached for permission to conduct research using his students as participants. The purpose of the research project was explained to the head of department and he was presented with a Participant Information Sheet (Annexure A) and the information sheet and consent form (Appendix B). Permission to conduct research in the science department was granted.

Invitation of Participants

After obtaining permission from the head of department the next step was to approach the participants after a lecture to request their participation in the research project. Those who were interested remained behind and were given the information sheet for pre-service teachers (appendix B). After the information had been read to them they were asked to propose a date and time when they would be available to discuss and complete the questionnaire.

The lecturer responsible for the chemistry course in the university was approached. The reason for visiting him was explained and he was handed the information sheet (appendix C). He read the information and agreed to be interviewed. A formal appointment in his office was arranged. Next, one of the laboratory demonstrators was approached and asked to participate in the research project. After being given the information sheet and consent form (appendix D) he agreed to participate in the study.

Data collection process

Data collection began with interviews. Of the number of students who agreed to participate in the research six agreed to be interviewed. Times and places for interviews were arranged. At the outset of each interview the purpose of the study and the interviewee's understanding of the information that had been given was confirmed. The interview began and the interviewee's responses were mechanically recorded. Some clarification was given together with encouragement to provide as many details as possible. The process was repeated upon arrangement with all students. All their responses were transcribed and are provided in appendices J to O.

The lecturer was interviewed in his office. Similarly, the laboratory demonstrator was successfully interviewed. The interviewees were made comfortable during the interview so that responses to the questions would be as accurate as possible (Creswell, 2012, p. 400).

For the questionnaires arrangements were made to see the participants after they had attended a lecture. Signed consent forms were collected to ensure that all participants had agreed to participate in the research project. Where students had lost their consent forms they were issued with new ones to sign. After collecting all consent forms the researcher issued the questionnaire to the students making sure that they did not write their names in the questionnaires and that they completed them individually. Participants were given ample time to complete the questionnaire and were thanked after their contribution had been collected.

The table below summarizes the data collection methods used in the study and when used.

Data Collection Method	When it was used
Interviews	At the beginning of the research
Questionnaire	At the end of the research

Table 1: Data collection methods used

3.7 Data Analysis and interpretation

Data analysis was done in two stages. The first stage was to analyse the data obtained from the participants (interviews and questionnaire). The raw data provided perceptions of participants regarding practical work. The second stage of analysis involved examining documents. The documents were examined to check if the views of the participants relate to what the documents outline. The documents offer better evidence that can be used to answer the research questions. There are four documents analysed: 1) practical manual physical science III A (chemistry section), 2) secondary school physical science IV (chemistry laboratory manual), 3) physical science III course content, 4) physical science IV course content, 5) physics III course manual, 6) physics IV course manual, 7) preservice teachers laboratory reports (chemistry III, chemistry IV, physics III and physics IV), and 8) Curriculum and Assessment Policy Statement (CAPS) Physical Sciences.

The aim of the analysis was to discover relationships and make sense of the data. Hatch (2002: 148) indicates that “analysis means organizing and interrogating data in ways that allow researchers to see patterns, identify themes, discover relationships, develop explanations, make interpretations...”. All these procedures were performed in order to make sense of the data (Hitchcock and Hughes, 1995). Hitchcock and Hughes (1995: 299) also indicate that this can be achieved by “sorting the data into manageable units” which involves breaking data into categories. This method was employed in this study in order to address the research questions.

Research questions, conceptual framework and personal experience were used to formulate categories used to guide the analysis of data. Hatch (2002:161) calls this approach of data analysis typological analysis. Stake (1995:78) indicates that in data analysis for case studies, “often the patterns will be known in advance, drawn from research questions, serving as templates for analysis”. In addition to the patterns known in advance, new patterns emerged upon analysis of data. Those patterns were not ignored in the study. Stake (1995) also indicates that sometimes patterns emerge unexpectedly; hence it is important to go through the data for new categories.

Practical manuals and course packs were analysed to check the relationship between box A and box D in Figure1. Practical manuals and laboratory scripts were analysed to check the

relationship between box B and box C in Figure 1. Curriculum and Assessment Policy Statement (CAPS) Physical Sciences and practical manuals were analysed to check if the practical done by preservice teachers are relevant to what CAPS advocates.

3.8 Ethical Issues

All the participants of this study were informed of the objectives of the study before they participated in it. Consent forms were issued to all the participants and information letters were issued to them before the commencement of the study. The letters had all the relevant information and the purpose of the study. Opie (2004) indicates that if the research is only intended for the researcher to be awarded a qualification, then it is unethical to do that study. The wider benefits of the study were well highlighted in the letters.

I adhered to all ethical standards outlined by the ethics committee of the University of the Witwatersrand. The research proposal containing the relevant letters was sent to the University of the Witwatersrand ethics committee. Permission from the ethics committee was granted to conduct the study.

3.9 Limitations of the study

The relatively small sample size of the participants cannot be a fair representation of all educational institutions for teacher training. The views of participants are subjective by nature thus they cannot be generalized.

3.10 Conclusion

The above section described how the study was carried out. The section looked at all the procedures followed in collecting data. Finally the section described the sample, and then discussed the research instruments, including the validity and reliability of the instruments. The next chapter presents an analysis of the results.

Chapter 4

Results and Analysis

4.0 Introduction

The following chapter presents the results obtained from the study and the analysis of results. As mentioned in the previous chapter, a typological model and document analysis was used in the study. This chapter thus provides an outline of how the model was developed and implemented for this study. The data collected included both qualitative and quantitative data. Results therefore have both components of qualitative and quantitative. As mentioned in the previous chapter, the questionnaires were used to generate the quantitative part of the data while the interviews generated the qualitative part.

4.1 Typological model

There are essentially two types of typologies or categories that will be analysed in this chapter. The typologies are informed by the research questions and some emerged from the data. The typologies are effectiveness level 1 and effectiveness level 2. Each typology was studied in order to cover other aspects that emerged from the data and aspects covered by literature.

The first typology deals with the connection between what preservice teachers are intended to learn and what they actually learn, as highlighted in figure 1. In addition to that, all the things that practical work covers or attempts to cover were examined. Whether those things conformed with the part of the definition of science provided by the Department of Basic Education was questioned; whether physical sciences

“promote knowledge and skills in scientific enquiry and problem solving; the construction and application of scientific and technological knowledge; an understanding of the nature of science and its relation to technology, society and the environment” (DBE, 2011a, p.8).

From the data, the views of participants regarding scientific inquiry and their understanding of the nature of science and skills gained from practical work were investigated. For practical work done by preservice teachers to be effective, its relevance to the CAPS curriculum must be clear. This is because preservice teachers will be implementing the curriculum in the near future.

The purposes or roles of practical work as highlighted in chapter two are part of what was analysed from the data. If science student teachers have naïve views about the purpose of doing practical work, then the work they are engaged in is unlikely to be effective. The types of practical work advocated by CAPS and done by science student teachers ought to cover at least all the types of practical work highlighted in chapter 2. The assumption was that if science student teachers were involved in one type rather than all the types of practical work then the degree of effectiveness would decrease. The interviews were read with one typology in mind and different colors were used to identify codes from data. Table 2 summarizes all the aspects under effective level 2.

Category	Code
Effectiveness level 2	
Pre-service teachers learn what they were intended to learn	EP
The practicals are relevant to the content taught	ER
Practicals are relevant to CAPS/ Similar to those done at high school	ES
<i>Types of practical work</i>	
Demonstrations	TD
Experiments	TE
Investigations	TI
Projects	TP
<i>Roles and purposes of practical work</i>	
Encourage accurate observation and careful recording	RA
Promote simple, common sense, scientific methods of thought	RB
Develop manipulative skills	RC
Give training in problem solving	RD
Fit the requirements of practical examination regulations	RE
Elucidate the theoretical work so as to aid comprehension	RF
Verify facts and principles already taught	RG
Be an integral part of the process of finding facts by investigation and arriving at Principles	RH
Arouse and maintain interest in the subject	RI
Make physical phenomena more real through actual experience	RJ
Provide first-hand experience, so that pupils can ‘see it for themselves’ and in some cases do it themselves	PA
Test ideas by making predictions, setting up a valid test, collecting reliable evidence and relating what is found to the original idea. This practical work should be theory based	PB
Experience of ‘doing science’ through carrying out an investigation which has a degree of open-endedness	PC

Table 2: Categories and codes of effectiveness level 2

Participant's ideas based on the codes were then tallied and frequency tables generated per typology. From the interviews, quotes were provided to elaborate the ideas each participant provided in relation to a specific typology. For example, if the lecturer and four science student teachers had the same ideas about roles of practical work; the number of times they mentioned a certain "role" was counted and recorded on the frequency table. For each participant, quotes were provided to substantiate the point made. The same procedure was followed in the second typology; effectiveness level 1.

Code	Frequency of ideas from Lecturer	Frequency of ideas from lab demonstrator	Frequency of ideas from student A	Frequency of ideas from student B	Frequency of ideas from student C	Frequency of ideas from student D	Frequency of ideas from student E	Frequency of ideas from student F
EP	1							
ER	2		2	1	1	2		2
ES	2		1	1	1			
TD			2	2	2		1	1
TE	3	1	3	3	2	3	1	3
TI					1	1	1	
TP					1			
RA	1		1					
RB								
RC	1		1	1	1			
RD								
RE								
RF	1	1	1	1	1	1		
RG						1	1	1
RH								
RI	1							
RJ								
PA								
PB								
PC					1	1	1	

Table 3: Frequency of ideas of participants of effectiveness level 2

4.2 Results of effectiveness level 2

Referring to Table 3, the lecturer confirmed that science student teachers do learn what practical work intends them to learn. However, he regarded what they do as an initiation and as a way to make them confident to perform experiments when they teach. This is evident in this explanation which the lecturer gave about practical work:

Basically they do learn some theory which accompanies the practical activity in the form of pre-lab assignments and post-lab assignments; and the hope is that as result of doing that they do some learning. But essentially what I think we are achieving is simply initiating them so that they be able to confidently perform experiments when they go out to teach. (Lecturer L interview, lines 104-108, Appendix I)

To some extent, therefore, the lecturer's objectives for doing practical work are achieved as students do learn some theory and some skills. The lecturer mentioned that sometimes they develop knowledge of science process skills (Lecturer interview, lines 88-89, Appendix I). According to the lecturer, "practical work is more about teaching them the laboratory skills and trying to make them understand what happens in content lectures rather than inquiry itself." (Lecturer interview, line 38-40, Appendix I)

The connection between practical work and content knowledge taught (relevance criteria) which is mentioned in chapter 1 under research questions was well corroborated (see Table 3, code ER). Lecturer L clearly sees the link between what is done in theory and what is done during practicals. This is evident below:

We always try to make sure that there is coherence between what is done in theory and in laboratory work. But practically you find that one is always ahead of the other...sometimes the theory comes before the practicals and sometimes the practicals come before the theory. (Lecturer L interview, lines 70-73, Appendix I)

It is difficult to align what is done in theory exactly with what is done in practical activities because some theories require practical activities which are impossible to do in the laboratories. A good example would be the atomic theory. It is unrealistically expensive to have gold foils and other equipment relevant to the practical available. However, efforts are made to establish coherence. This is corroborated by student A below:

Our theory is mostly aligned with practicals and this enhanced my understanding of concepts better, however sometimes we do conduct practicals before theory is taught. (Student A interview, lines 73-75, Appendix J).

Suggestions were made by student F that it would have been better if the theory was done before the practicals. Student F stated reasons as quoted below:

An effective practical is one that is introduced before the lesson; learners cannot manipulate results to impress the teacher because in most cases the theory is not yet known. (Student F interview, lines 87-89, Appendix O)

From the frequency table, Table 3, it is evident that most preservice teachers agree that there is a connection between practical work they do and the theory they do. Preservice teachers were asked in the questionnaire if practical work enabled them to do the things they were taught in lectures. The graph below provides their responses:

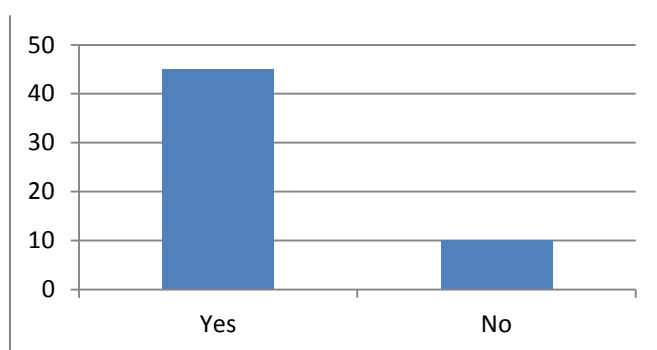


Figure 2: Graph of Preservice teachers' responses on relevance criteria.

The graph corroborates the view that practical work done by preservice teachers enables pre-service teachers to learn what they were taught in lectures. The graph illustrates that 82% of pre-service teachers agree that practical work is related to what they do in lectures whilst 18% disagree with the statement. The results answer the first two research questions.

Document analysis

In order to verify views of participants regarding effectiveness level 2, four practical manuals (2 chemistry and 2 physics) were examined. A comparison was made with the course content packs of chemistry and physics in third year and final year.

Physical science III A (chemistry section)

The aim of the course is stated clearly on the course content pack. The lectures' objectives (box A, Figure 1) for the course can be established from the aim of the course. The extract below was taken from the course content pack:

1. Introduction

This section of the course introduces students to the basic ideas and develops their understanding of selected concepts in Chemistry. It prepares students to be able to handle with confidence relevant Chemistry concepts covered in the Secondary School (Grade 10- 12) Physical Science curriculum. The teaching approach aims to develop both students' mastery of Chemistry content and appropriate pedagogical approaches in the teaching of School Chemistry. The course content will cover aspects of Organic Chemistry and Electrochemistry.

