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CHAPTER 1

ORIENTATION TO THE STUDY

“La química sin la práctica es muerta” (Juan Bencosme Arias). The teaching and learning of chemistry without engaging in practical work is ‘dead’.”

1.1 Introduction and background

The purpose of this study was to explore the interface between teacher professional identity and the practice of Inquiry-Based Laboratory Work (IBLW). Laboratory work in this study was considered as the process in which learners learn chemistry through the handling of materials and the manipulation of equipment (Hofstein & Mamlok-Naaman, 2007). The chemistry laboratory provides physical and authentic environments for learners to experience chemistry in accordance with the learning theory of constructivism (Boghossian, 2006; Miller & Miller, 1999). The terms ‘laboratory work’, ‘practical work’ and ‘experiments’ were used interchangeably at times in the discussions that follow. Although the term ‘laboratory work’ specifies the location in which the practical activities, investigations or the experiments are conducted, it does not change their nature (Hofstein & Mamlok-Naaman, 2007).

Laboratory work plays a crucial role in the teaching and learning of chemistry in secondary schools (Witteck et al., 2007; Millar, 2004). An examination of subject policies reveals that scientific inquiry in which the scientific method is employed should form part of the learning activities for learners (Bradbury, 2010; Department of Education, 2011; Hofstein & Lunetta, 2003). Laboratory work provides an avenue for teachers and learners to engage in activities in which they can employ the scientific method. Laboratory work should be practiced in a way that is meaningful and beneficial to learners (Hofstein, 2004; McDonnell et al., 2007; Hofstein & Naaman, 2007; Limniou et al., 2007).

One way of making laboratory work more meaningful is to incorporate inquiry activities that are conducted by learners. Inquiry in the laboratory constitutes a number of actions that can be performed by learners. These actions include posing scientifically oriented questions, forming hypotheses, designing and conducting scientific investigations,

formulating and revising scientific explanations, and communicating and defending scientific arguments (Hofstein & Naaman, 2007; Limniou et al., 2007). This study only focused on three crucial inquiry actions which are the posing of the investigative question, designing of experiment procedures and articulation of solutions.

Twenty years after the advent of democracy in South Africa there is still unequal access to laboratory work in secondary schools. "...nearly 80 per cent of schools are still without science laboratories" says the Government Gazette (2010:8). The public school system is multi-layered as it consists of diverse schools from different contexts. Schools that enjoyed privileges because they were formerly reserved for Whites during the apartheid era have better laboratory facilities than schools from other contexts which were reserved for Blacks (Selod & Zenou, 2003). Accordingly, from the findings of this study it was observed that public schools formerly categorised under model C may have four well equipped science laboratories whilst a public school in the townships has one classroom which works as a make-shift science laboratory. South African Human Rights Commission (2012) in the Charter of Children's Basic Education Rights pronounces that access to education for some children in places like rural areas is hindered by infrastructural backlogs and shortages of learning materials. As a developing country South Africa is still working on issues of access and redress for formerly marginalised groups of the population. The study was conducted as teachers and the Education Department are battling with the realities of inequity and inequality in learner accessibility to laboratory work opportunities.

The recently introduced CAPS syllabus is one way of ensuring equitable learner access to laboratory work. The syllabus proposes redress to the existing disparities in learner access to meaningful science education brought about by the legacy of apartheid by embedding scientific inquiry in the physical sciences content. The syllabus aims to instil the spirit of scientific inquiry by stipulating that teachers should constantly engage learners in some prescribed experiments and any other practical work activities that teachers can facilitate for their learners (Department of Basic Education, 2011). This is in accordance with the goals of policies enshrined in the Education White Paper 6 (2001) aimed at assisting schools to tackle social cohesion issues such as race relations, redress and access. Teachers in all school contexts are compelled to implement the policies on practical work no matter

the situation in which they find themselves in terms of access to laboratory infrastructure, equipment and materials. For this reason this study was conducted in schools with standard science laboratory settings, classrooms turned into make-shift science laboratories and classrooms temporarily equipped for laboratory work. It was interesting to study the influence of teacher professional identity in the different school and laboratory contexts.

Internationally, this study was conducted against a background in which researchers are raising concerns on whether learners are meaningfully engaged in inquiry activities during laboratory work (Barrow, 2006; Osisima & Onyia, 2008; Lustick, 2009; Nakedi & Rollnick, 2010; Naidoo & Govender, 2010; Enyedy et al., 2006). Literature reveals concerned voices that lament the perpetuation of traditional laboratory instructional practices in schools which deprive learners of opportunities to engage in inquiry work (Cheung, 2007; Luehmann, 2007; Naidoo & Govender, 2010; Coenders, 2010). The literature reviewed established that laboratory work in chemistry is short of being meaningful because teachers are resorting to traditional methods like ‘cookbook style’ laboratory work instead of the more reform-oriented inquiry practices (Hofstein, 2004; McDonnell et al., 2007). Authors like Prince and Felder (2006) and Domin (2007) explain that in ‘traditional’ methods, teaching and learning are deductive processes. Scientific concepts and theories are availed to learners before specific examples and applications can be made. Similarly, in inquiry based methods, teaching and learning are inductive processes. A teacher may teach the effect of surface area on the rate of reaction deductively by first explaining to learners how surface area affects speed of reaction. The teacher may tell learners that increasing surface area results in an increase in the speed of reaction. This would be followed by practical activities to demonstrate what is already known. Alternatively, the teacher may first engage learners in practical work in which they conduct experiments with surface area as an independent variable. Learners would then analyse and interpret data collected so that they may discover patterns and relationships on their own. After these activities learners may reach a conclusion on the relationship between surface area and speed of reaction.

There is abundant literature affirming the benefits and importance of IBLW to the process of teaching and learning school chemistry (Vhurumuku et al., 2006; Bradbury, 2010;

Buntine et al., 2007; Elliot et al., 2008; King et al., 2008; Tan & Goh, 2008). The benefits of laboratory work in school chemistry are so immense that the discussion made here might not do justice in capturing the extent of their significance. However, for the purposes of this study, a few benefits are highlighted. Vhurumuku et al. (2006) propound that laboratory work is one of the best ways of teaching and learning science after finding that it promotes students' understanding of the nature of science and scientific literacy. This is supported by Buntine et al. (2007) who explained that laboratory work is important to help bridge the gap between the molecular and the macroscopic levels of chemistry through the promotion and improvement of subject matter mastery and scientific reasoning. Bradbury (2010) posited that one of the aims of inquiry- oriented approaches is for teachers and students to realise that the representation of ideas in science should be based on evidence and laboratory work presents an avenue to practice inquiry.

Laboratory work is one of the strategies that enable teachers and students to engage actively in scientific inquiry activities. In the process of learning chemistry through laboratory work, students are given an opportunity to behave like chemistry scientists (Elliot et al., 2008; Bradbury, 2010). Laboratory work is also used to support the implementation of other kinds of reform in chemistry education. King et al (2008) concluded that one of the best ways to ensure the success of the context-based approach to chemistry is by engaging students in extended experimental investigations. Tan and Goh (2008) also posit that laboratory work is one of the strategies used to achieve reflective learning. All this demonstrates that IBLW is of great value to chemistry education.

Other voices from literature reveal that learners are being engaged in inquiry in the laboratory but at different levels of complexity (Bretz & Fay, 2008; Fay et al., 2007; Domin, 2007; Hattingh et al., 2007; Dudu & Vhurumuku, 2012). A close-up review of literature reveals that laboratory work may not always be branded simply as traditional or inquiry-oriented but rather manifests itself along a continuum on which there are milestones that can be identified depending on the amount of information revealed to learners (Bretz & Fay, 2008; Fay et al., 2007; Domin, 2007). The characterisations of inquiry were considered as IBLW practices in this study. Rubrics were developed to characterise IBLW in terms of levels of complexity (Domin, 2007; Bretz & Fay, 2008; Fay

et al., 2007) after the realisation that in practice teachers do not facilitate inquiry in the chemistry laboratory in a uniform way.

Literature (Milne et al., 2006; Upadhyay, 2009; Prosser, 2006; Predetti et al., 2008; Hick, 2008; Elawar et al., 2007) tries to explain why teachers prefer and practice particular pedagogic strategies. One area that has received this kind of attention is the adoption of either traditional or reform oriented approaches in implementing practical work in science (Hick, 2008; McDonnell et al., 2007, Domin, 2007; Limniou et al., 2007; Roehrig et al., 2007). Findings from the work done by Roehrig et al. (2007) reveal that teachers can be classified as traditional, mechanistic and inquiry-based implementers in reform curriculum implementation. Expounding on this, the authors said traditional implementers held traditional beliefs, mechanistic implementers held transitional reform-based and other predominantly traditional beliefs, and the inquiry-based implementers held transitional and reform-based beliefs.

Reform-oriented approaches in practical work include IBLW in which practical work should include inquiry activities. One literature position advocates that teacher professional identities are at the centre of successful curriculum implementation since teachers are the chief implementers (Bantwini & King-McKenzie, 2011; Jita & Vandeyar, 2006). This becomes more pronounced if curriculum issues are reform-oriented like inquiry-based strategies (Coenders, 2010; Morgan, 2004). Faced with unfavourable contextual factors like intensification of workloads (Stoffels, 2006), language barriers (Webb, 2009) and lack of laboratory materials (Makgato & Mji, 2006; Makgato, 2007), teachers use their professional identities as personal resources in facilitating the teaching and learning process (Morgan, 2004; Keys; 2007).