2. Course content

The objectives on the diagram aim to enhance mastery of a section of chemistry that is taught at secondary school (Grade 10-12). The content covered are organics chemistry and electrochemistry. The skills that preservice teachers are expected to gain from the course are not stated in the content manual. When examining the practical manual, every content ought to be taught has a relevant practical except for the introduction lecture. The diagram below show a table of planned practical activities with relevant content taught in lectures:

ending			
Week 1	Introduction to Organic Chemistry	Introductory lecture, What did we learn in NSII Course, Introduction to Organic Chemistry structural complexity of organic compounds and catenation	No practical for this week Go and read not play
Week 2	Organic Molecules: Functional Groups and Nomenclature	Functional Groups and Nomenclature of Organic Molecules- Classes of hydrocarbons, Aliphatic compounds- Aromatic compounds	Practical 1: Properties and Identification of Hydrocarbons
Week 3	Organic Molecules: Functional Groups and Nomenclature	Functional Groups and Nomenclature of Organic Molecules, Drawing hydrocarbons,	Practical 2: Properties and Identification of Hydrocarbons (continued)
Week 4	Isomerism in Organic compounds	Nomenclature and Introduction to Isomerism in Organic Compounds	Practical 3: Test tube reactions of alkenes
Week 5	Types of Organic Reactions and reactions of important functional groups	Aliphatic Chemistry Reactions, Alkanes, Alkenes, Alkyl Halides, Alcohols, Acids, Aldehydes, Ketones, Reaction Synthesis	Practical 4: Properties of alcohols and phenols
Week 6	Aromatic hydrocarbons and their chemistry	Introduction to Aromatic Chemistry, Nomenclature, Reactions of Aromatic Compounds, Aromatic Functional Groups and Reactions	Practical 5: Reactions of aldehydes and ketones
Week 7	Electrochemistry	Oxidation and Reduction, Balancing Redox Equations	Practical 6: Making a plastic from potato starch and investigating the effect that adding 'plasticiser' has on the properties of the polymer Practical 7: Qualitative redox reactions
Week 8	Electrochemical Reactions	Voltaic cells and concentration cells, Thermodynamics and electrochemistry, Electrochemistry -technical and analytical applications	Tutorial
Week 9	Electrochemical Reactions	Standard electrode potentials	Revision for Test 2
Week 10	Electrochemical	Free energy and electrical work and electrolytic cells	

There is a clear link between what is being taught in lectures and what is done in practical activities. If the lectures objective is to develop preservice teachers' mastery of chemistry content, then the practical activities designed are in line with the intention of the lecturer.

Physical science IV (chemistry section)

The aim of the course was clearly stated on the course pack. Knowledge, skills and attitudes were also clearly stated. The extract below show the objectives of the course (what the lecturer intended preservice teachers to learn):

Skills and attitudes to be obtained by preservice teachers are clearly stated

AIMS OF THE COURSE:
The course aims to encourage students to acquire **knowledge**, develop **skills** and **competencies**, and to develop **positive attitudes** towards Physical Science and towards the teaching and learning of Physics and Chemistry. Some of these aims are elaborated upon below.

Knowledge

Students are expected to:

- Build a framework of knowledge based on reading, observation, experience and reflection.
- Evaluate the knowledge they have acquired in the light of new information.

Skills

Students are expected to develop a variety of science related and other skills such as the ability to:

- observe accurately
- record precisely by a variety of means
- communicate information in a number of ways
- transform information in a number of ways
- apply information in a number of ways
- Recognize the application of Physical Science concepts in a variety of unique situations

Attitudes

Students are expected to

- appreciate the role of science in our everyday lives
- acknowledge the role of science in economic development
- show appreciation of and respect for all of our natural resources
- recognize the relevance of science to local, contextual and indigenous knowledge
- value science as a human activity
- understand that knowledge does not live in books. It is **constructed** by human beings
- be versatile and seek own innovative solutions to novel physical science problems using what they have learned
- Be independent and go beyond lectures in your studies

The practical activities on the practical manual and the content being taught in lecture rooms are the same:

Practical No	Practical Content
Practical 1:	Biochemistry: Making polymers
Practical 2	Organic Functional Groups
Practical 3	Organic Mechanisms
Practical 4	Chemical Change
Practical 5	Galvanic
Practical 6	Phase Equilibrium

For example practical 5 deals with galvanic cells and the content being taught before the practical is indeed electrochemistry.

Similar results were obtained when examining the physics component of both third year and final year preservice teachers. There is a clear link between the practical activities done by preservice teachers and what was intended for them to learn.

Relevance to CAPS

The other aspect of effectiveness as mentioned earlier is whether practicals are relevant to CAPS and similar to those done at high school. Lecturer L confirmed that the practicals done by pre-service teachers are relevant to the ones advocated by the CAPS document. This is evident from the following transcription from the interview:

Yes, yes of course, we try to make them to get the sort of skills and do the sort of experiments they will do in classroom situation. In fact ... err ... the current third years just done grade 10 experiments, ja, but they also do experiments which are not done in the schools. ... ja ... which are more demanding. (Lecturer L interview, line 50-53, Appendix I)

According to lecturer L, before he joined the university, pre-service teachers were doing practicals similar to those done by students who are doing BSc which were irrelevant to

teaching. (Lecturer L interview, line 95-96). Lecturer L did amendments to the practicals so that they are relevant, as evident below.

So when I joined the university I said no they are doing pracs which are irrelevant for school science. So the pracs that they must do have to be relevant to school science, not the more advanced practicals. In any case, most of them come to the university without the requisite laboratory skills or practical skills. (Lecturer L interview, line 98-101, Appendix I).

It would appear that some respondents regard practical work at university as being relevant to what is done at secondary school in compliance with CAPS. This view is corroborated by student B:

The practicals advocated by CAPS have equal value if not the same in varsity...and last week we did conservation of mass which was equivalent to the one of grade 10. (Student B interview, line 48-49, Appendix K).

The questionnaire administered also asked about the link between practical work at the university and what they will teach in the future (CAPS). The graph below provides a summary of responses from fifty five (55) pre-service teachers. The question asked was: Do you think there is a link between the practical work that you do now and what you will teach in the near future? The responses are shown on figure 3 below:

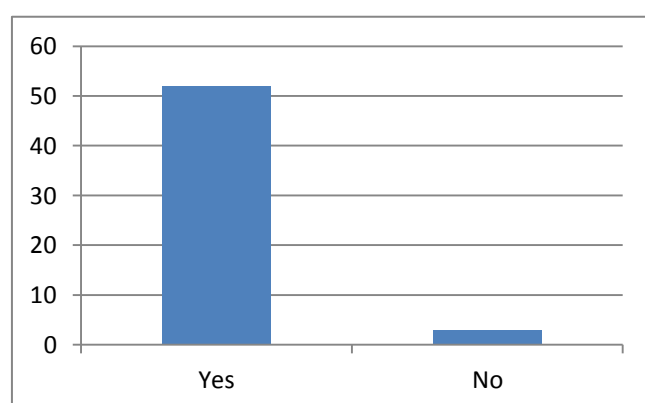


Figure 3: Graph of Preservice teachers' responses regarding CAPS relevance.

Figure 3 shows that 95% of preservice teachers think that there is a link between practical work they do at university and what they will teach at schools. One student under the 'Explain' column mentioned that he had observed on teaching experience when they visit schools that same topics covered by the practicals at university were also covered at school. The other 5% of pre-service teachers could not see the link because they teach at senior primary level.

Type of practical work

The other category in which the effectiveness of practical work is scrutinized is named ‘the type of practical work done by preservice teachers’. CAPS focuses on four types of practical work i.e. demonstrations, experiments, investigations and projects (explained in detail in chapter 2). The results in Table 3 show that the type of practical work done at the university is experiments. The only time demonstrations are mentioned in the data is when a laboratory demonstrator is doing demonstration or when pre-service teachers did it during teaching experience.

I have done demonstration for electrostatics by using balloons and rulers in a classroom due to lack of funds for a lab. (Student B interview, line 51-52, Appendix K)

It shows however that pre-service teachers are aware of demonstration as type of practical work. When asked how science can be taught as an inquiry, student A replied:

By giving learners a case study and ask them to go conduct an investigation. Err ... a fieldwork to help learners link what they learn to reality. Do demonstrations and be involved in discovery learning. (Student A interview, line 36-38, Appendix J).

It seems that the university ignored some aspects highlighted by the CAPS document. In the CAPS document, part of formal assessment practical work is broken down into three units: 1) “Practical activities” which refer to practical demonstrations, experiments or projects used to strengthen the concepts being taught; 2) “Experiment” which refers to a set of outlined instructions for learners to follow in order to obtain results to verify established theory; and 3) “Practical investigations” which require learners to go through the scientific process (CAPS) (DBE, 2011a). The data showed that the University of Witwatersrand focuses only on “experiments”.

Lecturer L confirmed that the institution does not consider “practical investigations”. The researcher asked: how much freedom would you give your students to investigate problems in the labs? The response was as follows:

Rarely do we give them freedom, the problem for investigations is normally designed, when you look at the nature of or the extent of inquiry; you are looking whether it is closed-ended, whether it is open-ended inquiry. In most teaching, the lecturer or the teacher defines the problem of investigation. But when it

is a clearly open-ended that is when you have the students coming up with the investigative problems themselves. (Lecturer L interview, line 30-35, Appendix I).

Similar responses to the same question were given by almost all the pre-service teachers interviewed.

I can say that at some point the practicals are not very flexible; we are always given prescribed practicals and would be best if they would at least give us an opportunity to conduct the experiments our own way. (Student A interview, line 43-45)

No, ah they give us the “aim”, “procedure” and instruction that we need to follow during practicals and all we do is to get results not to do our own experiments. (Student B interview, line 36-38, Appendix K)

We aren’t given much freedom because the lab manual is detailed. Everything that required to be done is written on the lab manual. I personally follow it. (Student C interview, line 27-28, Appendix L)

I will say we are given little freedom. Most of the time we just follow what the prac manual wants but we do have some freedom to do the pracs ourselves instead of looking at the demmie doing it. (Student E interview, line 36-38, Appendix N)

These are just some of the quotes from the interviews that illuminate the point that the type of practical work done does not include open-ended inquiry or investigations. Instead the only type of practical work done at the university is “experiments” which refer to a set of outlined instructions for learners to follow in order to obtain results to verify established theory. Among the objectives of this study was to find out the type of practical work done by pre-service teachers.

Lecturer L responded to the research question of type of practical work and all interviewed preservice teachers corroborated his statement:

No, most of the experiments done here are really rediscovering; rarely do we ask them to plan and investigations ja. The method is clearly outlined and they must follow the method and give results and so on and so forth. We do not ask them to propose investigations and so on. (Lecturer L interview, line 77-80, Appendix I).

When examining the CAPS document the practical activities done by learners at secondary school level are similar but of a lower level to those done at the tertiary institution. The extract below was taken from the CAPS document clearly show some of the experiment that are similar to what the third year and final year preservice teachers are doing:

Grade	Term	Prescribed Practical Activities Formal Assessment	Recommended Practical Activities Informal Assessment
12	Term1	<u>Experiment (Chemistry)</u> Preparation of esters	<u>Experiment (physics)</u> Draw a graph of position vs. time and velocity vs. time for a free falling object. AND Use the data to determine the acceleration due to gravity. OR <u>Experiment (Chemistry)</u> Reaction of alkanes and alkenes with bromine and potassium permanganate OR making a polymer like "slime" or "silly putty".
	Term 2	<u>Experiment (Chemistry)</u> How do you use the titration of oxalic acid against sodium hydroxide to determine the concentration of the sodium hydroxide? OR <u>Experiment (Physics)</u> Conservation of linear momentum.	<u>Investigation (Physics)</u> Perform simple experiments to determine the work done in walking up (or running up a flight of stairs). By timing the run and walk (same flight of stairs) one can enrich the concept of power. OR <u>Experiment (Chemistry)</u> Rate of chemical reactions with sodium sulphite and hydrochloric acid OR chemical equilibrium.

There is however a variation in the type of practical work that the preservice teachers do compare to the type done at secondary schools. Most of the formal assessment tasks are experiment with grade 10 and level having few projects and demonstrations as informal assessments.

Roles and purposes of practical work

The category effectiveness level 2 also looked at roles and purposes of practical work. The assumption here is that if one has naïve views about the roles and purposes of practical work, then it is unlikely that that can be done effectively. The results showed that the lecturer had a much broader understanding of the roles and purposes of practical work. Students, on the other hand, could only identify two roles out of the roles mentioned by literature in chapter 2. Table 3 confirms that the frequency of ideas shows code RF which deals with

elucidating the theoretical work so as to aid comprehension. This is evident in this explanation which the lecturer gave:

Experiments from the literature are said to perform four broad aims: 1) which is contested you know; an understanding of scientific knowledge itself; 2) to bring about students' interest and motivation in the subject; 3) developing science process skills, manipulative skills and 4) the understanding of the nature of science. Those are the four major aims of experiments in science. (Lecturer L interview, lines 42-46, Appendix I).

Pre-service teachers' and the lab demonstrator interviews showed knowledge of at least two roles of practical work, as evident from these statements from the interviews:

They serve as proof of scientific concepts and laws and they also help learners get understanding of content. (Students D interview, lines 36-37, Appendix M)

The role of experiment in science is to prove that scientific laws are true. (Students F interview, line 40, Appendix O)

Experiments in science supplement what you were taught in class which is theory...and that is why most students complain if the practical is not about what they have learnt in class. (Laboratory demonstrator L interview, line 28-30, Appendix P)

In summary, the results show that pre-service teachers hardly engage in the experience of 'doing science' through carrying out an investigation which has a degree of open-endedness. Instead, they are engaged in practical work that verifies what science already knows by following sets of instructions in experiments. Results also showed that practical work done by pre-service teachers is relevant to what they learn in lectures and also relevant to the CAPS document. The next part of analysis focused on effectiveness level 2.

4.3 Results of effectiveness level 1

The second typology is the effectiveness level 1. This deals with the design of practicals, and details of context, to ascertain whether student teachers actually do what they have to do. (See figure 1). The aim of this typology was to discover factors that could affect the effectiveness of practical work done by pre-service teachers. Those things might include the learning environment, resources, design of laboratory manuals and support from laboratory demonstrators. If the laboratories are well resourced and the laboratory manuals are well designed it is likely that practical work will be effective. The typology focused also on skills gained by pre-service teachers when conducting practicals.

Resources are very important to the effectiveness of practical work. Other problems regarding practical work may arise due to learners not understanding the instructions and procedures in situations where apparatus is inadequate, resulting in students not being able to do what the teacher intended (Abrahams & Millar, 2008). It was therefore important for this case study to include resources and support for pre-service teachers as part of effectiveness level

2. Table 4 summarises all the aspects under effective level 1.

Category	Code
Effectiveness level 1	
<i>Design of laboratory manuals</i>	
Instructions are clear and easy to follow	DA
Aim of practical task is clearly stated	DB
<i>Roles of laboratory demonstrators</i>	
Lab demonstrators provide support for pre-service teachers	LA
<i>Resources</i>	
Labs are well equipped with sufficient apparatus	AA

Table 4: Categories and codes of effectiveness level 1

During analysis of the questionnaire, the same procedure to effectiveness level 1 was followed. Frequency of ideas from participants was tabulated below in table 5.

Code	Frequency of ideas from Lecturer	Frequency of ideas from lab demonstrator	Frequency of ideas from student A	Frequency of ideas from student B	Frequency of ideas from student C	Frequency of ideas from student D	Frequency of ideas from student E	Frequency of ideas from student F
DA								
DB			1	1	1	1	1	
LA	1		3	1	2	2		
AA					1			1

Table 5: Frequency of ideas of participants of effectiveness level 1

As mentioned previously, the design of the laboratory manuals can contribute to the effectiveness of practical work. The lecturer was asked if he designed the laboratory manual himself. The response was:

No, I don't design my own; I just get ready-made experiments or tasks. There is really not time for that, I wish I could have more time. (Lecturer L interview, lines 55-56, Appendix I)

Ready-made laboratory manuals might not include some things that the lecturer intended to cover, but because of time constraints it is easy to use ready-made experiments. Perhaps if the lab manuals were edited, aspects of the nature of science would be included.

Table 4 provides evidence that the response regarding instructions is not in line with the statement coded DA. Pre-service teachers think the instructions on the lab manuals are not clear enough. This is evident from the interviews:

No, the lab manuals give unclear instruction. (Student B interview, line 71, Appendix K). Sometimes they aren't easy to follow and unclear. (Student C interview, line 64, Appendix L). Clear but not easy to follow, they are ambiguous. (Student D interview, line 66, Appendix M). Instructions are sometimes confusing (Student E interview, line 76, Appendix N). Sometimes they write a long story to give a simple instruction. (Student F interview, line 66, Appendix O).

Preservice teachers agree that the instructions of experiments are not always clearly stated in the laboratory manuals.

Laboratory demonstrators play a key role in the effectiveness of practical work. They are the ones who stay with preservice teachers during the actual practical. Lectures only come when required. It is therefore important to know if they are well prepared to perform this duty. Lecturer L explained their role in the interview.

They just supervise the students' pracs and assist with the manipulation of equipment. (Lecturer L interview, line 66-67, Appendix I).

Pre-service teachers also corroborate the role of laboratory demonstrators as is evident from table 4.

They always help me with setting up experiments equipment...err ...they always challenge us and they are motivating us. (Student A interview, line 69-70, Appendix J).

However, it is important to note that lab demonstrators need a little more training and development than what they currently receive. Lecturer L and the demonstrator interviewed mentioned the type of training the demonstrators get prior to assisting with practical work at the institution.

Ah most of them are not given training; they are just given an induction not necessarily training as such. It is assumed that they are students who have done

the practicals before and so on and so forth... there is no special training for lab demonstrators. (Lecturer L interview, lines 58-61, Appendix I).

The laboratory demonstrator interviewed confirmed that the training was not sufficient.

Yes, it is two hours every year. (Laboratory demonstrator interview, line 48,

Appendix P). When asked if he achieved the aims of the practicals, the lab demonstrator responded:

No, because often both students and lab demonstrators do not know what they are doing. (Laboratory demonstrator interview, line 48, Appendix P).

Laboratory resources are usually a factor that contributes to the ineffectiveness of practical work in science education. Pre-service teachers when interviewed mentioned that schools they visit during teaching experience are not well resourced in terms of laboratory equipment. It appears evident from the interviews.

Equipment sometimes restricts us err sometimes when conducting experiments we have to start with a particular section due to lack of equipment. (Student A interview, lines 62-63, Appendix J). Sometimes we find that equipment and chemicals are not sufficient and as a result we have to start the experiment by doing certain sections which sometimes we are not comfortable with. Err this inconvenience us. Some apparatus are not always in good condition. (Student A interview, line 88-91, Appendix J).

We did not have enough chemicals sometimes here at Wits, for example sodium iodide was mixed with lead nitrate accidentally and we were unable to use the lead nitrate since they said it was finished. (Student B interview, line 55-57, Appendix K)

No, sometimes we have to wait for other groups and some apparatus are limited and we have to improvise. (Student D interview, lines 73-74, Appendix M)

No, some are not available or there is a shortage. They are not always in good condition and sometimes we use other apparatus to substitute the required ones because they are not available. (Student E interview, lines 84-86, Appendix N)

All the apparatus and chemicals are in good shape, they are just not enough for larger groups. (Student F interview, lines 74-75).

The data clearly show that there is a shortage of apparatus. Literature previously showed that the shortage of time and lack of resources for practical work contribute to the challenges faced when doing practical work.

The example below shows a practical activity that was observed by the researcher. Preservice teachers encountered difficulties during this activity because preservice teachers did not understand the instructions:

Method

Arrange the apparatus as directed (see experiment G3). Make sure that the thread supported by the cork is at least 1m long. The pendulum is given a **small displacement** (less than 5 degrees one way) and time is measured for 20 swings. The **Periodic time T** is deduced. Repeat this procedure for different lengths of string l .

Results and Discussion

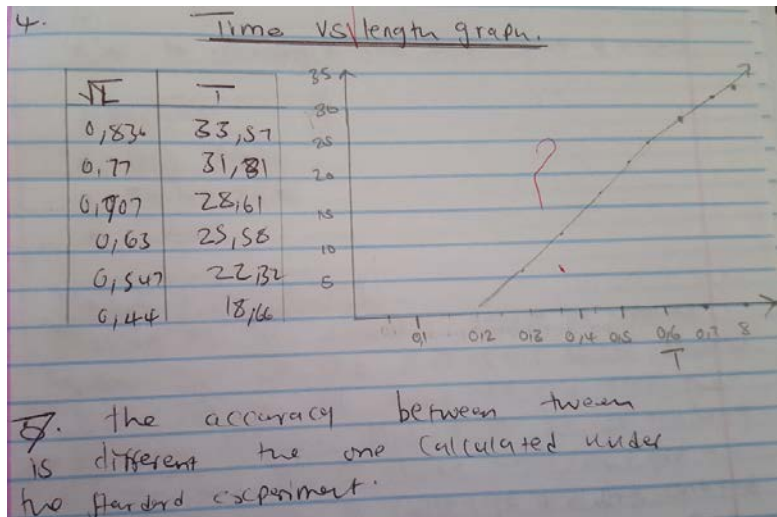
Tabulate your results as follows and answer the questions below:

Length (cm)	$\sqrt{l}$ (m)	Time for 20 oscillations				Period (T) (secs)
		t_1 (s)	t_2 (s)	t_3 (s)	t_{ave} (s)	

- Use dimensional analysis to explain why we do not need to know the mass of the pendulum bob in the calculation of g :
- Draw the set-up of the apparatus used in this experiment

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The experiment seem simple until the value of calculated g is not making sense, this was due to the lack of understanding of instructions. Most preservice teachers did not know how to deduce the period, hence the graphs did not make sense so was the value of g .



The instructions supposed to show the relationship between the time for 20 oscillations and the period (T). There are other examples of experiments (LRC circuits with CRO) were apparatus did not work properly, instructions were confusing resulting on preservice teachers being unable to do what the task intended.

In summary the results showed that laboratory manuals have some instructions which are not clear for preservice teachers. Results also showed that laboratory demonstrators are helpful to preservice teachers, though their training is not enough. From the data, it was evident that laboratories are well equipped but not with sufficient apparatus. Other aspects (knowledge of NOS, general perception of pre-service teachers, etc.) were collected using the questionnaire as an instrument. A summary of the results is given below.

4.4 Summary of Quantitative Results

The questionnaire was designed so that participants could indicate “agree”, “neutral”, or “disagree” with certain statements. The summary of statements is given in Table 6 below.

Statements	Code
There is NO difference between scientific theory and scientific law	NOS
Data are the same thing as evidence	NOSI
Confident when conducting practicals	CA
Stressed and frustrated when doing practicals	SF
I always see the link between practicals done and theory taught	PT
I gain skills of handling apparatus	HA
I gain skills of data analysis	AD
I gain skills of report writing	RW

Table 6: Summary of statements from the questionnaire.

The number of participants who agreed with the above statements was recorded and the bar graph in figure 5 was created to summarise their views.

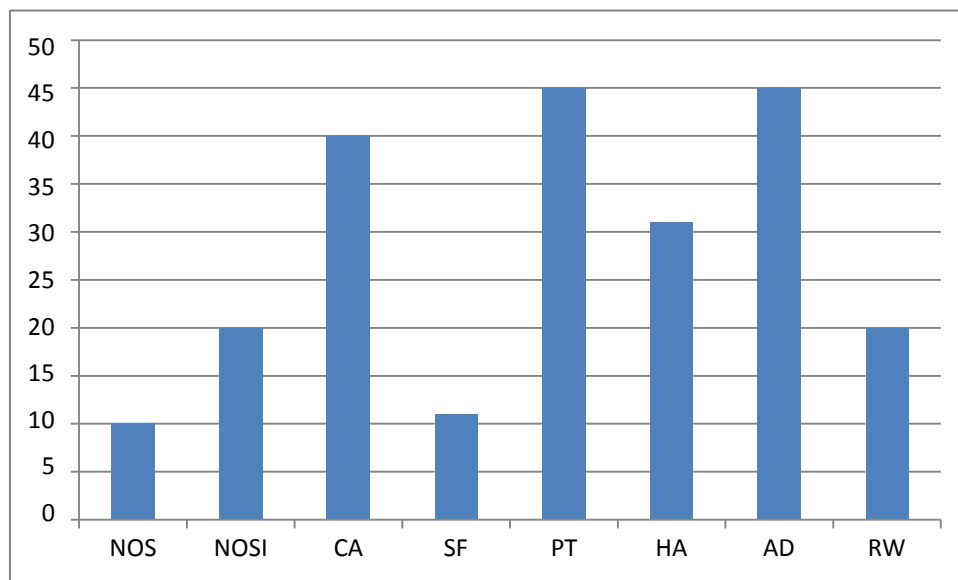


Figure 4: Number of participants that agreed to statements given in table 6

The data showed that 18% of pre-service teachers who answered the questionnaire agree that there is no difference between scientific theory and scientific law. This means that 18% of pre-service teachers have a rather naïve view of the nature of science. Of course, one question on the nature of science cannot fully determine their views on the subject. Perhaps further research should be conducted to find out their understanding of the nature of science. Thirty six percent of preservice teachers think that data is the same as evidence. This shows that they do not fully understand the nature of scientific inquiry. However, a generalisation is impossible since there was only one statement related to the nature of scientific inquiry.

It is evident from the data that in this sample 73% of pre-service teachers felt confident when conducting practicals. 20% of pre-service teachers felt stressed and frustrated when doing practical work. As it was noted in the findings of effectiveness level 2, 82% of the sample of preservice teachers agrees that they always see the link between practicals done and theory taught.

Preservice teachers were asked to list skills that they gained when doing practical work. 56% of preservice teachers wrote that they gained skills of handling apparatus, 82% wrote that they gained skills of data analysis and 36% gained skills in report writing. Some of them had a combination of all the skills mentioned above. The results show that the sample of pre-service teachers does get manipulative skills when doing practical work.

4.5 Analysis of Results

The results obtained above were analysed using the theory explained in chapters one and two. The following section attempts to make inferences from the data. The inferences made are supported by the literature. The section tried to analyse what the participants said, as well as what they failed to mention.

Effectiveness level 2

According to Pekmez *et al.* (2005) practical work can be defined from the perspective of the movements influencing it. Lecturer L shared the same sentiment as Pekmez when he mentioned that it depends on what you want to achieve when doing practical work. The aspect of preservice teachers being able to learn what they were intended to learn depends on what was intended by the lecturer or the particular practical. The intention of the lecturer for

depicts practical work as the means for discovery learning wherein learners develop their thinking. The practical work manual (Educ 3015 practicals, 2016) has post-lab questions related to the practical. Part of the intention of the lecturer is to encourage students to think about what lies behind the practical. “Learners have to be thinking about what lies behind what they are doing rather than simply applying a practiced process” (Pekmez *et al.* 2005: 11). The study did not investigate whether or not students achieved this.

The study did, however, manage to cover aspects of practical work relevant to the content taught. Practical work can be offered with the purpose of “enhancing the mastery of subject matter” (Perking-Gough, 2007, p. 93). Responses from Lecturer L are evident that the practical work done by pre-service teachers tries to enhance the mastery of subject matter. Pre-service teachers also agreed that there is a link between what they do in lectures and what they do in the laboratories. This brings us to the type of practical work that pre-service teachers do.

The type of practical work advocated by CAPS is inquiry based education. *Inquiry* refers to diverse ways in which *scientists* study the natural world, propose ideas, and explain and justify assertions based upon evidence derived from scientific work. It also refers to more authentic ways in which *learners* can investigate the natural world, propose ideas, and explain and justify assertions based upon evidence and, in the process, sense the spirit of science (Hofstein & Lunetta, 2004). It does not appear that the university achieved the type of practical work advocated by CAPS. Results showed that preservice teachers are engaged in one type of practical work, namely “experiments”. However, results showed that schools are also doing the same type of practical work (experiments).

The function of practical work within both university and school curricula is to help students understand the nature of science (NOS) and to adopt new scientific concepts, principles, and models (Nivalainen, Asikainen, Sormunen & Hirvonen, 2010). This view is also mentioned by the CAPS document.

“Physical Sciences promote knowledge and skills in scientific enquiry and problem solving; the construction and application of scientific and technological knowledge; an understanding of the nature of science and its relation to technology, society and the environment” (DBE, 2011a, p.8).

The study tried to elicit pre-service teachers’ views on NOS. The findings showed that 18% of pre-service teachers have a rather naïve view of nature of science. The study did not focus

much on NOS but Lecturer L confirmed that practical work done by pre-service teachers did not include the nature of science. He was asked if the practicals included a certain level of nature of science and his response was:

Occasionally we give them assignments about nature of science but those assignments are not necessarily related to laboratory work. (Lecturer L interview, line 111-114, Appendix I)

This may indicate that what CAPS advocate for practical work is not well followed by the implementers of the curriculum. Of course the university does not have to follow the CAPS document as it is because it has its own curriculum to follow. However, pre-service teachers will be expected to teach the curriculum taught in schools. The study attempted to find the relationship between the practicals offered to pre-service teachers and the practicals offered to schools. Perhaps more research should be done to inquire whether schools implement the curriculum successfully and, if not, what challenges they face.

Types of practical work

The literature identifies several types of practical work. Lecturer L mentioned that pre-service teachers are mostly offered one type of practical work. Hodson (1993) emphasized that the principal focus of laboratory activities should not be limited to learning specific scientific methods or particular laboratory techniques. Instead, students in the laboratory should use the methods and procedures of science to investigate phenomena, solve problems, and pursue inquiry and interests. The study showed that pre-service teachers are offered practical work which is limited to the rediscovery of what is already known. This is not bad as it prepares pre-service teachers to introduce their learners to the scientific community. However, by focusing on one type of practical work, preservice teachers end up not knowing the other types and their importance. Results showed that demonstrations are introduced to pre-service teachers by lab demonstrators due to shortage of apparatus. This limits pre-service teachers from experiencing the real benefits of doing demonstrations. For example, pre-service teachers need to know that a teacher does not necessarily have to be in a laboratory to do demonstrations. Demonstrations are those activities done by the teacher in order to help explain certain concepts. Skills needed to demonstrate should be

part of teacher training since the primary goal of teachers is to help pupils develop as scientists and to explain scientific concepts to learners.

Roles and purposes of practical work

The role of practical work in science teaching is “to encourage accurate observation and description, making phenomena more real, arousing and maintaining interest and promoting a logical and reasoning method of thought” (Science Community Representing Education [SCORE], 2008, p. 5). Only one student from the six interviewed viewed the role of practical work as being related to encouraging accurate observation and careful recording. Arousing and maintaining interest was not mentioned by pre-service teachers interviewed. Only lecturer L commented on this aspect.