Science is a two-pronged subject in which theory has to be studied alongside practical work (Tsaparlis, 2009; Hofstein, 2004; Millar, 2004). Science has inquiry as one of the educational goals that should be fostered in the process of teaching and learning (Hofstein & Lunetta, 2003; Department of Education, 2011; Millar, 2004; Hofstein & Naaman, 2007). One of the ways to achieve this educational goal is to engage learners in laboratory work. The meaningful teaching and learning of chemistry cannot be achieved without the

incorporation of practical activities in which learners interact with materials and equipment as they engage in activities (Millar, 2004). For being at the helm of instructional programmes implementation teachers make most of the decisions as to how learning is going to happen through the decisions they make or fail to make. This implies that processes of learning hinge on teachers' set of beliefs, knowledge and skills (Settlage et al., 2009; Joseph and Heading, 2010). Keys (2007) regards a teacher's set of beliefs, practices, practical theories and craft knowledge to be his/her teacher professional identity. Inquiry practice is one learning theory that teachers can employ as they conduct their classroom practices.

Since most national science curricula, including that of South Africa, embody inquiry as an educational goal and learning theory to develop knowledge and skills (Bradbury, 2010; Department of Education, 2011), inquiry now becomes a requirement to be complied with as teachers conduct their classroom practice. Teacher actions are a manifestation of their professional identity positions in terms of personal resources that they bring to the classroom. Based on this notion the practice of inquiry is considerably determined by teacher professional identities.

The laboratory is an essential facility in the teaching of chemistry in the school. Incorporating inquiry in the chemistry laboratory makes laboratory activities more meaningful (McDonnell et al. 2007). Teachers' skills as pedagogical experts will determine the forms of inquiry that they are able to facilitate in the chemistry laboratory. There is sufficient evidence to suggest that some teachers are struggling to ensure learner autonomy in the learning processes (Stoffels, 2006; Ramnarian, 2011; Makgato & Mji, 2006; Makgato, 2007). However, there is also sufficient evidence that some teachers are able to rise above the challenges using their personal resources in the form of teacher professional identities (Stoffels, 2006). Bretz and Fay (2008) confirm that inquiry in the chemistry laboratory exists in more than one form. The forms can be placed along a continuum ranging from simple to complex depending on the degree of learner autonomy allowed in the learning process. Mudau (2007) even observes that teachers may use inquiry for different purposes which are in this case to develop procedural knowledge and to develop

conceptual knowledge. What comes out clearly is that teachers do not conduct inquiry-based laboratory work (IBLW) in the same way.

To provide context for this study it is important to mention that chemistry in South African secondary schools is studied as part of physical sciences as a subject. This comprises chemistry and physics. Therefore to research the interface of teacher professional identity and the practice of IBLW in school chemistry may, in essence, be in school physical sciences. The same teacher may be teaching both components of science and data collected on the practice of laboratory work may apply both to chemistry and physics. The practice of laboratory work is considered in a general sense and not for particular topics. The embodiment of secondary school chemistry in physical sciences as a learning area for Grades 10-12 implies that chemistry teachers are actually physical sciences teachers. Accordingly, they should be specialists for both chemistry and physics. This study is placed in the secondary school chemistry laboratory and the inquiry practices that the teachers can facilitate in that setting.

The study is conducted against a backdrop in which debates are raging on how teaching and learning strategies should be more learner-centred than they are teacher-centred. The Department of Education (2011) specifies that physical sciences should promote knowledge and skills in scientific inquiry. Teachers are also working in an environment characterised by curriculum innovations, the latest of which is the phasing in of the Curriculum and Assessment Policy Statement (CAPS) in 2012. The underlying assumption in this study is that the practice of inquiry in the laboratory is determined by teacher professional identities. An examination of teacher inquiry practices and teacher professional identity dispositions might help to elucidate the interface between IBLW practice and teacher professional identity.

Based on the findings that teachers do not practice inquiry in the same ways (Milne et al. 2006; Bretz & Fay, 2008) accordingly it was important to first of all establish the inquiry-based practices that were employed by teachers in the laboratory. In the same vein, it became critical to find out how teacher identity directs teachers towards particular inquiry practices in the laboratory based on the assumption that teachers use their professional

identity dispositions as a filter to interpret and make decisions about classroom practice (Tompson, 2010; Roehrig et al., 2007; Keys, 2007). The concept of teacher professional identity is continually being defined (Komba & Katabaro, 2013). Healey and Hays (2014) contend that a professional identity is a culmination of a developmental process that empowers them to understand their self-concept by articulating their role and philosophy. The study of teacher professional identity in this research was achieved by exploring the nature of teacher perceptions, beliefs, commitment and motivation, sense of agency, professional training and development, prior school experiences and contextual settings that shaped their IBLW practice.

The choice of teacher professional as a lens to study how teachers facilitate IBLW was partly propelled by the realisation that it provides a more holistic and comprehensive framework because it treats teachers as whole persons (Olsen, 2008). Teacher identity gave room for the examination of all aspects in the personal, professional and socio-cultural lives of teachers that interface with practice in IBLW. I did not want to restrict the study to particular aspects of teacher identity. I was not clear which teacher identity aspects would be influencing the practice of IBLW in South African schools and therefore the study had to be exploratory. Teacher professional identity is well established as a research area (Beijaard et al., 2004). As such, researchers use teacher professional identity to get more insights as they endeavour to conceptualise the needs of student teachers (Beijaard et al., 2004; Olsen, 2008). By extrapolation from the idea above, this study used teacher professional identity to better understand the behaviour of chemistry teachers in the science laboratory. Teacher professional identity is also a relevant framework to study teacher practice because it is one of the pedagogical tools used in teacher professional training and development (Olsen, 2008).

Ultimately, after establishing teacher inquiry practices and how teacher professional identities resulted in certain laboratory inquiry practices, it was hoped that the study would be able to explain why teachers had an affinity for certain practices from an identity lens. Accordingly this study asks, *how does teacher professional identity interface with the practice of IBLW in school chemistry?*

1.2 Rationale for the study

The study is of personal significance and importance to me. I spent most of my professional years teaching science. The inspiration to undertake this particular study stems from my long standing belief developed during secondary schooling and teacher training that chemistry is best taught and learnt in the laboratory. In my personal experience I have noticed that the chemistry laboratory is a very special building in the school which is located with care after considering a number of issues, some of which include the safety and well-being of learners and teachers. At the university that I attended for teacher training the chemistry department and laboratories were situated on the uppermost floors of buildings and students were prompted to notice this arrangement as soon as they embarked on their studies. In the three secondary schools where I taught science and the school I attended for secondary education, the laboratory buildings were located a distance apart from other buildings. The assumption is that activities in a chemistry laboratory produce gases and other substances that might be harmful to humans upon exposure to them. This is physical and practical evidence that chemistry is a practical subject of which laboratory work is a part.

I still hear the voice of one of my chemistry methodology lecturers clearly in my head emphasising that chemistry is a practical subject. This is in line with findings from literature that laboratory work is an essential part of school chemistry (Witteck et al., 2007; Bennett & O'Neale, 1998). It can be appreciated that it is through practical work in the form of experiments, investigations and other forms of inquiry that scientists in the history of chemistry made important discoveries that translated into scientific theories and concepts. However, personal experience and authors like Millar (2004) contend that the teaching and learning of secondary school science is not necessarily about making new discoveries in terms of scientific concepts and theories. Practical work provides authentic opportunities in which learners can experience chemistry as an alternative learning strategy. Millar (2004:7) says,

Learning science at school is not the discovery or construction of ideas that are new and unknown. Rather it is making what others already know your own...but there is still cognitive work to be done to grasp it, so as to be able to explain it in turn to someone else or to apply it to new situations.

This observation about practical work in school chemistry is affirmed by Bell et al. (2005) upon propounding that inquiry in school settings is different from inquiry in undergraduate settings. The realisation that inquiry in school chemistry laboratories is not necessarily done to discover new chemistry concepts and theories inspired me to study the laboratory inquiry practices in schools and how teachers facilitate the inquiry activities using a teacher identity lens. The research journey was exploratory in nature because from the literature reviewed some laboratory inquiry practices could be established but not much was said on why teachers had an affinity to facilitating certain inquiry practices for their learners. Teacher professional identity was one of the lenses that seemed reasonable to use for the study.

To further justify the undertaking of this study the following reasons have been identified. First, current trends in science education have seen the embodiment of inquiry in most national science curricula (Lustick, 2009; Bantwini, 2010). Laboratory activities have a distinctive and central role in the chemistry curricula which makes them an essential part of secondary school chemistry lessons (Hofstein & Mamlok-Naaman 2007; Witteck et al., 2007). IBLW falls under inquiry-based strategies and it is one way in which teachers can implement the curriculum specifications that emphasise the practice of inquiry learning. Laboratory activities provide teachers with means of promoting inquiry by practicing IBLW. The IBLW approach is one of the reform-oriented approaches that align with reform trends in science education in particular. Jansen (2007) further observes that in responding to what we teach, it becomes apparent that the traditional teaching roles are becoming redundant.

Second, upon engaging with literature a number of things came up as debates rage on as to what constitutes inquiry and the researcher was able to identify a grey area in which to position the research. It is important to point out that inquiry in this study is considered as it applies to science teaching and learning in the context of laboratory work. Literature revealed that there is no consensus about what is inquiry as posited by Barrow (2006). Osisima and Onyia (2008) in their study raise questions on what science teachers believe to be inquiry-based instruction after realising that teachers are seen not to practice inquiry in

the same way. However, for this study inquiry is considered in the light of the purpose of laboratory work in school science as enunciated by Millar (2004:20):

In thinking about the role of practical work, it is important to bear in mind the significant differences between the research laboratory and the teaching laboratory (or classroom); and between research scientists exploring the boundaries of the known and students trying to come to terms with already accepted knowledge.

Further examination of literature revealed that authorities place inquiry on a continuum on which it starts from a lowest level to a high level. Rubrics were even developed to assist in the measuring of inquiry (Bretz & Fay, 2008; Fay et al., 2007; Domin, 2007; Hattingh et al., 2007; Dudu & Vhurumuku, 2012). This serves to confirm that teachers may understand inquiry in laboratory work in different ways and hence they do not practice it in the same way. From literature it could be established that barriers to effective implementation of IBLW in secondary schools are well documented, for example in studies done by Stoffels (2005) in the South African context and Cheung (2007) on the international landscape. Studies also show that laboratory work may be practiced using ‘traditional’ methods which are lacking in inquiry or reform-oriented methods that incorporate inquiry (McDonnell et al., 2007; Domin, 2007; Hick, 2008). Significant research efforts are also directed at the shaping of professional identities of teachers as they endeavour to facilitate inquiry activities (Milne et al., 2006; Melville et al., 2008; Roehrig et al., 2007; Tompson, 2010; White et al., 2010; Stolk et al., 2010). However, little has been found in the reviewed literature on the interface between teacher professional identity and how teachers specifically facilitate question posing, steps of experiment procedure design and articulation of solutions during laboratory work.

Third, the context in which the study is situated presented unique characteristics that would provide justification for conducting research. The South African curriculum has been subjected to a number of curriculum reforms and innovations due to the increasing pressure to participate in internationally set standards of performance like the Education for All programmes, the Trends in International Mathematics and Science Study and the growing incorporation of computer-based technologies in the classroom (Jansen, 2007). Day (2007) observes that governments put in place educational reform interventions with good intentions of raising standards. However teachers’ existing practices are challenged

which results in periods of temporary destabilisation, increased workloads and little or no attention is paid to teachers' identities in the form of motivation, efficacy, commitment, job satisfaction and effectiveness (ibid). Fritz et al. (2010), in their study of teacher identity as a lived experience in the face of change in South Africa, propound that in-depth inquiries should be conducted on how teachers are coping even amidst poor and unsupportive conditions. Vos et al. (2010) allude to the importance of doing further investigation on ways in which teachers are dealing with innovative teaching materials. This became one of the motivations for conducting this research on the inquiry practices in the laboratory through a teacher professional identity lens.

1.3 Research questions

The main research question for this study is:

- How does teacher professional identity interface with the practice of Inquiry-Based Laboratory Work in school chemistry?

The following are the secondary research questions of the study:

- What are the teacher professional identity positions in the practice of IBLW in South African schools?
- How do personal identity traits influence teacher identity positions in IBLW practice?
- How do school contextual settings influence teacher identity positions in IBLW practice?

Research aim and objectives

The aim of this research study is to explore how teacher professional identity influences the practice of IBLW in school chemistry. The following research objectives were identified:

- Establish the teacher professional identity positions in the practice of IBLW in South African schools.
- Explore how personal identity traits influence teacher identity positions in IBLW practice.
- Explore how school contextual settings influence teacher identity positions in IBLW practice.

1.4 Theoretical framework

The study used social identity theory as a theoretical framework. It was appropriate to use an identity theory because it presented a comprehensive framework to explain teacher professional identity. On realising that voluminous literature affirms the existence of several attempts to define and redefine the identity theory as a construct, (Hornsey, 2008; Korte, 2007; Zembylas, 2003; Kelchtermans, 2005; Akkerman & Meijer, 2011), a decision was reached on the use of social identity theory. Tenets of the social identity theory are firmly grounded in identity theory; however, social identity theory explains the transformation of identity as individuals become part of a group or groups (Korte, 2007; Reicher et al., 1995; Fielding et al., 2008; Huddy, 2001). Professional teacher identity in the practice of IBLW may be considered a group-based identity since it is developed as individuals become science teachers.

Basically, social identity theory is a psychological, socio-cultural and philosophical construct (Kelchtermans, 2005; Zembylas, 2003; Vygotsky, 1978; Varghese, 2005; Akkerman & Meijer, 2011; Lee, 2012). Based on this a number of tenets can be identified inherent to social identity theory. First, identity is defined by cognitive and affective traits of an individual (Kelchtermans, 2005; Zembylas, 2003). Second, identity is complex as it consists of subsystems in the form of personal identity and social identity (Reicher et al., 1995). Identity can also be fragmented into role identities (Tsui, 2007). Third, identity is continuously evolving since it is influenced by contextual settings (Varghese et al., 2005; Vygotsky, 1978). Fourth, identity is shaped by teacher narratives and stories of their experiences (Beijaard et al., 2004). Fifth, identity in the context of professional teacher identity is significantly defined by professional training and development (Malderez et al., 2007; Edwards & Blake, 2007). Sixth, identity is also defined by teacher agency which is their capacity to perform their duties effectively in given contexts as well as their affinity to certain roles (Beauchamp & Thomas, 2009). Teacher beliefs, perceptions, commitment, motivation, professional development and training, past and present experiences, teacher agency, teacher narratives, contextual settings and learner populations are at the core of how the social identity theory has been used as a theoretical framework.

1.5 Conceptual framework

A conceptual framework was identified from literature in order to explain the other face of the study which focuses on the IBLW in school chemistry as an instructional practice.

1.5.1 Inquiry-based teaching and learning strategy

Inquiry in this section will be applied to the context of chemistry laboratory work. According to Hofstein (2004) learners engaging in IBLW ask questions and hypothesise, plan experiments, conduct the planned experiments, analyse results, ask further questions and present the results in a scientific way. Inquiry is rooted in the theory of constructivism in which the process of teaching and learning is learner-centred and takes into account the learner's own ways of meaning making since the construction of knowledge happens in the mind of the learner (Hunter et al., 2010; Eick & Reed, 2001; Wink, 2010; Lotter et al., 2006).

Inquiry teaching and learning strategies are embodied in national curricula (Eick & Reed, 2001; Barrow, 2006; Bantwini, 2010; Mudau, 2007; Onwu, 2008). The Department of Basic Education (2011:8) outlines that:

Physical sciences promote knowledge and skills in scientific inquiry and problem solving; the construction and application of scientific and technological knowledge; an understanding of the nature of science and its relationships to technology, society and the environment.

In chemistry education inquiry comes as a philosophy, guiding the teaching and learning processes as well as a teaching and learning strategy (Barrow, 2006; Wink, 2010). It can also be considered to be a pedagogical strategy and reform-oriented approach (Vos et al., 2010; Hick, 2008; Prosser, 2006). The inquiry-based instruction was considered as a teacher role identity (Akkerman & Meijer, 2011) in this study (refer to chapter 2.8.3.1).

1.6 Overview of research methodology

The epistemological, ontological and methodological considerations were made with an ultimate aim of finding how best to get insights into how teacher professional identities interface with the practice of IBLW in school chemistry. This is a qualitative case study.

Data generation mainly relied on teacher stories through semi-structured interviews, open-ended observations, focus-group interviews with learners and lesson observations. Meaning making was done through a social-constructivist lens.

Table 1.1 An outline of the research methodology

Title	The influence of teacher professional identity and the practice of inquiry-based laboratory work (IBLW) in school chemistry	
Epistemological paradigm	Social constructivism	
Methodological paradigm	A qualitative approach	
Research design	Case study, narrative inquiry	
Selection of participants	Purposive sampling	Seven grade 10-12 physical science teachers practicing inquiry-based laboratory work in the teaching and learning of school chemistry. 1 teacher drawn from a former model C, former Indian, former Coloured schools and 2 teachers from African and private schools. Grade 10-11 learners who are taught by these teachers and participate in the inquiry-based laboratory activities also become research participants.
Pilot study	A pilot study in one school and one teacher was conducted to test whether the data collection instruments were generating sufficient and relevant data as well as testing whether the process of analysing data is appropriate for the data collected.	
Data collection methods	Semi-structured interviews; Focus group interviews; Document analysis Observations	
Data documentation	Field notes; Researcher journal; Audio recordings; Transcriptions	
Data analysis	Narrative analysis and Content analysis	
Ethical considerations	Researcher as a non-participant observer, informed consent and voluntary participation; confidentiality and anonymity of research participants; protecting participants' from harm	
Quality criteria of the study	Confirmability, Credibility, Transferability and Dependability	

Meta-theoretical paradigm

In this inquiry meaning making was viewed through a social constructivism framework. The epistemological standing of meaning making in social constructivism is based on the assumption that meaning has a public element whereby individual subjects have to reach consensus on what is considered as truth (Boghossian, 2006). With teacher professional identity being a social, evolving and multiple construct (Beauchamp & Thomas, 2009; Beijaard et al., 2004; Assaf, 2008; Upadhyay, 2009, Varghese et al., 2005; Akkerman & Meijer, 2011), the ontological position that realities are multiple and socially co-constructed, (Boghossian, 2006), would be one of the appropriate perspectives to understand teacher identity (refer to chapter 3.2).