Abraham and Saglam (2010), when referring to an earlier work by Kerr (1963, p.27) identified other roles of practical work that pre-service teachers did not mention during interviews. Table 3 showed that nothing was said about the following functions of practical work: Promote simple, common sense, scientific methods of thought; give training in problem solving; fit the requirements of practical examination regulations; be an integral part of the process of finding facts by investigation and arriving at principles; and make physical phenomena more real through actual experience. Some of these roles are being achieved by practical work done by pre-service teachers. For example preservice teachers do write practical examinations so practical work done by pre-service teachers does cover the role of fitting the requirements of practical examination to regulations.

Perking-Gough (2007) also indicates that practical work can be intended for the development of teamwork abilities. The research did not cover this aspect but students do achieve teamwork abilities when they are involved in practical work. Perhaps future research can look at the nature of teamwork, interactions and argumentation within practical work. It is possible that meaningful interactions between those involved in practical work could be a measure of its effectiveness.

Experience of ‘doing science’ through carrying out an investigation which has a degree of open-endedness was mentioned by preservice teachers when interviewed. However, the degree of open-endedness is very low in respect of their activities. In fact, pre

service teachers do get the experience of ‘doing science’ but are involved in closed-ended type of investigations. For example, Practical 1 on the practical manual (Educ 3015 practicals, p. 1-6) ensures that preservice teachers are getting some experience of doing science. The practical is about verifying the law of Conservation of Matter. The practical is an example of closed-ended inquiry since it has a set outline to be followed. However, when following the procedures, pre-service teachers do get the experience of ‘doing science’ since they do verify the law. Perhaps if they were given freedom to come up with a hypothesis and test its validity they would have had a chance to experience ‘doing science’ in a more open-ended way.

In summary; effectiveness level 2 analysis showed that practical work done by pre-service teachers is relevant to the content being taught in lectures. Preservice teachers also agreed that the practical work they do enhances mastery of subject matter. The findings showed that CAPS do similar practical tasks that preservice teachers do, with an exception of investigations and projects. However, it was shown that preservice teachers are doing similar types of practical work as the ones done at school level. The study showed that preservice teachers are involved in one type of practical work – namely ‘experiments’. Findings showed that preservice teachers know of few roles and purposes of practical work. However, they benefit from some of the roles of practical work without them being aware of it.

Effectiveness level 1

Design of laboratory manuals

Further problems regarding practical work may arise due to learners not understanding the instructions and procedures in situations where apparatus is inadequate, resulting in them not being able to do what the teacher intended (Abrahams & Millar, 2008). The results showed that pre-service teachers have difficulties in understanding the instructions given in laboratory manuals. If preservice teachers do not understand the instructions, practical work will not be effective because they will not achieve the outcomes of the practicals if the instructions are not clear.

Millar (2004) notes that practical work is most likely to be effective when learning objectives are clear and relatively few in number for a given task. When examining the practical manual, it was evident that most of the practical tasks have clear objectives for a specific task. Preservice teachers interviewed also mentioned that the practical manual has clear objectives. Clear objectives guide the practical, making it likely to be effective.

Roles of laboratory demonstrators

Laboratory demonstrators play an important role in the effectiveness of practical work. They offer support and assistance to pre-service teachers as they perform practicals. Findings from the study showed that pre-service teachers find lab demonstrators helpful in setting up the apparatus and in demonstrating some of the practicals. However, it is possible that they could offer more assistance if their training was intensified.

Resources

According to Hofstein & Lunetta (1980) poor laboratory facilities become barriers to individual laboratory work and teachers resort to teacher demonstrations. In this case study, results showed that laboratory facilities are in good condition but inadequate for all pre-service teachers. Because of that, laboratory demonstrators sometimes do demonstrations due to lack of adequate apparatus. Pre-service teachers are then disadvantaged because they have to manipulate the apparatus and discover phenomena for themselves.

The problem of resources is evident even at school level. Most preservice teachers do not get a chance to do practical work at school level due to lack of resources. Makgato (2006) did a study focusing on factors that contribute to poor performance in maths and science and one of the findings included the use of practical work. In particular, the study showed that lack of resources contributed to poor performances. One of the points that learners complained about was the lack of laboratory equipment (Makgato, 2006). It is important for learners to be introduced to practical work at high school level. That way they will gain the skills needed to conduct practicals effectively; hence tertiary level programmes can focus on developing other set of skills and purposes of doing practical work.

4.6 Conclusion

In this section I will highlight the main issues arising out of the discussion in this chapter. There are essentially two typologies or categories that were analysed in this chapter. The typologies are effectiveness level 1 and effectiveness level 2.

Under effectiveness level 2 the main issues analysed were dealing with the connection between what science student teachers are intended to learn and what they actually learn amongst other issues. The summary of what was analysed in effectiveness level 2 is presented in Table 2. From the results it is evident that most students agree that there is a connection between practical work they do and the theory they do. Lecturer L also agreed that there is a link between what is done in theory and what is done during practicals. From the quantitative results 82% of pre-service teachers agree that practical work is related to what they do in lectures; from the whole sample 18% disagree with the statement.

The results showed that practicals done by preservice teachers currently are partially relevant to the CAPS document. The content being covered by practical work is relevant to what is being covered at high school level. However, by contrast, the type of practical work advocated by CAPS is inquiry based education which is not entirely covered by science student teachers. The study showed that pre-service teachers are offered practical work which is limited to rediscovering what is already known. Findings showed that pre- service teachers know of few roles and purposes of practical work.

For effectiveness level 1, the results showed that pre-service teachers have difficulties in understanding the instructions given in the laboratory manual. Findings from the study showed that pre-service teachers find lab demonstrators helpful in setting up the apparatus and in demonstrating some of the practicals. The results showed that the design of the laboratory manuals has instructions which are not clear for pre-service teachers. Results also showed that laboratory demonstrators are helpful to pre-service teachers, though their training is insufficient. Finally results showed that laboratory facilities are in good condition though inadequate for all pre-service teachers and also that pre-service teachers do acquire manipulative skills when doing practical work.

The next chapter presents the discussion of results and conclusion to the whole study.

Chapter 5

Discussion and conclusion

5.0 Introduction

This chapter presents the discussion and conclusion wherein an attempt is made to answer the research questions. The implications of the findings of the study for the curriculum, recommendations, and lessons learnt from the study are provided. The chapter provides a conclusion to the whole study.

5.1 Research questions

What type of practical work do science student teachers do?

It was evident from findings that science student teachers are involved in experiments which provide a set of outlined instructions for learners to follow in order for them to obtain results and verify established theory.

How do science student teachers relate practical work to the concepts being taught in lectures?

The connection between practical work and content knowledge taught (relevance criteria) was well established from the study. There is enough evidence from data to support the contention that the content taught is relevant to practical work done by preservice teachers. The theory which accompanies the practical in the form of pre-lab assignments and post-lab assignments ensure that there is a link between what science student teachers do in lectures and what they do in the laboratories. In that way, science student teachers relate practical work to the concepts being taught.

To what extent do the practical tasks enable the science student teachers to do/learn the things the lecturer intended them to do/learn?

There are different aims for doing practicals in science. For science student teachers, an important aim is to prepare them to be able to incorporate practical work in their teaching. The lecturers confirmed that they were succeeding in initiating skills in science student teachers so that they were able to confidently perform experiments when they went out to

teach. Preservice teachers also confirmed that they saw the relevance between what they did in the labs and what they would do when they began teaching. Documents that were analysed also confirmed that the practicals enabled preservice teachers to do/learn what the lecturer intended for them to do/learn.

To what extent do the practical tasks done by science student teachers align with practical work specified in the CAPS document?

The CAPS document has much to say about practical work. It is not known whether schools do what the document stipulates but it is evident that the practicals done at Wits University are similar to those done at school level. Of course, the university covers much deeper content so more difficult practicals are done as well. In any case teachers must have more knowledge and more skills than learners. There are other aspects that the CAPS document stipulates that are not covered by the university curriculum. An example would be open-ended investigations.

5.2 Implication of findings for CAPS

In the CAPS document, formal assessment practical work is broken down into three units: 1) “Practical activities” which refer to practical demonstrations, experiments or projects used to strengthen the concepts being taught; 2) “Experiment” which refers to a set of outlined instructions for learners to follow in order to obtain results to verify established theory; and 3) “Practical investigations” which require learners to go through the scientific process (CAPS) (DBE, 2011a). However, this study showed that pre-service teachers are involved only in “experiments”. They do not go through the scientific process. Pekmez *et al.* (2005: 20) indicate that, “when operating within a faulty framework, practical work could only succeed by accident rather than design”.

If secondary schools do the same type of practical work as universities then schools themselves do not implement the curriculum policy. Rogan and Grayson (2003) indicate that South Africa is in danger of falling into the trap of designing visionary and educationally sound policies for the national curriculum whilst not focusing on how to implement those policies. If curriculum policies are not implemented, learners are disadvantaged.

5.3 Recommendations

Bennett (2003: 96) indicates that, “the messages emerging from current thinking on practical work are that the emphasis needs to shift from doing to discussions.” Therefore, the university needs to shift from doing only one type of practical work to discussions on the possibility of introducing other neglected aspects of practical work. The discussions might lead to amendments, not only to the university but perhaps to the secondary schools as well. The practicals done by preservice teachers should include the following:

1. Practical work done by preservice teachers must be designed to cater for specific aims. As was mentioned by Pekmez *et al.* (2005) practical work can be defined from the perspective of the theories influencing it.
2. Some of the practicals in the manual should focus on developing manipulative skills while other practicals should focus on discovery and further investigations. This will assist preservice teachers in becoming versatile and well prepared to cover what the curriculum recommends.
3. The laboratory manuals should be re-designed so that the instructions are clear and easy to follow.
4. The first few weeks must be dedicated to introduce preservice teachers to practical work. This part of the course should include all the important aspects needed for practical work to be effective. The course might include the following topics:

- ☐ Safety issues in the lab
- ☐ Introduction to practical work
- ☐ Types of practical work
- ☐ Purposes of practical work
- ☐ Types and functions of apparatus
- ☐ How to write a laboratory report

The course might take the first two weeks before the actual practicals, where preservice teachers are initiated in all the necessary information regarding practical work. While preservice teachers are engaged in the course, lab demonstrators can be offered adequate training. The training could include similar skills as those offered to pre-service teachers.

On the issue of resources, obviously more funding is needed for more apparatus. The university should consider prioritising the raising of funds for science labs from various donors. The departments of Higher Education and Basic Education should be involved in transforming all science laboratories in the country. Science cannot be learned without effective practical work. Practical work cannot be effective without adequate resources. Therefore it should be a priority for the government to change the current state of the laboratories. An alternative solution to the shortage of apparatus is to limit the number of students enrolled for physical sciences. This would ensure that those who are enrolled have sufficient materials to do practical work.

5.4 Lessons learnt from the study

It was previously assumed that practical work could be offered only to verify scientific laws and theories. It was learned that practical work can be offered depending on the purpose of the practical. Additionally, it was learned from lecturer L that there is lot of contestation in the literature as to the benefits of practical work. For example, someone who does not understand the theory behind a titration will not benefit by performing a titration, no matter how accurate the titration may be. A number of things need to be considered for practical work to be effective.

Many factors need to be considered in order to strengthen the training of science teachers. Many types of practical work need to be catered for by the university curriculum in order to initiate student teachers into various types of practical work; since they are offered for different reasons and they have different benefits. The instructions in manuals should be in language that is clear and unambiguous. More resources should be available in laboratories to ensure that all science student teachers have a chance to be ‘hands-on’ in all practical activities

5.5 Shortcomings

Firstly, more data could have been obtained from participants if unstructured interviews had been used to collect data. Limited data was collected due to the nature of research instruments. Secondly the time frame for the entire study was limited; hence some of the

research questions were removed to save time. Lastly observations on laboratory procedures might have given more detailed data had more time been available.

5.6 Conclusion

The study focused on the effectiveness of practical work done by science student teachers in preparing to be science teachers. The main purpose of the study was to evaluate the effectiveness of the practical tasks done by the science student teachers as part of their teacher training. The study was conducted because practical work plays an important role in the teaching and learning of science. The study aimed to assist teacher educators in designing practical tasks which are useful and effective in the teaching and learning of science both in tertiary level and high school level.

The study focused on; a) The connection between practical work and content knowledge taught (relevance criteria); b) the design of practical activities, so that they test specific skills (validity criteria) and c) the mapping out of such skills so that they represent the full domain of skills required of a competent science teacher when aligned with the CAPS document.

Literature related to the study was reviewed. It included the following aspects: 1) historical use of practical work, 2) definitions of practical work and its role in teaching and learning, 3) the effectiveness and purpose of practical work, 4) how practical work should be used, 5) types of practical work, and 6) challenges in using practical work in teaching science.

The study showed that practical work done by pre-service was effective to some extent. Practical work was effective because it was closely related to the content being taught in lectures. The study showed that practical work done by preservice teachers was similar to what was being done at high school level; however it did not cover all the aspects that the CAPS document advocates. Nonetheless, the study showed that preservice teachers are involved in meaningful practical work.

The study showed that there are challenges faced by pre-service teachers when doing practical work. Some of the challenges include shortage of equipment and unclear instructions of laboratory manuals. Suggestions were provided to overcome these challenges.

The study aimed to shed light on issues related to the effectiveness of practical work done by preservice teachers for the benefit of stakeholders involved in practical work. It appears, however, that further studies should be conducted on ways to improve the effectiveness of practical work both in tertiary institutions and high schools. The study was useful because it raised awareness of many components involved in practical work in science education that may have been previously overlooked.

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APPENDICES

Appendix A: LETTER TO THE HEAD OF SCHOOL/ Head of Division. 20 April 2015

Dear _____

My name is *Thabo Mkalipi* I am a Masters student in the School of Education at the University of the Witwatersrand. I am doing research on *The effectiveness of practical work done by pre-service teachers as part of their training*.

My research involves a study of practical work used by pre- service physical science teachers, in particular during the training of becoming of physical science educators. I believe that science teaching will be far more successful if teachers use practical work as part of their teaching and also if they have the culture of linking the content learnt in science classrooms to the practical tasks done by the learners. So this research project seek to find out if the practical work done by pre-service teachers is effective or not.

The reason why I have chosen this Division is because it has strong focus on teacher education, and in particular, physical science teachers. In addition, most of the School of Education's graduates teach in rural and urban areas. It is of great interest therefore to see how the School of Education is preparing its teachers to teach quality science through practical work.

I am inviting your division to participate in this exciting venture. I plan to visit the division every week to observe your 3rd and 4th year students doing physics practical work. The names of the research participants and identity of the university, the school and the Division will be kept confidential at all times and in all academic writing about the study. The Division's privacy will be maintained in all published and written data resulting from the study. All research data will be destroyed between 3-5 years after completion of the project.

Please let me know if you require any further information. I look forward to your response as soon as is convenient.

Yours sincerely,

Thabo Mkalipi

Dear Student

My name is *Thabo Mkalipi* and I am an MSc student in the School of Education at the University of the Witwatersrand.