Methodological paradigm

A qualitative approach was used in this research based on the tenets outlined by Devetak et al. (2010). First, the approach is inductive, constructivist, interpretative and exploratory. Second, the world is viewed through the eyes of the research participants. Third, the approach takes into account and describes the context. Fourth, the approach emphasizes the process and not the final results. Fifth, the approach is flexible in which concepts and theories are developed as outcomes of the research process.

The choice for a qualitative research was informed by the exploratory nature of the study. The case study focused on the interface between teacher professional identity and the practice of IBLW as a phenomenon. A qualitative study provided an opportunity to gain deeper understanding of the phenomenon of interest, (Hanson et al., 2005; Johnson & Onwuegbuzie, 2004). Context was also of significance because the study was undertaken in five different school settings of the post-apartheid South African education system. Themes emerged from the generated data (refer to chapter 3.3).

Research strategy

There is a wide variety of ways in which to conduct qualitative research. Devetak et al. (2010) say that in qualitative research it is possible to combine different kinds of research like a case study and narratives. The qualitative approach in this study will be in the form of a case study in which narrative research was applied. Teacher stories have the power to

shape teacher professional identity, (Burns & Bell, 2011; Lee, 2012; Smit & Fritz, 2008; Zembylas, 2003; Settlage et al, 2009; Beauchamp & Thomas, 2009; Beijjaard et al, 2004). Sikes & Gale (2001) propound that narratives provide links, connections, coherence, meaning and sense. Narrative research can be in the form of life stories, life histories, personal documents, and documents of life, life writing, personal accounts, narrative interviews and personal narratives, among other forms (Casey, 1996) (refer to chapter 3.4).

The use of a case study made it possible to use a number of data generation techniques in the form of semi-structured interviews with teachers, focus group interviews with learners, lesson observation, field notes and worksheet analysis.

Data generation methods

Two main classes of data generating techniques were used in this study. First, observation was used to collect open-ended first-hand information in the phenomena's natural settings (Creswell, 2008). Observation was an on-going process during the data collection period. It was used directly and indirectly. It was used directly when the researcher had to have first-hand experiences of how teachers facilitate laboratory work for learners. It was also used during the compilation of field notes, during the application of the other data gathering techniques and visits to the schools.

Second, interviews were conducted with both teachers and learners. Semi-structured interviews were conducted with teachers while learners were engaged in focus group interviews (refer to chapter 3.6).

Participant and site selection

Seven physical science teachers who engaged learners in laboratory work activities were selected to be participants in this study. These teachers taught in the Further Education and Training phase (FET) which are grades 10-12 from different research sites. Five research sites were used to provide cases in terms of context. The five research sites were a former model C school, a former Indian school, a former Coloured school, a private school and an African school. The sampling of the participants was purposive to ensure that only teachers who engaged in the practice of IBLW were selected. Each context had at least one teacher selected to participate in this study and at most two teachers were selected from a context.

Two teachers were selected from the African context, one from a township and another from a rural setting. Two teachers were also selected from a private school context (refer to chapter 3.5.1).

Pilot study

The data gathering techniques proposed for this study were tested by conducting a pilot study with one physical sciences teacher in an African township context. The results did not form part of the main research. The general aim of the pilot study was to ensure that the interviews and the observation techniques were effectively generating the intended data (refer to chapter 3.9).

Data documentation

A research journal was kept as it was useful for recording qualitative data. A research journal was used to condense, summarise and integrate data as well as for recording the insights and ideas as the researcher generated them (Spiggle, 1994). The transcription of digitally audio-taped interviews and video-taped laboratory activities and the field notes were other ways in which data was documented.

Data analysis

Content data analysis and narrative data analysis techniques were used to organise and make sense out the data collected. The semi-structured interviews resulted in lengthy teacher narratives which necessitated the use of narrative analysis before ultimately engaging in content analysis of all the data collected. Hsieh and Shannon (2005) describe the following steps of what they term 'conventional content analysis'. First, the researcher gets immersed in the data by reading data word by word, meanwhile making notes of his/her impressions. Second, codes are derived and labelled resulting in the division of text into content categories and sub-categories. Third, the categories are useful for organising data while connections among the content categories are established. Content categories are classified as central, supportive or distracting. Fourth, the relevant theories and other research findings are addressed in the discussion section of the study.

Friedl and Friedl (2002) describe the steps in the process of narrative analysis as follows. First, the researcher immerses him/herself in the data by reading the original texts. Second, the literary and literal translation of data is made in the language used in conducting the research. Third, the texts are divided into macro- and micro units, for example, a larger narrative may be subdivided into episodes which in turn may be divided into scenes. Fourth, a summary is made based on the ideas reflected by the narratives based on events and the participants. At the end of data analysis the interpretation that followed allowed the study to give insights into how teacher professional identity interfaced inquiry practices in the school chemistry laboratory (refer to chapter 3.8).

1.7 Research assumptions

The following research assumptions were identified from the literature:

Assumption 1:

Teacher professional identity has a significant bearing on teacher practice by informing teacher choices of teaching and learning strategies (Morgan, 2004; Tompson, 2010; Lotter et al., 2009; Roehrig et al., 2007; Stolk et al., 2010; White et al., 2010).

Assumption 2:

Teacher identity and teacher practice are closely interwoven (Day, 2007; Barrow, 2004; Keys, 2007).

Assumption 3:

Question posing, procedure of experiment design and articulation of solutions during laboratory work activities are inquiry actions (Hofstein & Naaman, 2007; Limniou et al., 2007; Bretz & Fay, 2008; Domin, 2007; Fay et al., 2007).

Assumption 4:

Inquiry in laboratory work can be placed along a continuum in which it progresses from simple to complex (Bretz & Fay, 2008; Domin, 2007; Fay et al., 2007). The placement of inquiry along a continuum gives rise to rubrics capable of characterising teacher IBLW practice.

Assumption 5:

Teacher professional identity is not a 'static' entity; it evolves over time (Beauchamp & Thomas, 2009; Beijaard et al., 2004; Assaf, 2008; Upadhyay, 2009; Varghese et al., 2005).

Assumption 6:

Teacher professional identity portrays multiplicity and can be fragmented into sub-identities and role identities (Tsui, 2007; Morgan, 2004; Akkerman & Meijer, 2011).

1.8 Quality measures

One way employed to ensure the trustworthiness of the findings in this study was the use of a number of instruments to collect data. These were semi-structured interviews, field notes, observations and a research journal. The taking of the study to five different school contexts was another way to ensure trustworthiness of the study findings. Credibility was ensured through member checking by considering feedback from the participants on the findings made. Credibility was also achieved by systematically building up arguments from the findings of the study and making sure that the findings and interpretations were matching with the collected data (Meriam, 2002). The research study supervisors were responsible for affirming the credibility of the study by constantly reviewing progress in the writing of the thesis.

Transferability was enhanced by giving a detailed account of the research methods, contexts and assumptions underlying the study so that it may be possible to transfer the study to other settings (refer to chapter 3.10). Transferability was also ensured by conducting the study in five different school contexts in South Africa. Meriam (2002) points out that a researcher should purposefully aim to achieve variation and diversity during sample selection. In the same vein thick descriptions of the contexts in which the study was conducted were made available in the discussions to make sure the study can be repeated in other contexts.

Confirmability was achieved through the employment of multiple sources of data to allow for corroboration of data collected. Riege (2003) and Meriam (2002) suggest that studies should generate a chain of evidence which should also be taken back to research participants for confirmation. This study used teacher interviews, focus group interviews

with learners, direct practical activity observations as teachers facilitated laboratory work for learners and the gathering of field notes.

Although the nature of research made it not to be totally free from researcher bias, this was reduced by documenting the process of inquiry, revealing the researcher's theoretical positions and biases and also making use of multiple sources of data (Shenton, 2004; Merriam, 2002). These measures ensured that the study findings become dependable.

1.9 Ethical considerations

A good qualitative research is one that is conducted in an ethical manner (Merriam, 2002). The observation of ethical conduct in this study consisted of going through standard procedures of getting an ethical clearance letter from the relevant department in the University. In summary participants were protected from harm by maintaining their anonymity. The participants' rights to consent were protected as they willingly participated and their consent was solicited prior to their involvement. The researcher displayed a good measure of integrity and honesty throughout the study to ensure that the research is of high quality (Punch, 2005) (refer to chapter 3.11).

1.10 Limitations of the study

This is a qualitative case study and therefore the findings made cannot be generalised for they are unique to the participants and the contextual settings used. Although the study set out to explore the interface of teacher professional identity with IBLW in school chemistry, chemistry is actually offered as physical sciences; therefore, the study findings may actually be for both physics and chemistry or physical sciences. The study did not focus on particular topics in chemistry but on how teachers facilitated inquiry during laboratory work.

1.11 Definition of terms

Conceptualisation of terms was necessary to define the focus of the study in as far as the use of the terms is concerned. It is appreciated here that the terms may be used differently

in other contexts. The terms were conceptualised in order to clarify how they have been used in this study.

Inquiry-based laboratory work (IBLW)

Laboratory work is often referred to by other terms such as practical work or experimental work (Dillon, 2008). There are numerous actions that learners can perform when they engage in Inquiry-Based Laboratory Work (Bell et al., 2005; Limniou et al., 2007; Hofstein & Lunetta, 2004; Hofstein & Naaman, 2007). For the purpose of this study IBLW is considered to occur when learners pose questions, design steps of experiment procedures and articulate solutions to investigative questions.

Professional identity

Healey and Hays (2014) define professional identity in the following manner:

Professional identity is the result of a developmental process that facilitates individuals to reach an understanding of their profession in conjunction with their own self-concept, enabling them to articulate their role, philosophy, and approach to others within and outside of their chosen field.

In this study I chose to use the above definition of professional identity as it encapsulates the concept that professional identity results from professional training and development. Chemistry teachers gain the title after going through professional training in universities and colleges. Teachers also develop their professional identity through practice.

Teacher professional identity

Komba and Kataro (2013) contend that the construct of teacher professional identity is continually being defined. Literature characterises teacher professional identity as a psychological, philosophical and social construct (Kelchtermans, 2005; Zembylas, 2003; Vygotsky, 1978; Lasky, 2005; Varghese, 2005; Akkerman & Meijer, 2011). Teacher professional identity in this study refers to the nature of teacher perceptions, beliefs, commitment and motivation, sense of agency, professional training and development, prior school experiences and contextual settings that shape the IBLW practice. However Komba (2013) says that teacher professional identity is also defined by professional certification, professional experience, adherence to a professional code of conduct, membership in a professional association and professional humility.

Identity positions

Andreouli (2010) defines position as a set of rights and duties that can be said or done from a certain stand point. The author also describes position as having a relational character to other positions. In this study identity positions are considered as a set of characteristics that define the manner in which teachers facilitate IBLW for learners. This results in the characterisation of teacher identity stand points in IBLW in relation to other identity positions.

Identity traits

The definition of identity traits is given as an extrapolation from the definition given by the American Psychiatric Association (APA) of the term ‘personality traits’. Identity traits in this study are considered as enduring sets of beliefs and patterns of perceiving past experiences, knowledge and skills and states of motivation and commitment as teachers facilitate IBLW for learners.

Interface

One of the definitions given by Dictionary.com of the word ‘interface’ is that it is a common boundary or interconnection between two systems. This study brought together two fields of study which are teacher professional identity and IBLW in school chemistry. The interface between teacher professional identity and IBLW in this study is regarded as an interaction between teacher identity traits and positions in the practice of IBLW.

Practice

The Merriam-Webster dictionary says that to practice is to get professionally engaged in the application of ideas. In this study the practice of IBLW is the incorporation of inquiry into chemistry practical work as a teaching and learning strategy.

School chemistry

The term ‘school chemistry’ in this study refers to a system of chemistry concepts and theories which constitute part of the physical sciences syllabus for Grades 10-12 learners in secondary schools in South Africa.

Inquiry

In this study inquiry is considered to be firmly rooted in the scientific method. Engaging in inquiry constitutes facilitating learners to pose questions, design experiments, make predictions, choose the independent and dependent variables, decide how to analyse results, identify underlying assumptions, communicate results and support their own conclusions among other actions (French & Russel, 2002; Abrahams & Millar, 2008; Limniou et al., 2007).

Contextual settings

The Meriam-Webster dictionary defines ‘context’ as the interrelated condition in which something exists or occurs. In this study contextual settings are considered as a set of environmental conditions in which teachers practice IBLW. The environmental conditions influence the manner in which teachers facilitate IBLW for learners. The environmental conditions include time, physical and socio-cultural contexts.

1.12 Outline of chapters

Chapter 1: Orientation of the study

Chapter 1 is the orientation of the study. I introduce readers to the nature of study. In the discussion I present the study background culminating in the articulation of the rationale of study. I pose one major and three secondary questions. I also give an overview of the theoretical and conceptual frameworks used. I proceed by giving a brief overview of the research methodology and design. I outline research assumptions and study limitations. I end the chapter by defining the key terms used in the study.

Chapter 2: Literature review

In chapter 2 I discuss the literature reviewed by developing and organising arguments pointing to the theoretical position of the study. Literature reviewed was on teacher professional identity, identity theories, inquiry-based strategies, and the practice of IBLW in school chemistry and South African school contexts as determined by socio-cultural and economic conditions. I summarise findings emanating from the international landscape and South African contexts. This chapter also contains discussions of the social identity theory and inquiry-based instruction as theoretical and conceptual frameworks of the study

respectively. Efforts were made to show how identity theory and inquiry-based strategies were used as frameworks to hang the arguments put forward by the study. With the social identity theory I explained teacher professional identity formation in IBLW practice while I used inquiry-based instruction to explain IBLW as an instructional practice.

Chapter 3: Research design and methodology

In this chapter I outline how the empirical part of this research was conducted. I start by describing the meta-theoretical framework used by way of presenting arguments that point to the epistemological, ontological and axiological positions of the study. The positions are in line with social constructivism. I further discuss the research strategy of inquiry as a qualitative case study in which narrative research is applied. I depict in detail the whole process of data collection, analysis and interpretation ensuring that the processes are theoretically well grounded. I also describe how I conducted a pilot study to perfect the instruments used to collect data.

Chapter 4: Findings of the study

In this chapter I give vivid and detailed descriptions of the research findings and the researcher's experiences during the process of data collection. Some of the vivid and detailed descriptions were made possible by frequent inclusions of participants' original interview extracts to assist the researcher's narrative as the findings were presented. I organised the findings in three emerging broad themes. The three broad themes have sub-themes and several categories under them. I used figures and tables to summarise the sub-themes and categories under each theme. As a qualitative research, the presentation of the research findings allows readers to embark on an exploration of personal experiences through the study as they immerse themselves in the thick and rich descriptions.

Chapter 5: Analysis and discussion of findings

This chapter consists of my voice as the researcher as I present scholarly arguments based on the findings of the study by comparing and contrasting them with findings in the reviewed literature. I conduct a discussion on how study findings echo the existing literature; differ from the findings made elsewhere in literature and how study findings are silent about certain issues in existing literature. I made efforts to demonstrate how study

findings speak to the identity theory and inquiry-based instruction as theoretical and conceptual frameworks of the study. My discussions in this chapter culminate in engaging the readers on what the study has contributed to filling part of the gap identified during conception of the research question.

Chapter 6: Recommendations and conclusions

In this concluding chapter, I summarise the study findings and I also discuss what was observed to be the limitations and significance of the study. Research assumptions are revisited and finally recommendations for further research and instructional practice in IBLW are made.

1.13 Chapter summary

This chapter familiarises the reader with the nature of study by providing an introduction and background context to the research problem and the rationale of the study before presenting the research question. The chapter also serves to briefly describe the theoretical and conceptual frameworks on which the arguments are made and the research methodology. In order to assist the reader to understand the delimitations of the study, research assumptions are presented and the limitations of study discussed. Operational definition of terms is given by conceptualising key terms used in the study. The chapter concludes by describing the structuring of the writing of the thesis by outlining chapters of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review has been done with the major aim of finding out what authorities say about the interface between teacher professional identity and inquiry-based laboratory work. The first attempt at discussions made in this literature review focuses on the different perspectives through which teacher identity is viewed. This is attributed to the varied philosophical standings on which researchers hang their arguments. An attempt to make a summary of the main characteristics of teacher professional identity salient from the available literature is also made. The philosophical standings of researchers as well as how teacher identity is characterised play a major role in influencing the manner in which findings are interpreted in studies on teacher professional identity and teacher practice.

The discussions also focus on the findings of how teacher professional identity influences teacher practice in general and on how it influences inquiry-based instruction on the international scene. This is followed by an attempt to discuss findings made regarding the practice of inquiry-based laboratory work (IBLW) in school chemistry. In the South African landscape the discussions are about the debates on teacher professional identity derived from literature as well as practical work in South African schools. An attempt is also made to describe the different contexts in which schools in South Africa are operating for this is of particular interest and importance in this study.

Literature in which researchers studied teacher identity as it interfaces with curricula reform and innovation efforts was also reviewed and the major findings noted. In South Africa one of the major issues studied has been the introduction of new curricula such as Outcomes Based Education (OBE) (Bantwini, 2010; Bantwini and King-McKenzie, 2011; Nakedi & Rollnick, 2010). On the international scene, some of the curriculum issues studied included inquiry-based instruction (Cheung, 2010; White et al., 2010; Fay et al., 2007; Melville et al., 2008), teaching chemistry in context (Coenders, 2010; Stolk et al.,

2010; Vos et al., 2010; King et al., 2008), high stakes testing (Assaf, 2008; Upadhyay, 2009) and the promotion of Science, Technology and Society Education (STSE) (Predetti et al., 2008). In some of the research studies the connection between teacher identity and the curriculum issues is not explicit but implicit since the authors make no mention of teacher identity as a concept (Coenders et al., 2008; Vos et al., 2010; King et al., 2008). I have noticed the scarcity in the literature that deals directly with teacher professional identity and the practice of IBLW in secondary school chemistry. The arguments in this study have been organised around social identity theory as a theoretical framework. This theoretical framework is used together with the concept of inquiry-based instruction in science teaching and learning.