I am doing research on: **The effectiveness of practical work done by pre-service teachers as part of their training.** My research is concerned with the use and effectiveness of practical work that you do as part of your teacher training course. I believe that science teaching will be far more successful if teachers use practical work as part of their teaching and also if they have the culture of linking the content learnt in science classrooms to the practical tasks done by the learners. It is important thus to know your views as a student on the effectiveness of practical work that you do. In this study, I will observe your physics practical sessions and make some notes in what I observe. I will also like to interview some of you.

I would like to ask for your permission to participate in these observations and interviews sessions weekly. I will also not use your name, but will make one up so that if I comment on what you say in the interview, no one will be able to know that it is you.

However, please remember that you will not be forced to participate. If you decide halfway through that you do not want to continue with the study, this is completely your choice and will not affect you negatively in any way. All information about you will be kept confidential in all my writing about the study. Also, all collected information will be stored safely and destroyed between 3-5 years after I have completed my project.

I look forward to working with you! Please feel free to contact me if you have any questions.

Yours sincerely,

Thabo Mkalipi

Student Consent Form

Please fill in the reply slip below if to indicate your willingness to participate in my study called:

My name is: _____

Circle one

Permission to observe you in class

I agree to fill in a questionnaire. YES/NO

I agree to be interviewed YES/NO

I understand that I do not have to answer all the questions YES/NO

Informed Consent

I understand that:

- ☐ My name and information will be kept confidential and safe and that my name and the name of the university will not be revealed.
- ☐ All the data collected during this study will be destroyed within 3-5 years after completion of the project.

Sign_____ Date_____

Dear _____

My name is Thabo Mkalipi and I am an MSc student in the School of Education at the University of the Witwatersrand. I am doing research on: **The effectiveness of practical work done by pre-service teachers as part of their training.**

My research is concerned with the use and effectiveness of practical work that you do as part of your teacher training course. I believe that science teaching will be far more successful if teachers use practical work as part of their teaching and also if they have the culture of linking the content learnt in science classrooms to the practical tasks done by the learners. It is important thus to know your views as a lecturer in the effectiveness of practical work that you prepare for students. In this study, I will observe your physics practical sessions and make some notes in what I observe. I will be using the laboratory manual that you designed and I would like to interview you based on the laboratory work you are involved in.

This study will help shed light on the way we science teachers can implement and use practical work effectively during the teaching of science. It also aims to improve our students' understanding of the use of practical work. The benefits derived from this research may include an increased awareness of the importance, effectiveness and usefulness of the use of practical work in science classrooms and it may also shed light on nature of practical work. It will also assist you in preparing laboratory manual for the future practical work, as you will get feedback on the effectiveness of the practical work that you design.

I was wondering whether you would mind if I interview you, and your students. Your name and identity will be kept confidential at all times and in all academic writing about the study. Your individual privacy will be maintained in all published and written data resulting from the study. All research data will be destroyed between 3-5 years after completion of the project. You will not be advantaged or disadvantaged in any way. Your participation is voluntary, so you can withdraw your permission at any time during this project without any penalty. Please let me know if you require any further information.

Yours sincerely,

Thabo Mkalipi

Lecturer's Consent Form

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called:

I, _____ give my consent for the following:

Permission to observe your laboratory

Permission to be interviewed

I agree to be interviewed for this study.

YES/NO

I know that I can stop the interview at any time and don't have to

Informed Consent

I understand that:

- ☐ My name and information will be kept confidential and safe and that my name and the name of the university will not be revealed.
- ☐ I do not have to answer every question and can withdraw from the study at any time.
- ☐ All the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign_____ Date_____

Appendix D: INFORMATION SHEET LABORATORY DEMONSTRATOR 20APRIL
2015

Dear _____

My name is Thabo Mkalipi and I am an MSc student in the School of Education at the University of the Witwatersrand.

I am doing research on: **The effectiveness of practical work done by pre-service teachers as part of their training.** My research is concerned with the use and effectiveness of practical work that you do as part of your teacher training course. I believe that science teaching will be far more successful if teachers use practical work as part of their teaching and also if they have the culture of linking the content learnt in science classrooms to the practical tasks done by the learners. It is important thus to know your views as a lecturer in the effectiveness of practical work that you prepare for students. In this study I will be using the laboratory manual that you designed and I would like to interview you based on the laboratory work you are involved in.

This study will help shed light on the way we science teachers can implement and use practical work effectively during the teaching of science. It also aims to improve our students' understanding of the use of practical work. It will also assist you in preparing laboratory manual for the future practical work, as you will get feedback on the effectiveness of the practical work that you design. Your name and identity will be kept confidential at all times and in all academic writing about the study.

Your individual privacy will be maintained in all published and written data resulting from the study. All research data will be destroyed between 3-5 years after completion of the project. You will not be advantaged or disadvantaged in any way. Your participation is voluntary, so you can withdraw your permission at any time during this project without any penalty. Please let me know if you require any further information.

Thank you very much for your help.

Yours sincerely,

Thabo Mkalipi

Laboratory demonstrator Consent Form

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called:

I, _____ give my consent for the following:

I agree that you interview me YES/NO

Informed Consent

I understand that:

- ☐ My name and information will be kept confidential and safe and that my name and the name of the university will not be revealed.
- ☐ All the data collected during this study will be destroyed within 3-5 years after completion of my project.
- ☐ I can withdraw my support for the interview at any time

Sign_____ Date_____

Appendix E: **The Interview Schedule for lecturer**

Introduction

The following interview contains a total of 25 questions. The interview aims to find information on the effectiveness of practical work that your students do as a preparation to be a science teacher. Please feel free to answer the questions as best as you can. Note that all the information you provide will be part of a study, however your confidentiality will remain anonymous.

Biography

How many years have you been lecturing Sciences (Physics, Chemistry or Life science)?

What is the highest qualification that you have?

1. Tell me about your background and pre-service training.

2. Tell me about your experiences with science courses in middle-high school and college. Lab experiences? Long-term investigations?

3. Why should we teach science? What are your broad goals for teaching science

4. How do you believe students learn science best?

5. If I ask you to give me a metaphor for “scientific inquiry” what would you tell me? Explain how this relates to what scientist do (inquiry)?

6. Current reform in science education calls for teaching “science as inquiry”. Tell me, how would you teach science as inquiry? What practices in your view, account for teaching science as inquiry? What are your views of teaching science as inquiry?

7. How much freedom would you give your students to investigate problems of their own choosing?

8. In your own understanding, what is the role of experiment in science?

9. What do you understand about Inquiry Based Science, and how is Inquiry Based Science in the teacher education program?

10. Are you familiar with the CAPS document? If yes, what does the CAPS document say about practical work in science briefly?

11. What is the relationship if any between practical work that student do at tertiary level and the practical activities advocated by CAPS document?

12. Do you design your own practical tasks? If yes, what kind of resources you use to design the practicals?

13. What challenges do you face when designing practical work?

14. How do you overcome the challenges you face when doing practical tasks?

15. Do you offer training for lab demonstrators? If yes, how long is the training?

16. What are the major roles of lab demonstrators? Please explain your answer

17 What is the relationship if any, between what you do in lectures and what students in the labs?

18. Comment on the design of the lab manuals. 1) Do they have specific aims for every lab? 2) Are the instructions clear and easy to follow? 3) Do they include pre and post lab? And 4) Do you always achieve the aims of the practical? If not, what causes that?

- 1) _____
- 2) _____
- 3) _____
- 4) _____

19. Comment on apparatus and resources (chemicals, graph papers, etc.) needed to do the practical. 1) Are students provided with all the required apparatus and resources? If not, what is the course of that? 2) Are the apparatus given to students always in good condition and relevant to the practical task?

20. What type of practical work do you think you set for your students? Choose from the following (You can have more than one choice, write only A, B, C, D, E, F or all of the above): A) involves making observations; B) posing questions; C) examining books and other sources of information to see what is already known; D) planning investigations; E) reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; F) proposing answers, explanations, and predictions; and communicating the results.

21. Do the practical work that your student do involve the following: 1) “Practical activities” which refer to practical demonstrations, experiments or projects (_____) 2) “Experiment” will refer to a set of outlined instructions for learners to follow in order to obtain results to verify established theory(____); and 3) “Practical investigations” will require learners to go through the scientific process(_____)

22. In your own understanding, what type of practical can be called effective?

23 a) what is the purpose of the practical work that you give your students?

b) How do you ensure that the practical work design achieves this purpose?

24. What suggestions would you provide on ways in which science practical work can be conducted effectively in your department?

25 Is there anything you would like to add, related to anything that we talked about today?

Thank you for your participation.

Appendix F: **The Interview Schedule for third year and final year students**

Introduction

The following interview contains a total of 22 questions. The interview aims to find information on the effectiveness of practical work that you do as a preparation to be a science teacher. Please feel free to answer the questions as best as you can. Note that all the information you provide will be part of a study, however your confidentiality will remain anonymous.

1. Tell me about your experiences with science courses in middle-high school and college. Lab experiences? Long-term investigations?

2. Why should we teach science? What are your broad goals for teaching science?

3. How do you believe students learn science best?

4. If I ask you to give me a metaphor for “scientific inquiry” what would you tell me? Explain how this relates to what scientist do (inquiry)?

5. Current reform in science education calls for teaching “science as inquiry”. Tell me, how would you teach science as inquiry? What practices in your view, account for teaching science as inquiry? What are your views of teaching science as inquiry?

6. How much freedom are you given when to investigate problems of your own choice? Are you getting that freedom during your weekly practical work?

7. In your own understanding, what is the role of experiment in science?

8. What do you understand about Inquiry Based Science, and how is Inquiry Based Science in the teacher education program?

9. Are you familiar with the CAPS document? If yes, how does the CAPS what does the CAPS say about practical work in science?

10. What is the relationship if any between practical work that you do at tertiary level and the practical activities advocated by CAPS document?

11. Have you done practical work during your teaching experience? If so, how successful was it?

12. What challenges do you face when doing practical work? (Both at tertiary level and high school level)

13. How do you overcome the challenges you face when doing practical tasks?

14. How do lab demonstrators assist you when doing your weekly practical work? Explain your answer

15. What is the relationship if any, between what you do in lectures and what you do in the labs?

16. Comment on the design of the lab manuals. 1) Do they have specific aims for every lab? 2) Are the instructions clear and easy to follow? 3) Do they include pre and post lab? And 4) Do you always achieve the aims of the practical? If not, what causes that?

1) _____

2) _____

3) _____

4) _____

17. Comment on apparatus and resources (chemicals, graph papers, etc.) needed to do the practical. 1) Do you always get all the required apparatus and resources? If not, what is the course of that? 2) Are the apparatus given to you always in good condition and relevant to the practical task?

18. What type of practical work do you think you do? Choose from the following (You can have more than one choice, write only A, B, C, D, E, F or all of the above): A) involves making observations; B) posing questions; C) examining books and other sources of information to see what is already known; D) planning investigations; E) reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; F) proposing answers, explanations, and predictions; and communicating the results.

19. Do the practical work that you do involve the following: 1) “Practical activities” which refer to practical demonstrations, experiments or projects (_____) 2) “Experiment” will refer to a set of outlined instructions for learners to follow in order to obtain results to verify established theory(____); and 3) “Practical investigations” will require learners to go through the scientific process(_____)

20. In your own understanding, what type of practical can be called effective?

21. What skills (being able to do what) will contribute to the effectiveness/ ineffectiveness of practical work?

22. What suggestions would you provide on ways in which science practical work can be conducted effectively in your department?

Thank you for your participation.

Appendix G: **The Interview Schedule for Lab demonstrator**

Introduction

The following interview contains a total of 24 questions. The interview aims to find information on the effectiveness of practical work that your students do as a preparation to be a science teacher. Please feel free to answer the questions as best as you can. Note that all the information you provide will be part of a study, however your confidentiality will remain anonymous.

Biography

How many years have you been lecturing Sciences (Physics, Chemistry or Life science)?

What is the highest qualification that you have?

1. Tell me about your background and pre-service training.

2. Tell me about your experiences with science courses in middle-high school and college. Lab experiences? Long-term investigations?

3. Why should we teach science? What are your broad goals for teaching science

4. How do you believe students learn science best?

5. If I ask you to give me a metaphor for “scientific inquiry” what would you tell me?
Explain how this relates to what scientist do (inquiry)?

6. Current reform in science education calls for teaching “science as inquiry”. Tell me, how would you teach science as inquiry? What practices in your view, account for teaching science as inquiry? What are your views of teaching science as inquiry?

7. How much freedom is given to students to investigate problems of their own choice?

8. In your own understanding, what is the role of experiment in science?

9. What do you understand about Inquiry Based Science, and how is Inquiry Based Science in the teacher education program?

10. Are you familiar with the CAPS document? If yes, what does the CAPS document say about practical work in science briefly?

11. What is the relationship if any between practical work that student do at tertiary level and the practical activities advocated by CAPS document?

12. What challenges do you face when supervising students during practical work?

13. How do you overcome the challenges?

14. Are you being offered training to be a lab demonstrator? If yes, how long is the training?

16. What are the major roles of lab demonstrators? Please explain your answer

17. Comment on the design of the lab manuals. 1) Do they have specific aims for every lab? 2) Are the instructions clear and easy to follow? 3) Do they include pre and post lab? And 4) Do you always achieve the aims of the practical? If not, what causes that?

- 1) _____
- 2) _____
- 3) _____
- 4) _____

18. Comment on apparatus and resources (chemicals, graph papers, etc.) needed to do the practical. 1) Are students provided with all the required apparatus and resources? If not, what is the course of that? 2) Are the apparatus given to students always in good condition and relevant to the practical task?

19. What type of practical work do you think you set for your students? Choose from the following (You can have more than one choice, write only A, B, C, D, E, F or all of the above): A) involves making observations; B) posing questions; C) examining books and other sources of information to see what is already known; D) planning investigations; E) reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; F) proposing answers, explanations, and predictions; and communicating the results.

20. Do the practical work that your student do involve the following: 1) “Practical activities” which refer to practical demonstrations, experiments or projects (_____) 2) “Experiment” will refer to a set of outlined instructions for learners to follow in order to obtain results to verify established theory(____); and 3) “Practical investigations” will require learners to go through the scientific process(_____)

21. In your own understanding, what type of practical can be called effective?

22 a) what is the purpose of the practical work that you give your students?

b) How do you ensure that the practical work design achieves this purpose?

23. What suggestions would you provide on ways in which science practical work can be conducted effectively in your department?

24 Is there anything you would like to add, related to anything that we talked about today?

Thank you for your participation.

Appendix H: The Questionnaire for Students (third and final year)

Instructions

- ☐ Please answer the following questions as honest as possible.
- ☐ Do not write your name or your student number on the questionnaire as we want to protect your identity.