2.2 The philosophical assumptions underlying perspectives in the teacher professional identity literature

A review of the voluminous literature reveals that teacher professional identity is a psychological, philosophical and social construct (Kelchtermans, 2005; Zembylas, 2003; Vygotsky, 1978; Lasky, 2005; Varghese, 2005; Akkerman & Meijer, 2011; Lee, 2012). Lee (2012:35), apart from highlighting the philosophical richness of the concept of identity, further propounds that:

An accessible vantage point for unravelling identity is to consider how it has been handled in psychology and sociology. Risking oversimplifications, the former has generally emphasized internal or essentialist aspects of identity as characteristics of individuals, whereas the latter has understood it to be a collective property of people engaged in social interaction.

There is evidence from literature that to look at teacher professional identity is to study how personal attributes and dispositions, whether they be from the affective or cognitive domains, and contextual factors interface in informing classroom practice (Settlage et al., 2009; Elawar et al., 2007; Battery & Franke, 2008; Joseph and Heading, 2010). Elawar et al. (2007) contend that learning about teacher identity is to learn about factors that are influencing the teachers' sense of purpose, self-efficacy, motivation, commitment, job satisfaction and effectiveness in the classroom. Teachers use their identities as a filter for reform ideas (Morgan, 2004; Jita & Vandeyar, 2006; Keys, 2007; Coenders, 2008).

One perspective seems to focus on the intrinsic factors in the shaping of teacher identity and teacher practice. As a result numerous studies have been conducted in which researchers investigate how the affective domain of teachers interfaces with teacher practice as is the case of the role of emotions in shaping identity (Zembylas, 2003; Kelchtermans, 2005; Brigido et al., 2010; Prosser, 2006; Thomas, 2005). Other research studies focus on teacher beliefs and perceptions and their role in the shaping of identity and teacher practice (Keys, 2010; Nakedi & Rollnick, 2010; Lotter et al., 2010, Predetti et al., 2008). Some researchers believe that teachers' experiences in the cognitive domain have the potential to shape the process of instruction and hence efforts to construct the desired identities through professional development (Taitelbaum et al., 2008; Sterling & Frazer, 2010; Thompson, 2010; Lotter et al., 2009; White et al., 2010; Naidoo & Govender, 2010).

Socio-cultural perspectives derived from literature occupy a significant space in current debates on teacher identity (Varghese et al., 2005; Lasky, 2005; Vygotsky, 1978; Milne et al., 2006). This perspective recognizes that teachers are immersed in socio-cultural contexts which have a significant bearing on teacher professional identity and teacher practice (ibid.). Milne et al. (2006), using socio-cultural theory to understand the relationship between teacher change and a science programme, found that teachers do not implement what they learn during their professional training in the same way. This has been attributed to the different working conditions that the teachers are subjected to as well as the nature of teachers' previous social experiences (ibid).

The different perspectives through which to view teacher identity has resulted in researchers failing to arrive at consensus in the way they define identity although they have been able to agree on some characteristics inherent in the concept (Beauchamp & Thomas, 2009; Akkerman & Meijer, 2011). Varghese et al. (2005:22) seemingly on one end of the continuum propound that, "identity is not a fixed, stable, unitary, and internally coherent phenomenon, but is multiple, shifting and in conflict." This position may seem to be in contradiction with the understanding of teacher identity in psychology where the emphasis is on the internal aspects of the individual in understanding teacher practice (Lee, 2012; Kelchtermans, 2005; Zembylas, 2003). Day (2007:603) point out the existence of the apparent contradictions by saying, "This is not to say that teachers do not themselves in

different ways seek and find their own sense of stability within what appears from outside to be fragmentary identities.” Akkerman and Meijer (2011) observe that the most common recurring characterisation of teacher identity found in the literature is that it is social, multifaceted and evolving in nature. However, Akkerman and Meijer (2011:311) further propound that:

It is problematic to completely neglect modern notions of identity. Literature on teacher identity does seem to acknowledge this, stating that identity is not only multiple, discontinuous and social, but also uniform, continuous and individual.

On taking this philosophical position Akkerman and Meijer (2011) worked at bringing together the findings on the concept of identity by putting forward the dialogical approach of viewing teacher identity while at the same time eliminating seemingly contradictions in the findings.

The available literature (Zembylas, 2003; Kelchtermans, 2005; Akkerman & Meijer, 2011) depicts evidence of significant contributions in defining and redefining the identity construct from the fields of psychology and sociology and the debate is still raging as to which makes teacher identity a viable field of research.

2.3 Features of teacher professional identity emerging from literature

After the review of literature certain features stand out to be characteristic of teacher professional identity. Although there is not a consensus as to exactly what the concept is, there are shared elements that most scholars agree should be included in a definition. Teacher identity is individual, dynamic, uniform, multidimensional, complex, socio-cultural and has institutional roots as well as a sense of agency, and the power of narratives and discourse in the shaping of identity is also recognised (Zembylas, 2003; Beijaard et al., 2004; Kelchtermans, 2005; Lasky, 2005; Varghese, 2005; Akkerman & Meijer, 2011). Some researchers may even use these characteristics to hang arguments when discussing findings.

The dynamism of teacher identity which is referred by Akkerman and Meijer (2011) when characterising identity as discontinuous may, in my opinion, be emanating from the socio-

cultural contexts which are ever changing. A case in point is the curriculum reform efforts which are typical of the education systems (Jansen, 2007; Day, 2007; Parker, 2006; Msila, 2007). Upadhyay (2009) and Assaf (2008) investigated the impact of the high-stakes testing environment on elementary teachers' identities and their influence on the maintenance of science teaching. The studies demonstrated the evolving nature of identity. Faced with a high-stakes school environment teachers have to negotiate their identities and teaching practices to meet administrative demands. Upadhyay (2009) found that it was possible for teachers to maintain their identities in the form of beliefs and perceptions about science education and at the same time find means of meeting the administrative demands of high-stakes testing, thus adopting a new identity. Assaf (2008) found that the subject under study went from being a reading teacher who strongly believed in nurturing real readers to a teacher increasingly worried if her students could sail through high-stakes testing.

The evolving nature of teacher identity having been undoubtedly confirmed in most of the literature reviewed (Beauchamp & Thomas, 2009; Beijaard et al., 2004; Assaf, 2008; Upadhyay, 2009; Varghese et al., 2005). Akkerman and Meijer (2011:310), however, contend that, "... an entirely decentred characterisation of identity leads to the question of how a person can maintain and have any sense of self through time." Enyedy et al. (2005) say that teaching is intensely personal suggesting that it should vary from teacher to teacher by being unique and particular to individuals. This emanates from the individual nature of identity which Akkerman and Meijer (2011) observe as being continuous making it possible to distinguish one teacher from the next. Schepens et al. (2009) acknowledge the power of personal traits in the shaping of identity.

Nevertheless there may be some commonalities in the traits of teachers who participate in the same communities of practice (Wenger, 2004; Hunter et al., 2006; Battery & Franke, 2008). Lee (2012) speaks of teachers possessing a science identity; therefore, it is possible to tell a pre-service teacher what a chemistry teacher should be like by painting a picture of what is expected of chemistry teachers and their practice (Akkerman & Meijer, 2011). Brigido (2010), on examining the nature of emotions that pre-service primary teachers experience in the teaching of chemistry and physics, found that the teachers showed signs

of nervousness, anxiety, tension, worry and despair. This study demonstrated the existence of commonalities in the identities of a group of individuals participating in the same community of practice.

The totality of teacher identity has been shown to be composed of sub-identities (Beauchamp & Thomas, 2009; Tsui, 2008; Akkerman & Meijer, 2011; Smit & Fritz, 2008). Tsui (2008) refers to the sub-identities as role identities. This perspective helps to show what shapes teacher identity and what it is constituted of. Some of the sub-identities include professional identity, personal identity, situated identity, social identity (Smit & Fritz, 2008; Akkerman & Meijer, 2011) and the claimed identity which emanates from teachers' narratives about how they perceive their identities (Akkerman & Meijer, 2011). The multiple nature of identity reveals the major shapers of identity because, as Settlage et al. (2009) affirm, identity results after the merging of multiple dimensions. These dimensions include a sense of agency, professional training, narratives and discourse, teacher as a natural component (Beauchamp & Thomas, 2009; Settlage et al., 2009) and contextual factors that emanate from socio-cultural settings (Beauchamp & Thomas, 2009; Lasky, 2005; Varghese et al., 2005; Milne et al., 2006). On teacher natural component, Beauchamp & Thomas (2009) highlight the power of emotion and reflection in shaping identity.

Taking into consideration the efforts made so far to define and characterise teacher identity, what emerges is that the construct can be said to be complex (Tsui, 2008; Elawar & Lizarraga, 2010). Defining teacher identity in an all-encompassing manner has so far proved to be elusive (Elawar & Lizarraga, 2010; Akkerman & Meijer, 2011).

2.4 The international landscape

Teacher identity does not emerge as a new theme in teaching literature; however, an on-going interest by researchers on the subject is evident (Jita & Vandeyar, 2006; Malderez et al., 2007; Lee, 2012). Beijaard et al. (2004) identified three categories of research focus under which the teacher professional can be placed, namely: first, research focusing on professional identity formation (Moore, 2008; Lamote & Engels, 2010; Monereo, 2010;

Forbes & Davis, 2008); second, research directed towards the identification of characteristics inherent in teacher professional identity (Akkerman & Meijer, 2011; Kelchtermans, 2005; Zembylas, 2003, Varghese et al., 2005; Beauchamp & Thomas, 2009); and, third, research efforts focusing on the representation of teacher professional identity through teacher stories (Smit et al., 2010; Burns & Bell, 2011; Smit & Fritz, 2008).

While there is considerable research on teacher professional identity from the perspective of general teaching, (Jita & Vandeyar, 2006) there is a significant gap in what is known about the shaping of identities within specific subject matter contexts (Lasky, 2005; Jita & Vandeyar, 2006). In the current wake of widespread curriculum reform and innovative teaching (Day, 2007; Jansen, 2007) it becomes important to investigate how teachers are dealing with change in an attempt to provide them with support to sustain certain critical pedagogies like the practice of IBLW (Vos et al., 2010; Prosser, 2006).

2.4.1 How teacher professional identity influences teacher practice

It is important to recognise that teacher practice and in particular the practice of IBLW is an identity position taking into account that the totality of teacher identity is constituted by sub-identities (Beauchamp & Thomas, 2009; Tsui, 2008; Akkerman & Meijer, 2011; Smit & Fritz, 2008). Considering that teacher identity is multidimensional (Beauchamp & Thomas, 2009), a science identity (Lee, 2012) can be considered as a role identity within the totality of teacher professional identity. In the same way the practice of IBLW is a role identity position within the science teacher identity. For these reasons and for the purposes of this study the practice of IBLW by chemistry teachers is a form of identity in itself. After all, the sub-identities are closely interwoven. (Day, 2007:604):

There is an unavoidable interrelationship between professional and personal, cognitive and emotional identities if only because the overwhelming evidence is that teaching demands significant investment of these (ibid.).

Hence investigating how teacher professional identity influences teacher practices like IBLW is about examining the aspects that make teacher identity and their dynamic interrelationship.

From the literature reviewed some of the major shapers of teacher practice as an identity position are personal identity (Day, 2007; Battery & Franke, 2008; Settlage et al., 2009),

professional training and development (Taitelbaum et al., 2008; Sterling & Frazer, 2010; Stolk et al., 2010; Coenders, 2010; Lotter et al., 2006; White et al., 2010), contextual settings (Milne et al., 2006; Lasky, 2005; Bantwini & King-McKenzie, 2011), narratives and discourses (Beijaard et al., 2004; Smit et al., 2010; Burns & Bell, 2011; Smit & Fritz, 2008) and a sense of agency (Lasky, 2005; Settlage et al., 2009; Beauchamp & Thomas, 2009; Milne et al., 2006).

2.4.1.1 Personal identity

It has been demonstrated that teacher practice is influenced by emotion (Lasky, 2005; Prosser, 2006; Zembylas, 2003; Brigido et al., 2010; Kelchtermans, 2005), beliefs and perception (Keys, 2010; Nakedi & Rollnick, 2010; Lotter et al., 2010; Predetti et al, 2008), knowledge (Naidoo & Govender, 2010; White et al., 2010; Nakedi & Rollnick, 2010; Taitelbaum et al, 2008), epistemological orientations (Taitelbaum et al., 2008; Erduran et al., 2007; Siry & Lara, 2011) and reflection (Melville et al., 2009; Tan & Goh, 2008; Beauchamp & Thomas, 2009). In summary teachers carry personal histories, emotions, values and knowledge which shape how they conduct professional practice in the classrooms (Settlage, 2009; Battery & Franke, 2008). Thomas (2008), in a commentary on research papers on teacher identity, emotion and change in Canada, the Netherlands and the United States, observed that teachers' emotional experiences of school reform influence the following: first, their risk taking and identity formation and, second, their learning and development by creating an environment of uncertainty. Thomas (2008) also concludes that change theory could be valuable to guide the implementation of reform and that there are individual similarities and differences in the response to change.

Bantwini (2010) contends that reform proposals are subject to individual interpretations which may result in the formulation of new meanings that in turn act as a map of curriculum implementation and determines their success. Coenders (2010) posits that teachers may decide to make use of the materials and strategies that match their perspectives and discard or modify the ones that do not. Vos (2010) agrees with the notion that teachers incorporate reform and innovations into largely unaltered practices and that their ways of thinking about their practice is rather linked to their belief system than to the new curriculum mandates.

The following findings from literature support the notion that personal identity influences teacher practice. Malderez et al. (2007) found that the development of a teacher identity is a core aspect of the experience of becoming a pre-service teacher after realising that, teacher perceptions and early experiences of teacher development are differentiated. Lamote & Engels (2010) found that pre-service teachers with work placement experience developed a more enhanced view of learning and teaching compared to students without this experience and that male students tended to attach more importance to discipline in the classroom, while their female counterparts focused more on learner involvement.

In science education the teachers' epistemological views of science influence how they conduct and portray science in the classroom (Lotter et al., 2006). This may explain why teachers still hold on to traditional methods of teaching, embraced the active methods of teaching or are somewhere in between (Roehrig et al., 2007).

2.4.1.2 Professional training and development

Battery and Franke (2008) posit that identity is shaped by the knowledge and skills teachers acquire and, in turn, identity shapes the knowledge and skills that teachers seek to develop. It is upon this assumption that some researchers advocate for purposeful professional development to achieve identity formation (Taitelbaum et al., 2008; Sterling & Frazer, 2010; Stolk et al., 2010; Coenders, 2010; Lotter et al., 2006; White et al., 2010). The professional development efforts have been targeted at both the pre-service teachers as part of training and the professional teachers.

Teacher education programmes are to a larger extent responsible for professional identity construction (Edwards & Blake, 2007; Malderez et al., 2007; Monereo, 2010). The identity construction may be directed by state-mandated standardisation (Edwards & Blake, 2007), achieved through pre-service teacher mentoring (Malderez et al., 2007; Bradbury, 2010) or any other methodology like the use of a guideline for the analysis of critical incidents and events that can come up in the classroom to promote a deeper change directed at the conceptions, strategies and feelings of the teacher (Monereo, 2010; Lasky, 2005).

Predetti et al. (2008) outlined some requirements aimed at constructing a teacher identity position of pre-service teachers for the successful implementation of the Science Technology Society Education (STSE) philosophy. These include making pre-service teachers aware of the competing ideologies and images in science teaching, giving the pre-service teachers an opportunity to explore their political positions and controversial issues with the aim of making them see the need to accommodate diverse views, ensuring the development of pedagogical content knowledge (PCK) for the particular reform orientation to assist in the development of supporting beliefs and enhancement of future practices, addressing the theory/practice gap during teaching practice, and using case studies which provide concrete examples and act as a window to authentic practice during the process of teacher education. Even though these measures can be ensured during teacher education, there is a need to find answers to questions of how science teachers' professional identities change over time (ibid.). Moore (2008) found that teachers should have a social justice science teacher identity if they are to teach and act to improve science learning experiences for traditionally marginalised students. This role as a change agent should be developed during the process of teacher training.

For in-service teachers continuous professional development programmes on inquiry as a method of teaching and epistemological orientation have been seen to bring about positive changes in teachers (Taitelbaum et al., 2008; Erduran et al., 2007; Siry & Lara, 2011).

2.4.1.3 Contextual settings

Factors like school environment, nature of learner population, the impact of colleagues and school administrators play a part in the shaping of teacher identity (Beauchamp & Thomas, 2009). Bantwini and King-McKenzie (2011) observe that the successful implementation of reform in teaching practices depends on, among other things, the working conditions in the schools. Chong et al. (2011) found that newly qualified teachers experience mismatched expectations between what they had originally perceived of the profession and the reality that confronts them. Therefore, the authors recommend that school administration should address negative effects of contexts in order to maximise teacher commitment, motivation, and effectiveness, and self-efficacy, sense of purpose and job satisfaction. However, other findings suggest that the school environment as in organisational climate is not a strong

influence on what happens in the classrooms (Aldridge et al., 2011). Aldridge et al. (2011) propound that although organisational climate may be important during the implementation of new curriculum and for school improvement, it is unlikely that it will influence changes in an individual teacher's behaviour.

2.4.1.4 Narratives and discourse

The construction and shaping of identity is also a narrative and discourse process (Burns & Bell, 2011; Lee, 2012; Smit & Fritz, 2008; Zembylas, 2003; Settlage et al., 2009; Beauchamp & Thomas, 2009). Through discourse which is "talk and behaviour" teachers are able to show their "science identity" (Lee, 2012:36). Narratives can be used by teachers to make sense of their lived experiences by using stories to represent who they are and interpret the world (Coles, 1989; Bramberg, 2012; Lee, 2012). Bramberg (2012:2) attempts to explain what narratives are and what they can do in the following way:

When narrators tell a story, they give 'narrative form' to experience. They position characters in space and time and, in a very broad sense, give order to and make sense of what happened--or what is imagined to have happened. Thus, it can be argued, that narratives attempt to *explain* or *normalize* what has occurred; they lay out why things are the way they are or have become the way they are.