Section 0: Biography

Please tick the appropriate box

Age

Less than 20 years	21- 30 years	31- 40 years	41- 50 years	More than 51 years

Year of studying science at tertiary level

Final year	Repeating final year	Third year	Repeating third year	Second year

1. Gender

Male	Female

2. Content specialization

Physics	Chemistry	Life sciences

Section 1: Purposes attributed to practical work

Please tick the appropriate box

1.1. To what extend does practical work help you during your teaching experience?

Very helpful	Helpful sometimes	Neutral	I don't do practical work	Not helpful at all

1.2. Does the practical task enable you to do/learn the things you were taught in lectures?

Yes	No

1.3. Do you think there is a link between the practical work that you do now and what you will teach in the near future?

Yes	No
Explain	Explain

1.4. Do you think the practical work that you do is inquiry based (involves making observations; posing questions; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results)

Yes	No

Please answer the following questions:

1.5 Make a list of skills that contribute to the effectiveness/non-effectiveness of practical work done by pre-service teachers

Effectiveness	Non-effectiveness

1.6 List the skills that you gain when doing practical work

Skills

Section 2: Perceptions of engagement and control

Please tick the appropriate box

3.1. When doing practical activities, you follow the practical manual.

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

3.2. When doing practical activities you use your own materials.

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

3.3. You must always make sure you refer to previous content when students engage in practical tasks.

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

3.4. I always see the link of what I learned in class with the practical activity that I do.

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

3.5. If I don't ask questions it means that I understand what I have to do.

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

3.6. I gain understanding of conceptual aspect of the practical activity.

Strong Agree	Agree	Neutral	Strongly	Disagree

			disagree	

Section 4: Subjective experience

4.1. When conducting practical activities I feel...

Organized

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

4.2. Dominant

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

4.3. Stressed

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

4.4. Frustrated

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

Section 5: General

5.1 Practical work is necessary in the teaching and learning of science

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

5.2 CAPS document advocate the use of inquiry based practical work

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

5.3 I always do what the lab manuals intended for me to do.

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

Section 6: The Nature of Science

6.1. In your own opinion, the development of scientific knowledge requires experiments.

Strongly Agree	Agree	Neutral	Strong disagree	Disagree
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6.2. Science is based on experiments.

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

6.3 There is **NO** difference between a scientific theory and a scientific law

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

6.4 There is a difference between a scientific knowledge and opinion.

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

6.5 Data is the same thing as evidence

Strongly Agree	Agree	Neutral	Strongly disagree	Disagree

Thank You.

Appendix I: Interview transcript of lecturer (L) and the researcher (R) at the university:
01/03/2016

Line No	Interview Transcript
1	R: Ok thank you for agreeing to do this interview with me. It is about the
2	effectiveness of practical work that student teachers do here at Wits, it's a case
3	study. First I just want to know; how many years have you been lecturing physical
4	sciences...in general?
5	L: In general, more than twenty years
6	R: And then, your highest qualification?
7	L: It's a PhD
8	R: Ok, I just want to know; how do you believe students learn science best?
9	L: They learn science best by studying, doing practical work, through attending
10	lectures, through err I think at college level it's mainly through them being able to
11	follow up what happens in the lectures, ja, and through completing given
12	assignments and so on.
13	R: Then I want to ask about scientific inquiry. Err, how would you teach science as
14	an inquiry? As inquiry based?
15	L: First of all we have to understand what we mean by inquiry, and student
16	participation in inquiry does not necessarily mean that they understand the nature of
17	inquiry. So there are two things there, there is scientific inquiry itself and the nature
18	of scientific inquiry. The nature of scientific inquiry is about what an individual
19	attaches the ideas, the beliefs, the dispositions an individual has towards the
20	processes of science. That is what is referred as scientific inquiry. And, inquiry
21	itself is the practice of doing science.
22	R: Then how can you teach science as inquiry? Err perhaps, what practices account
23	for teaching science as inquiry?
24	L: What practices err, you see simply engaging learners in practical work and
25	investigative activities per se, is inquiry on its own. But it does not necessarily
26	translate to their understanding what enquiry entails or the nature of scientific
27	inquiry.
28	R: So, how much freedom would you give your students to investigate problems in
29	the labs?
30	L: Rarely do we give them freedom, the problem for investigations is normally
31	designed...err when you look at the nature of or the extent of inquiry; you are
32	looking whether it is close-ended, whether it is open-ended inquiry. In most
33	teaching, the lecturer or the teacher defines the problem of investigation. But when
34	it is a clearly open-ended that is when you have the students coming up with the
35	investigative problems themselves.
36	R: Here at Wits how does that go, do they have the freedom of doing open-ended
37	inquiry?
38	L: No no no, we don't do that, it's more about teaching them the laboratory skills
39	and try to make them understand what happens in content lectures rather than

40	inquiry itself.
41	R: In your own understanding what is the role of experiments in science?
42	L: Experiments from the literature are said to perform four broad aims: 1) which is
43	contested you know; an understanding of scientific knowledge itself; 2) to bring
44	about students' interest and motivation in the subject; 3) developing science
45	process skills, manipulative skills and 4) the understanding of the nature of science.
46	Those are the four major aspects of the aims of experiments in science.
47	R: So the practicals that the students do here at Wits, is there a link between what
48	they do here at tertiary and what they will do when they are teaching the CAPS
49	curriculum?
50	L: Yes, yes of course, we try to make them to get the sort of skills and do the sort of
51	experiments they will do in classroom situation. In fact even the current third years
52	just done grade 10 experiments, ja, but they also do experiments which are not done
53	in the schools; ja which are more demanding.
54	R: do you design your own practical tasks, if yes, what resources do you use?
55	L: No, I don't design my own; I just get ready made experiments or tasks. There is
56	really not time for that, I wish I could have more time.
57	R: Then lab demonstrators; do the schools offer training for them?
58	L: Ah most of them are not given training; they are just given an induction not
59	necessarily training as such. It is assumed that they are students who have done the
60	practicals before and so on and so forth... there is no special training for lab
61	demonstrators. By lab demonstrators do you mean the demmies?
62	R: Yes, the demmies, those who work in the labs.
63	L: No although they do get some form of induction. We hold an induction every
64	year.
65	R: So their major roles, what exactly they do?
66	L: They just supervise the students' pracs and assist with the manipulation of
67	equipment.
68	R: What is the relationship, if any, between what you do in lectures and what
69	students do in the labs?
70	L: We always try to make sure that there is coherence between what is done in
71	theory and in laboratory work. But practically you find that ah one is always ahead
72	of the other...sometimes the theory comes before the pracs and sometimes the pracs
73	come before the theory.
74	R: What type of practical work do you think the students do? Does it involve
75	making observations? Posing questions? Planning investigations? Or reviewing
76	what is already known?
77	L: No, most of the experiments done here are really rediscovering; rarely do we ask
78	them to plan and investigations ja. The method is clearly outlined and they must
79	follow the method and give results and so on and so forth. We do not ask them to
80	propose investigations and so on.
81	R: In your own understanding, what type of practical can be called effective? What
82	constitute an effective practical? Is it the one where they follow set of instructions
83	or is it where they investigate?
84	L: It depends on what... I think each practical should be designed for a purpose ja.
85	There are some pracs where you simply say ok I need this prac for...remember the
86	four major roles I told you about
87	R: Yes, it could be for manipulative skills, and then you focus on that.
88	L: Yes, one could be for enhancing the understanding of theory, ja, one could be for
89	developing their science process skills. <i>Although I want to add that there is lot of</i>

90	<i>contestation in the literature as to ah the benefits of practical work. E.g. someone</i>
91	<i>does not necessarily understand the theory behind a titration by performing a</i>
92	<i>titration no matter how accurate the titration can be.</i>
93	R: What suggestions would you provide on ways in which science practicals can be
94	conducted effectively here at Wits specifically as this is a case study?
95	L: You know when I came here originally eh, most of the practicals which have
96	been done here at the school of education, the students had to go and do BSc pracs.
97	R: Ok
98	L: So when I joined the university I said no they are doing pracs which are
99	irrelevant for school science. So the pracs that they must do have to be relevant to
100	school science, not the more advanced practicals. In any case, most of them come to
101	the university without the requisite laboratory skills or practical skills.
102	R: When they are doing the pracs, do the students actually do what you intended
103	them to do or to learn what you intended them to learn?
104	L: Basically they do learn some theory which accompanies the prac in the form of
105	pre-lab assignments and post-lab assignments; and the hope is that as result of
106	doing that they do some learning. But essentially what I think we are achieving is
107	simply initiating them so that they be able to confidently perform experiments when
108	they go out to teach.
109	R: Do the pracs that they do include a certain level of nature of science? Do they
110	learn about nature of science? Do they know about nature of science?
111	L: Uhm, occasionally we give them assignments about nature of science but those
112	assignments are not necessarily related to laboratory work. In order to understand
113	the nature of science which you must distinguish from the nature of scientific
114	inquiry.
115	R: Is the anything you would like to add related to what we talked about today?
116	L: Ah, I think the area of laboratory work in science is ah received much research
117	attention in the early 70's and early 80's and so on and so forth. And people were
118	beginning to question ah was it Hudson in 1996 who started to say that laboratory
119	work in school science was distorting the nature of science. There is vast amount of
120	literature about that, but that is for someone who is interested in the research aspect
121	of the role of laboratory work in school science. For example, I think two of my
122	master's students have done research on practical work in school science and there
123	are always differences between teachers' perspectives and what the learners expect
124	from laboratory work.
125	R: Thank you very much professor for taking your time and do this interview.
126	L: I hope I was sort of helpful to you.
127	R: Yes indeed, thank you

Appendix J: Interview transcript of a student (A) and the researcher (R) at the university:
02/03/2016

Line No	Interview Transcript
1	R: Thank you very much for allowing me to come and interview you. Answer the
2	questions to the best of your ability. There is no wrong or right answer. And if there
3	is something you did not get right err you can just ask me I will clarify you. I am
4	hoping that it will be 30 minutes long only. The interview contains a total of 22
5	questions. Some follow up questions will develop as the interview proceeds. The
6	interview aims to find information on the effectiveness of practical work that you
7	do as a preparation to be a science teacher. Please feel free to answer the questions
8	as best as you can. Note that all the information you provide will be part of a study,
9	however your confidentiality will remain anonymous. Tell me about your
10	experiences with science courses in middle-high school and university.
11	A: Science was generally challenging but interesting, err the exams were more
12	difficult than what we did in class, but I liked science.
13	R: What about your laboratory experiences? Did you do long term investigations?
14	A: For life sciences, the teacher went all out to try and conduct practicals so as to
15	help us link the theory with practical; we tried as many experiments however
16	sometimes we did not have the necessary equipment. Physical science was theory
17	dominated and we had labs that were not functional.
18	R: Why should we teach science? What are your broad goals for teaching science?
19	A: Science is a discipline that views the world from a different perspective; it is not
20	based on common sense understanding of phenomena. It therefore important that
21	we learn it as this will help the community to be scientifically literate.
22	R: How do you believe learners learn science best?
23	A: When practicals are conducted, when learners conduct investigation, when there
24	are demonstrations as visual stimulants.
25	R: So it is better when they see what they are learning about?
26	A: Yes, you mostly believe what you see.
27	R: If I ask you to give me a metaphor for “scientific inquiry” what would you tell
28	me?
29	A: Scientific inquiry is like window shopping
30	R: Please explain
31	A: Well, you have to look at different options of solving a problem.
32	R: How does this relates to what scientist do?
33	A: Scientist need to make investigations, gather information and make
34	observations.
35	R: Ok, Tell me how would you teach science as inquiry?
36	A: By giving learners a case study and ask them to go conduct an investigation. Err
37	a fieldwork to help learners link what they learn to reality. Do demonstrations and
38	be involved in discovery learning.
39	R: Do you conduct investigation and what you just mentioned here at Wits?

40	A: Not really, we don't do much discovery.
41	R: How much freedom are you given to investigate problems of your own choice? I
42	mean, are you given freedom during your weekly practical work?
43	A: I can say that at some point the practicals are not very flexible; we are always
44	given prescribed practicals and would be best if they would at least give us an
45	opportunity to conduct the experiments our own way.
46	R: In your own understanding, what is the role of experiments in science?
47	A: They are very crucial in consolidating what we learnt err they help me
48	understand theory much better.
49	R: Are you familiar with the CAPS document?
50	A: Yes
51	R: What does the CAPS document say about practical work in science?
52	A: It has prescribed about 2-3 practicals to be conducted at school.
53	R: What is the relationship, if any, between practical work that you do here at Wits
54	and the practical activities advocated by CAPS document?
55	A: The practicals are perfect and relevant. They even broaden our skills and prepare
56	us thoroughly.
57	R: Have you done practical work during your teaching experience?
58	A: Always, err they always working and maximize participation after conducting
59	practicals I always feel confident about teaching science.
60	R: What challenges do you face when doing practical work? I mean both at tertiary
61	and high school level.
62	A: Equipment sometimes restricts us err sometimes when conducting experiments
63	we have to start with a particular section due to lack of equipment.
64	R: How do you overcome this challenges you face when doing practical tasks?
65	A: I always find my demonstrators being helpful, with one or two not being helpful.
66	R: So when you don't have enough equipment you do demonstrations?
67	A: Yes
68	R: How do lab demonstrators assist when doing your weekly practical work?
69	A: They always help me with setting up experiments equipment...err they always
70	challenge us and they are motivating us.
71	R: What is the relationship, if any between what you do in lectures and what you do
72	in the labs?
73	A: Our theory is mostly aligned with practicals and this enhanced my understanding
74	of concepts better, however sometimes we do conduct practicals before theory is
75	taught.
76	R: Let us talk about the lab manuals. Do the lab manuals have specific aims for
77	every lab?
78	A: Yes, but they are not always clear.
79	R: Are the instructions clear and easy to follow?
80	A: No
81	R: Do they include pre-labs and post-labs?
82	A: Yes, pre-labs and post labs are always there and give us a sense of what we have
83	to do.
84	R: Do you always achieve the aims of the practicals?
85	A: Err yes
86	R: Ah tell me about apparatus and resources needed to conduct the practicals. Do
87	you always get the apparatus required by the lab?
88	A: Sometimes we find that equipment and chemicals are not sufficient and as a
89	result we have to start the experiment by doing certain sections which sometimes

90	we are not comfortable with. Err this inconvenience us. Some apparatus are not
91	always in good condition.
92	R: What type of practical work do you think you do here at Wits? Does it involve
93	making observations? Planning investigations? Or reviewing what is already known
94	in light of experimental evidence; using tools to gather, analyze, and interpret data
95	A: It involves reviewing what is already known and sometimes it involves
96	observations.
97	R: Who does the experiments that you observe.
98	A: The lab demonstrators
99	R: Do the practical work that you do involve: 1) practical activities which refers to
100	practical demonstrations, 2) experiments which refers to set outlined instructions
101	for you to follow or 3) practical investigations which requires you to go through the
102	scientific process?
103	A: Err it involve mostly the experiments were we have a set of instructions to
104	follow.
105	R: In your own understanding, what type of practical work can be called effective?
106	A: A practical whereby we formulate our own methods on conducting experiments,
107	they must not give us methods to follow
108	R: Why do you want to formulate your own methods?
109	A: Ah in order to come up with new things you know...
110	R: What skills will contribute to the effectiveness of practical work?
111	A: Being able to handle apparatus.
112	R: What suggestions would you provide on ways in which practical work can be
113	conducted effectively here at Wits?
114	A: They must give us a chance to conduct the practical our own way.
115	R: Thank you very much for your time
116	A: Pleasure

Appendix K: Interview transcript of a student (B) and the researcher(R) at the university:
02/03/2016

Line No	Interview Transcript
1	R: Thank you very much for allowing me to come and interview you. Answer the
2	questions to the best of your ability. There is no wrong or right answer. And if there
3	is something you did not get right err you can just ask me I will clarify you. I am
4	hoping that it will be 30 minutes long only. The interview contains a total of 22
5	questions. Some follow up questions will develop as the interview proceeds. The
6	interview aims to find information on the effectiveness of practical work that you
7	do as a preparation to be a science teacher. Please feel free to answer the questions
8	as best as you can. Note that all the information you provide will be part of a study,
9	however your confidentiality will remain anonymous. Tell me about your
10	experiences with science courses in middle-high school and university.
11	B: I had bad experiences with science, it was not that fun but I liked it; I liked it
12	since primary school.
13	R: What about your laboratory experiences? Did you do long term investigations?
14	B: I had a teacher that did not attempt to do lab experiments even though we had
15	labs. Err we never did long term investigation.
16	R: Why should we teach science? What are your broad goals for teaching science?
17	B: To see my school finally uses labs for practicals and science being fun and
18	exciting for learners. I also to see my learners doing experiments and collecting
19	data.
20	R: How do you believe learners learn science best?
21	B: Visualization, experiments and collecting data while the teacher guide learners
22	through teaching to correct misconceptions and learn more.
23	R: If I ask you to give me a metaphor for “scientific inquiry” what would you tell
24	me?
25	B: Is like a baby hungry for sucking milk from the mother
26	R: Please explain
27	B: Learners want knowledge from teachers just like babies do with mothers.
28	R: How does this relates to what scientist do?
29	B: Scientist also need knowledge
30	R: Ok, Tell me how would you teach science as inquiry?
31	B: I would give learners questions to try and see how they reason, their thinking
32	and also build on what they know. Furthermore I would give learners practical tasks
33	were they try to find out what tool is best for what procedure.
34	R: How much freedom are you given to investigate problems of your own choice? I
35	mean, are you given freedom during your weekly practical work?
36	B: No, ah they give us the “aim”, “procedure” and instruction that we need to
37	follow during practicals and all we do is to get results not to do our own
38	experiments.
39	R: In your own understanding, what is the role of experiments in science?
40	B: It’s important to us because it help us understand the content knowledge to; see
41	how we figured science out.

42	R: Are you familiar with the CAPS document?
43	B: Yes
44	R: What does the CAPS document say about practical work in science?
45	B: Teachers have to do practicals as part of assessment.
46	R: What is the relationship, if any, between practical work that you do here at Wits
47	and the practical activities advocated by CAPS document?
48	B: The practicals advocated by CAPS have equal if not the same in varsity...and
49	last week we did conservation of mass which was equivalent to the one of grade 10.
50	R: Have you done practical work during your teaching experience?
51	B: I have done demonstration for electrostatics by using balloons and rulers in a
52	classroom due to lack of funds for a lab.
53	R: What challenges do you face when doing practical work? I mean both at tertiary
54	and high school level.
55	B: We did not have enough chemicals sometimes here at Wits, for example sodium
56	iodide was mixed with lead nitrate accidentally and we were unable to use the lead
57	nitrate since they said it was finished.
58	R: How do you overcome this challenges you face when doing practical tasks?
59	B: I think talking to a demmie.
60	R: How do lab demonstrators assist when doing your weekly practical work?
61	B: They demonstrate and we are given lab guidelines to have steps followed.
62	R: What is the relationship, if any between what you do in lectures and what you do
63	in the labs?
64	B: We do experiments based on the theory; we go to the lab doing what is being
65	done in content. Err the content of some experiments require resource which we do
66	not have for example observing organism in water.
67	R: Let us talk about the lab manuals. Do the lab manuals have specific aims for
68	every lab?
69	B: Yes, they give us aim all the time in the lab
70	R: Are the instructions clear and easy to follow?
71	B: No, the lab manuals give unclear instruction.
72	R: Do they include pre-labs and post-labs?
73	B: Yes, they include pre-labs reports before you enter the lab
74	R: Do you always achieve the aims of the practicals?
75	B: No, the equipment has errors and the result differs.
76	R: Tell me about apparatus and resources needed to conduct the practicals. Do you
77	always get the apparatus required by the lab?
78	B: Sometimes
79	R: What type of practical work do you think you do here at Wits? Does it involve
80	making observations? Planning investigations? Or reviewing what is already known
81	in light of experimental evidence; using tools to gather, analyze, and interpret data
82	B: It involves observations eh and it involves reviewing what is already known and
83	sometimes
84	R: Who does the experiments that you observe.
85	B: The lab demonstrators and sometimes the lecturer
86	R: Do the practical work that you do involve: 1) practical activities which refers to
87	practical demonstrations, 2) experiments which refers to set outlined instructions
88	for you to follow or 3) practical investigations which requires you to go through the
89	scientific process?
90	B: Err it involve mostly the experiments were we have a set of instructions to
91	follow.

92	R: In your own understanding, what type of practical work can be called effective?
93	B: Creating or coming up with aim, posing question and observing.
94	R: What skills will contribute to the effectiveness of practical work?
95	B: Collecting data, using apparatus and good observation.
96	R: What suggestions would you provide on ways in which practical work can be
97	conducted effectively here at Wits?
98	B: Following instructions and demonstrating results
99	R: Thank you very much for your time and good luck on your studies
100	B: Thank you

Appendix L: Interview transcript of a student (C) and the researcher (R) at the university:
03/03/2016

Line No	Interview Transcript
1	R: Thank you very much for allowing me to come and interview you. Answer the
2	questions to the best of your ability. There is no wrong or right answer. And if there
3	is something you did not get right err you can just ask me I will clarify you. I am
4	hoping that it will be 30 minutes long only. The interview contains a total of 22
5	questions. Some follow up questions will develop as the interview proceeds. The
6	interview aims to find information on the effectiveness of practical work that you
7	do as a preparation to be a science teacher. Please feel free to answer the questions
8	as best as you can. Note that all the information you provide will be part of a study,
9	however your confidentiality will remain anonymous. Tell me about your
10	experiences with science courses in middle-high school and university.
11	C: It was always good to learn science
12	R: What about your laboratory experiences? Did you do long term investigations?
13	C: I never got involved or err exposed to experimental work in my high school
14	R: Why should we teach science? What are your broad goals for teaching science?
15	C: We need to teach science to clarify the things that happens around the world.
16	People will come up with their understanding of different concepts...this is to help
17	people get a better understanding of things or concepts in science.
18	R: How do you believe learners learn science best?
19	C: More practical work can help and demonstrations. Ah explanations also helps
20	R: If I ask you to give me a metaphor for “scientific inquiry” what would you tell
21	me?
22	C: I have no idea
23	R: Ok, Tell me how would you teach science as inquiry?
24	C: I don’t know what is scientific inquiry
25	R: How much freedom are you given to investigate problems of your own choice? I
26	mean, are you given freedom during your weekly practical work?
27	C: We aren’t given much freedom because the lab manual is detailed. Everything
28	that required to be done is written on the lab manual. I personally follow it.
29	R: In your own understanding, what is the role of experiments in science?
30	C: They clarify the content taught in class. This is to help those who understand
31	through observation to get better understanding of the content
32	R: Are you familiar with the CAPS document?
33	C: Yes
34	R: What does the CAPS document say about practical work in science?
35	C: According to the CAPS document teachers are expected to do practical work.
36	R: What is the relationship, if any, between practical work that you do here at Wits
37	and the practical activities advocated by CAPS document?
38	C: The practicals that are done here at Wits are pretty much the same as those that
39	are done in high schools. This enhances teachers to be able to construct their own
40	practical task in schools...even though sometimes the schools have limited
41	resources, the experiments are still done.
42	R: Have you done practical work during your teaching experience?
43	C: Yes, even though resources were limited, the practical was successful. They had

44	to make a flower with wires and put a light bulb so it can light up when all the
45	components are connected.
46	R: What challenges do you face when doing practical work? I mean both at tertiary
47	and high school level.
48	C: At tertiary is the writing and compiling the lab report and at high school is not
49	having enough resources.
50	R: How do you overcome this challenges you face when doing practical tasks?
51	C: I normally ask the demonstrator and sometimes my questions are not being
52	answered.
53	R: How do lab demonstrators assist when doing your weekly practical work?
54	C: They help with the setting up of the apparatus, but sometimes the practical is
55	difficult for them too.
56	R: What is the relationship, if any between what you do in lectures and what you do
57	in the labs?
58	C: Sometimes the practicals work doesn't relate to what we do in the lectures and
59	for some of us it becomes difficult to understand what is done on the in the lab.
60	R: Let us talk about the lab manuals. Do the lab manuals have specific aims for
61	every lab?
62	C: Yes, normally the topic explains a lot about the practical
63	R: Are the instructions clear and easy to follow?
64	C: Sometimes they aren't easy to follow and unclear.
65	R: Do they include pre-labs and post-labs?
66	C: Yes.
67	R: Do you always achieve the aims of the practicals?
68	C: Sometimes the experimental error occur
69	R: Tell me about apparatus and resources needed to conduct the practicals. Do you
70	always get the apparatus required by the lab?
71	C: Yes
72	R: What type of practical work do you think you do here at Wits? Does it involve
73	making observations? Planning investigations? Or reviewing what is already known
74	in light of experimental evidence; using tools to gather, analyze, and interpret data
75	C: It involves all of the mentioned things
76	R: Do the practical work that you do involve: 1) practical activities which refers to
77	practical demonstrations, 2) experiments which refers to set outlined instructions
78	for you to follow or 3) practical investigations which requires you to go through the
79	scientific process?
80	C: Err it involves practical activities and practical investigation
81	R: In your own understanding, what type of practical work can be called effective?
82	C: The one that will include making observations, posing questions.
83	R: What skills will contribute to the effectiveness of practical work?
84	C: Good measurement skills, clear demonstration before practical and clearly state
85	the aim of the practical.
86	R: What suggestions would you provide on ways in which practical work can be
87	conducted effectively here at Wits?
88	C: Set of instructions are required to follow...we should be free to come up with
89	our investigative questions and clearly state the aim of practical
90	R: But you said you were allowed to do that.
91	C: No we are not.
92	R: Ok, thank very much for agreeing to do this interview
93	C: Ok

Appendix M: Interview transcript of a student (D) and the researcher at the university:
03/03/2016

Line No	Interview Transcript
1	R: Thank you very much for allowing me to come and interview you. Answer the
2	questions to the best of your ability. There is no wrong or right answer. And if there
3	is something you did not get right err you can just ask me I will clarify you. I am
4	hoping that it will be 30 minutes long only. The interview contains a total of 22
5	questions. Some follow up questions will develop as the interview proceeds. The
6	interview aims to find information on the effectiveness of practical work that you
7	do as a preparation to be a science teacher. Please feel free to answer the questions
8	as best as you can. Note that all the information you provide will be part of a study,
9	however your confidentiality will remain anonymous. Tell me about your
10	experiences with science courses in middle-high school and university.
11	D: We had a great science teacher which made the experience a good one.
12	R: What about your laboratory experiences? Did you do long term investigations?
13	D: Our teacher enabled us to do practicals to explain the content, I really enjoyed it
14	and we had some long term investigation.
15	R: Why should we teach science? What are your broad goals for teaching science?
16	C: To understand natural phenomena scientifically.
17	R: How do you believe learners learn science best?
18	D: Science is the study of nature or natural phenomena so a teacher should enable
19	learners to study nature err practically is perfection.
20	R: If I ask you to give me a metaphor for “scientific inquiry” what would you tell
21	me?
22	D: Scientific inquiry is a hungry baby craving to be fed
23	R: Why do you say that?
24	D: It’s like when you are hungry for knowledge.
25	R: Ok, Tell me how would you teach science as inquiry?
26	D: I would teach science in an inductive way where we start with examples and
27	facts, then later we find out the concept in a discovery form. We don’t start with
28	concept memorization.
29	R: Are you involved in discovery learning here at Wits?
30	D: Not really.
31	R: How much freedom are you given to investigate problems of your own choice? I
32	mean, are you given freedom during your weekly practical work?
33	D: We are restricted or limited if I can say to the practical of the day. We don’t
34	have much freedom.
35	R: In your own understanding, what is the role of experiments in science?
36	D: They serve as proof of scientific concepts and laws err they also help learners
37	get understanding of content
38	R: Are you familiar with the CAPS document?
39	D: Yes
40	R: What does the CAPS document say about practical work in science?
41	D: It does promote practical work because there are marks according to practicals.
42	R: What is the relationship, if any, between practical work that you do here at Wits
43	and the practical activities advocated by CAPS document?

44	D: They are not in a similar level, first of all the equipment is abundant in
45	university but lacks in schools.
46	R: Have you done practical work during your teaching experience?
47	D: Yes, we did Ohm's law in circuits. Eh I also did indicators and pH scale...err we
48	also did electricity grid and also include some practical there.
49	R: What challenges do you face when doing practical work? I mean both at tertiary
50	and high school level.
51	D: Ah Lack of resources, lack of classroom management skills. Also the amount of
52	work required and not knowing criteria used to mark practicals.
53	R: How do you overcome this challenges you face when doing practical tasks?
54	D: I confront or inquire from demmies, work on time and pray and trust in God
55	R: How do lab demonstrators assist when doing your weekly practical work?
56	D: They are very helpful; they set up equipment and also explain the practicals. The
57	only thing they don't help us with is data capturing and writing lab reports.
58	R: What is the relationship, if any between what you do in lectures and what you do
59	in the labs?
60	D: Little relationship, but relevant because at times we do not see the relationship
61	but there is.
62	R: Let us talk about the lab manuals. Do the lab manuals have specific aims for
63	every lab?
64	D: Yes.
65	R: Are the instructions clear and easy to follow?
66	D: Clear but not easy to follow, they are ambiguous.
67	R: Do they include pre-labs and post-labs?
68	D: Yes.
69	R: Do you always achieve the aims of the practicals?
70	D: Yes, but at times you don't see the aim of the practical.
71	R: Tell me about apparatus and resources needed to conduct the practicals. Do you
72	always get the apparatus required by the lab?
73	D: No, sometimes we have to wait for other groups and some apparatus are limited
74	and we have to improvise.
75	R: What type of practical work do you think you do here at Wits? Does it involve
76	making observations? Planning investigations? Or reviewing what is already known
77	in light of experimental evidence; using tools to gather, analyze, and interpret data
78	D: Planning investigations, reviewing what is already known and making
79	observations.
80	R: Do the practical work that you do involve: 1) practical activities which refers to
81	practical demonstrations, 2) experiments which refers to set outlined instructions
82	for you to follow or 3) practical investigations which requires you to go through the
83	scientific process?
84	D: practical investigation
85	R: In your own understanding, what type of practical work can be called effective?
86	D: Inquiry based practical with a guide from practical book.
87	R: What skills will contribute to the effectiveness of practical work?
88	D: Questioning, analysis and accuracy of measurement
89	R: What suggestions would you provide on ways in which practical work can be
90	conducted effectively here at Wits?
91	D: Give at least one practical memo or guideline to show us how practical should
92	be reported.
93	R: Ok, thank very much for agreeing to do this interview

94	D: Pleasure.
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Appendix N: Interview transcript of a student (E) and the researcher (R) at the university:
03/03/2016

Line No	Interview Transcript
1	R: Thank you very much for allowing me to come and interview you. Answer the
2	questions to the best of your ability. There is no wrong or right answer. And if there
3	is something you did not get right err you can just ask me I will clarify you. I am
4	hoping that it will be 30 minutes long only. The interview contains a total of 22
5	questions. Some follow up questions will develop as the interview proceeds. The
6	interview aims to find information on the effectiveness of practical work that you
7	do as a preparation to be a science teacher. Please feel free to answer the questions
8	as best as you can. Note that all the information you provide will be part of a study,
9	however your confidentiality will remain anonymous. Tell me about your
10	experiences with science courses in middle-high school and university.
11	E: Science students were respected at school so it was cool to be a science student.
12	R: What about your laboratory experiences? Did you do long term investigations?
13	E: In high school we had labs but we never used them for practicals simply because
14	the teachers could not or err didn't know how to use them. I started using labs for
15	the first time in varsity and at first it was a challenge but at last I managed to fit in
16	and learn how to use them with the help of research, you know internet.
17	R: Why should we teach science? What are your broad goals for teaching science?
18	E: We teach science in order to develop scientific understanding and knowledge.
19	My broad goals for teaching science are to make science accessible to all kinds of
20	people even in special schools with the use of more teaching kits or materials.
21	R: How do you believe learners learn science best?
22	E: They learn science best by doing practicals, for example have concrete materials
23	when teaching bonding and equations have the molecular kit like the one we used in
24	labs at Wits.
25	R: If I ask you to give me a metaphor for "scientific inquiry" what would you tell
26	me?
27	E: Mixing chemicals is like baking a cake you have the right ingredients to bake a
28	perfect cake so is with mixing chemicals.
29	R: Tell me how would you teach science as inquiry?
30	E: Teaching science as inquiry for me will be giving learners a chance to give me
31	their opinions. I would ask what they know about a certain element, what is it used
32	for... in that way I can be able to build from their everyday knowledge and correct
33	misconceptions.
34	R: How much freedom are you given to investigate problems of your own choice? I
35	mean, are you given freedom during your weekly practical work?
36	E: I will say we are given little freedom. Most of the time we just follow what the
37	prac manual wants but we do have some freedom to do the pracs ourselves instead
38	of looking at the demmie doing it
39	R: In your own understanding, what is the role of experiments in science?
40	E: The role of experiment in science is to prove that scientific laws are true.
41	R: Are you familiar with the CAPS document?
42	E: Yes
43	R: What does the CAPS document say about practical work in science?

44	E: I think it does encourage practical work however teachers hardly follow it. They
45	do their own things and teach what they want not following CAPS document.
46	R: What is the relationship, if any, between practical work that you do here at Wits
47	and the practical activities advocated by CAPS document?
48	E: I personally don't see the relationship, I think the practicals we do are way
49	higher than the level of high school and the CAPS document.
50	R: Have you done practical work during your teaching experience?
51	E: I did it at special school and it was not that successful...err it didn't involve
52	chemicals but it was more of practical work using the molecular kit and the kids
53	were building compounds. That special school did not have apparatus and at a
54	special school it take time for learners to understand
55	R: What challenges do you face when doing practical work? I mean both at tertiary
56	and high school level.
57	E: At Wits the challenge is when doing the practical of oscillation, we don't know
58	when to start counting and this affects the results.
59	R: How do you overcome this challenges you face when doing practical tasks?
60	E: When learners in that special school did not understand instructions I ended up
61	having to explain to them individually which chowed time but was successful. The
62	teachers were not helpful I had to deal with the learners all by myself.
63	R: How do lab demonstrators assist when doing your weekly practical work?
64	E: They give a little guidance because they expect you to have read your prac
65	manual. We end up making mistakes by mixing chemicals and contaminating them
66	because they do not fully assist us.
67	R: What is the relationship, if any between what you do in lectures and what you do
68	in the labs?
69	E: There is normally no relationship. In the labs we go much deeper than what was
70	covered in the lecture. We therefore go and use Google to answer the post lab and
71	writing a report
72	R: Let us talk about the lab manuals. Do the lab manuals have specific aims for
73	every lab?
74	E: For some.
75	R: Are the instructions clear and easy to follow?
76	E: Instructions are sometimes confusing.
77	R: Do they include pre-labs and post-labs?
78	E: They do.
79	R: Do you always achieve the aims of the practicals?
80	E: No, the cause is probably human error when measuring chemicals due to the
81	instructions not being clear.
82	R: Tell me about apparatus and resources needed to conduct the practicals. Do you
83	always get the apparatus required by the lab?
84	E: No, some are not available or there is a shortage. They are not always in good
85	condition and sometimes we use other apparatus to substitute the required ones
86	because they are not available.
87	R: What type of practical work do you think you do here at Wits? Does it involve
88	making observations? Planning investigations? Or reviewing what is already known
89	in light of experimental evidence; using tools to gather, analyze, and interpret data
90	E: Planning investigations, reviewing what is already known and making
91	observations.
92	R: Do the practical work that you do involve: 1) practical activities which refers to
93	practical demonstrations, 2) experiments which refers to set outlined instructions

94	for you to follow or 3) practical investigations which requires you to go through the
95	scientific process?
96	E: We do all the kinds
97	R: In your own understanding, what type of practical work can be called effective?
98	E: The ones you conduct yourself or create the one that gives you more freedom to
99	decide what amount of chemicals you want to use.
100	R: What skills will contribute to the effectiveness of practical work?
101	E: Being able to create your own practical can be effective because it involves
102	everyone and people do not feel oblige to follow certain rules but this should come
103	with the caution of knowing the lab rules and how to use chemicals or handle them.
104	R: What suggestions would you provide on ways in which practical work can be
105	conducted effectively here at Wits?
106	E: Allow students to observe other means of doing practicals, give them the
107	freedom but supervise them.
108	R: Ok, thank very much for agreeing to do this interview
109	E: Pleasure.

Appendix O: Interview transcript of a student (F) and the researcher (R) at the university:
03/03/2016

Line No	Interview Transcript
1	R: Thank you very much for allowing me to come and interview you. Answer the
2	questions to the best of your ability. There is no wrong or right answer. And if there
3	is something you did not get right err you can just ask me I will clarify you. I am
4	hoping that it will be 30 minutes long only. The interview contains a total of 22
5	questions. Some follow up questions will develop as the interview proceeds. The
6	interview aims to find information on the effectiveness of practical work that you
7	do as a preparation to be a science teacher. Please feel free to answer the questions
8	as best as you can. Note that all the information you provide will be part of a study,
9	however your confidentiality will remain anonymous.
10	R: Tell me about your laboratory experiences? Did you do long term
11	investigations?
12	F: We had a lab but most if not all the chemicals had reacted and some evaporated,
13	so most of our practicals were chalkboard based, our teacher took time to draw all
14	the apparatus and we had to imagine color changes and so forth.
15	R: Why should we teach science? What are your broad goals for teaching science?
16	F: We must teach science so that learners can have an understanding of the physical
17	world. Err science is systemic that is why most universities allow a learner who did
18	science at school level to do accounting in university but converse is not true...this
19	shows that science gives fundamental thinking and reasoning skills
20	R: How do you believe learners learn science best?
21	F: Learners learn science best if they can do a practical before the lesson; this helps
22	one to see misconceptions that they have had before the lesson. If you do pracs after
23	the lessons, you already know what to expect so you can cheat and manipulate the
24	results.
25	R: If I ask you to give me a metaphor for “scientific inquiry” what would you tell
26	me?
27	F: I have no idea.
28	R: Tell me how would you teach science as inquiry?
29	F: I also have no idea.
30	R: How much freedom are you given to investigate problems of your own choice? I
31	mean, are you given freedom during your weekly practical work?
32	F: No, it’s only prescribed work.
33	R: In your own understanding, what is the role of experiments in science?
34	F: Experiment in science helps support or dispute certain theories and laws.
35	R: Are you familiar with the CAPS document?
36	F: I am not familiar with the CAPS but I know that it assumes that practical work
37	integrates on theory and helps learners understand well.
38	R: What does the CAPS document say about practical work in science?
39	F: I think it does encourage practical work however teachers hardly follow it. They
40	do their own things and teach what they want not following CAPS document.
41	R: What is the relationship, if any, between practical work that you do here at Wits
42	and the practical activities advocated by CAPS document?
43	F: I can only predict that practicals at university integrate what was taught in high

44	school and they compensate for pracs that were not done at all.
45	R: Have you done practical work during your teaching experience?
46	F: No, I haven't
47	R: What challenges do you face when doing practical work? I mean both at tertiary
48	and high school level.
49	F: In high school there is no resources, at tertiary level I find myself in lab where
50	there are few apparatus yet we are many, each station should have its chemicals
51	rather than having to wait for other groups to finish.
52	R: How do you overcome this challenges you face when doing practical tasks?
53	F: I read through the lab manual and understand the prac, while other students are
54	still reading I quickly gather chemicals and start working ... as soon as they get the
55	idea I am done with the prac.
56	R: How do lab demonstrators assist when doing your weekly practical work?
57	F: I don't find lab demonstrators helpful.
58	R: What is the relationship, if any between what you do in lectures and what you do
59	in the labs?
60	F: Our labs are ahead of topic we cover in class, when we go for lectures I realize
61	that we did the concepts from labs.
62	R: Let us talk about the lab manuals. Do the lab manuals have specific aims for
63	every lab?
64	F: No they do not.
65	R: Are the instructions clear and easy to follow?
66	F: Sometimes they write a long story to give a simple instruction.
67	R: Do they include pre-labs and post-labs?
68	F: Yes.
69	R: Do you always achieve the aims of the practicals?
70	F: No, sometimes factors such as temperature and pressure in the lab are not
71	controlled and slightly interfere with our results.
72	R: Tell me about apparatus and resources needed to conduct the practicals. Do you
73	always get the apparatus required by the lab?
74	F: All the apparatus and chemicals are in good shape, they are just not enough for
75	larger groups.
76	R: What type of practical work do you think you do here at Wits? Does it involve
77	making observations? Planning investigations? Or reviewing what is already known
78	in light of experimental evidence; using tools to gather, analyze, and interpret data
79	F: Involve making observations, reviewing what is known and proposing answers
80	and explanations.
81	R: Do the practical work that you do involve: 1) practical activities which refers to
82	practical demonstrations, 2) experiments which refers to set outlined instructions
83	for you to follow or 3) practical investigations which requires you to go through the
84	scientific process?
85	F: Practical activities and experiments.
86	R: In your own understanding, what type of practical work can be called effective?
87	F: An effective practical is one that is introduced before the lesson; learners cannot
88	manipulate results to impress the teacher because in most cases the theory is not yet
89	known.
90	R: What skills will contribute to the effectiveness of practical work?
91	F: Working systematically is the key to a successful lab session
92	R: What suggestions would you provide on ways in which practical work can be
93	conducted effectively here at Wits?

94	F: Instructions on the lab manual need to be clear, each station must have chemicals
95	for that practical, this save time for students and demonstrators...we don't have to
96	run around looking for chemicals.
97	R: Ok, thank very much for your honest response.
98	F: Pleasure, I hope something will be done about this.
99	R: Hope so too.

Appendix P: Interview transcript of a laboratory demonstrator (L) and the researcher (R) at the university: 01/03/2016

Line No	Interview Transcript
1	R: Ok thank you for agreeing to do this interview with me. It is about the
2	effectiveness of practical work that student teachers do here at Wits. First I just
3	want to know; how many years have you been a lab demonstrator?
4	L: Two years now.
5	R: And then, your highest qualification?
6	L: BSc honours in science education
7	R: Tell me about your background and pre-service training.
8	L: I don't have teaching experience, I only started teaching students as a
9	demonstrator
10	R: Tell me about your laboratory experiences? Did you do long term investigations?
11	L: At high school science was like memorizing everything without any practical, at
12	university things changed I was exposed to chemicals etc. and how labs operate.
13	R: Why should we teach science? What are your broad goals for teaching science?
14	L: We teach science to explain or connect ideas we have about the world and
15	exploring the unknown.
16	R: Ok, I just want to know; how do you believe students learn science best?
17	L: I believe in constructivism theory, err they learn best through the environment
18	were they construct knowledge.
19	R: Then I want to ask about scientific inquiry, how would you teach science as an
20	inquiry? As inquiry based?
21	L: Teacher giving students freedom to develop their own knowledge, through
22	practical work and open-ended investigations
23	R: So, how much freedom would you give your students to investigate problems in
24	the labs?
25	L: There is no freedom given to students at school as teachers design closed not
26	open-ended practicals.
27	R: In your own understanding what is the role of experiments in science?
28	L: Experiments in science supplement what you were taught in class which is
29	theory...err that is why most students complain if the practical is not about what
30	they have learnt in class
31	R: Are you familiar with the CAPS document?
32	L: Currently it encourages teachers to use practical work, although I have not read it
33	in a while.
34	
35	R: The practicals that the students do here at Wits, is there a link between what they
36	do here at tertiary and what they will do when they are teaching the CAPS
37	curriculum?
38	L: I have no idea as I never spent time comparing them
39	R: What challenges do you face when supervising students during practical work?
40	L: They often want to verify their answers and often they don't take time to read
41	instructions
42	R: How do you overcome these challenges?
43	L: We create activities that will force them to read their practicals beforehand, such
44	as the small test before practical or them investigate dangers of the chemicals they

45	will use on that prac.
46	
47	R: Are you being offered training to be a lab demonstrator?
48	L: Yes, it is two hours every year.
49	R: What are the major roles of lab demonstrators?
50	L: Assist the lecturers by facilitating the practicals; a demonstrator is a bridge
51	between students and lecturer.
52	R: What type of practical work do you think the students do? Does it involve
53	making observations? Posing questions? Planning investigations? Or reviewing
54	what is already known?
55	L: Making observations, reviewing what is already known and proposing
56	explanations. Mostly they follow a set of outlined instructions.
57	R: Let us talk about the lab manuals. Do the lab manuals have specific aims for
58	every lab?
59	L: Yes.
60	R: Are the instructions clear and easy to follow?
61	L: Most of them if the course has a designed manual.
62	R: Do they include pre-labs and post-labs?
63	L: Chemistry practicals only
64	R: Do you always achieve the aims of the practicals?
65	L: No, because often both students and lab demonstrators do not know what they
66	are doing
67	R: Thank you very much for your time
68	L: No problem