Using narrative research by employing narrative inquiry strategies and narrative analysis researchers are able to study identities of teachers. The assumption is that teachers are best positioned to recount their professional and personal experiences since they are the ones who have lived and are living them. Beijaard et al. (2004) posits that one of the ways used to study teacher professional identities is by collecting teacher stories after recognising their power to shape identities. Through telling stories teachers are able to express who they are by way of communicating their thoughts, emotions, perspectives, beliefs, meaning making, what they do in the classrooms, how and why they do the things they do, and past events in their life that are relevant to the object of research studies. By so doing they bring themselves and others into being (Lee, 2012).

2.4.1.5 Sense of agency

Agency can be considered to be the umbrella term for an individual's capacity to act (Milne et al., 2006). Beauchamp & Thomas (2009) argue that teachers achieve goals and transform contexts through their sense of agency. It follows that teachers' sense of agency

informs their actions which, in turn, shape their identities. Lasky (2005:914) propounds that, “Political, social and economic mediational systems shape school reform policy, which in turn mediates teacher identity, and teacher agency.” It can be deduced, therefore, that the relationship between teacher identity and sense of agency is that of a dynamic interplay.

The identity shapers discussed above act as potential definers of teacher professional identity and it is important to note that they are not the only ones but for the purposes of this study it was necessary to mention these few.

2.4.2 The influence of teacher professional identity on the practice of inquiry

The aim of this sub-section is to highlight the findings that link teacher professional identity and the practice of inquiry in science education from the reviewed literature.

The practice of inquiry as a teacher practice is also a teacher identity position based on the multiple nature of identity (Akkerman & Meijer, 2011; Beauchamp & Thomas, 2009; Forbes & Davis, 2008; Tsui, 2007; Morgan, 2004; Beijaard et al., 2004). It follows that the practice of inquiry is shaped in the same way as have been discussed in section 2.4.1. However it is important to realise that for the purposes of this study the practice inquiry is considered as a teacher identity position, a philosophy in science education (Barrow, 2006; Wink, 2010), a teaching strategy (Barrow, 2006; Roehrig et al., 2007; Lotter et al., 2006; Osisima & Onyia, 2008; Lustick, 2009) and that it is reform-based (Hick, 2008; Bantwini, 2010). There is significant evidence from literature on the use of the teacher identity as a lens in the investigations conducted on the practice of inquiry whether implicitly or explicitly (Melville et al., 2008; Cheung, 2010; White et al., 2010; Fay et al., 2007; Lustick, 2009; Osisima & Onyia, 2008; Lotter et al., 2006; Lotter et al., 2009; Milne et al., 2006).

From the findings the successful implementation of inquiry practice seems to hinge on the following: first, the role of professional development on the teachers’ knowledge of the nature of science (Naidoo & Govender, 2010; Nakedi & Rollnick, 2010); second, the role of teachers’ beliefs and perceptions of inquiry as well their epistemological orientations in

science education (Lotter et al., 2006; Roehrig et al., 2007; Siry & Lara, 2011; Erduran et al., 2007; Hick, 2008; Melville et al., 2008); and, third, the influence of socio-cultural settings (Milne et al., 2006) which may even be in the form of curriculum reforms like high-stakes testing, (Upadhyay, 2009). Milne et al. (2006) demonstrated in their study that contextual factors can either empower or restrict teachers in the practice of inquiry in the schools.

Following on the discussions made above the scholarly gap arises in the manner in which teacher professional identity is used as a framework in the study of teacher practices in inquiry. There are still questions on how the teacher professional identity characteristics influence the way teachers facilitate question posing, experiment procedure design and solution articulation. Therefore this particular study presents an opportunity to use the whole person's identity (Olsen, 2008) to study facilitation of inquiry actions in particular school settings. This is in contrast to situations where researchers use parts of teacher professional identity such as socio-cultural settings (Milne et al., 2006), teacher knowledge (Naidoo & Govender, 2010) and beliefs and perceptions (Erduran et al., 2007). In this study all professional identity aspects that interfaced with facilitation of inquiry actions in the chemistry laboratory became relevant.

The findings from the literature review seem to echo some general concerns about the practice of inquiry in schools. Barrow (2006) reviewed the historical development of the interpretation of inquiry throughout the 20th century in science education and posits that there is no consensus about what is inquiry. If this is anything to go by, then the implementation of inquiry-based strategies is compromised. Osisima and Onyia (2008) in their study raised questions on what teachers believe to be inquiry-based instruction. In a research study Lustick (2009) observed that the participants in his study would rather define, describe and share ideas about the concept than engage in scientific inquiry. Naidoo and Govender (2010) observed that, although post-graduate teachers have adequate understanding of the nature of science, they tend, however, to teach the main concepts in traditional teaching-lecturing modes. This is supported by Nakedi and Rollnick (2010) who discovered mismatches between what teachers say they do in their classrooms and their actual classroom practices. Enyedy et al. (2006) raise the argument that even though

numerous programmes and technologies have been developed in response to the strong movement to promote inquiry-based science education and teachers are made to participate in professional development, there still remains a large and documented amount of variability from class to class.

From the discussions made above it can be concluded that the influence of teacher professional identity on the practice of inquiry in science is significant and worth studying.

2.5 The practice of Inquiry Based Laboratory Work (IBLW) in school chemistry

This section discusses the general findings in the practice of IBLW in school chemistry through reviewing what literature says about the types of inquiry that can be practiced in school chemistry, the rationale for practicing IBLW and the challenges associated with it.

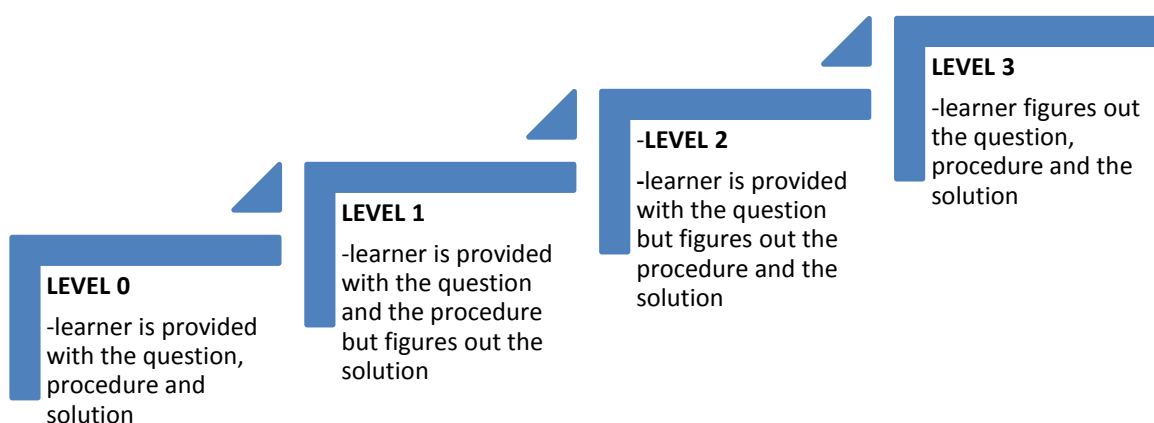
2.5.1 Types of IBLW in school chemistry

Inquiry can be conducted in varied ways according to the level of student-centredness or teacher-centredness allowed in the stages of question posing, procedure construction and solution construction (Bretz & Fay, 2008; Dudu & Vhurumuku, 2012; Mitchell, 2007). From the models of inquiry described by Mitchell (2007) as well as Bretz and Fay (2008), the lowest level of inquiry is when the question, procedure and solution are provided for the learner while at the highest level inquiry learners provide the question, procedure and solution.

In this study the description adapted by Bretz and Fay (2008) of the levels of inquiry will be adopted. Bretz and Fay (2008) say that the levels of inquiry are in a form of a continuum that ranges from level 0 to level 3. In level 0 the question, procedure and solution are provided for the learner. In level 1 the question and the procedure are provided for the learner but the solution is learner constructed. In level 2 the question is provided for the learner but the procedure and solution are learner constructed. In level 3 the question, procedure and solution are all learner constructed. Teachers are able to apply inquiry according to the needs of the learners (Domin, 2007; McDonnell et al., 2007). The active participation of learners is ensured because the generation of knowledge is done

inductively by deriving general principles from data collected (Domin, 2007). The following figure summarises the levels of inquiry that may manifest in school chemistry laboratories as teachers facilitate inquiry activities for learners.

Figure 2.1 Levels of school chemistry laboratory inquiry



Source: Adapted from Bretz and Fay (2008)

Although learners are allowed a considerable degree of autonomy during inquiry teachers still play the role of facilitating and guiding the process of learning (Schoffstall & Gaddis, 2007; Kirschner et al., 2004). The varied complexity in the levels of inquiry from simple to more complex forms as we move from level 0 to level 3 allows teachers strategically to make use of inquiry according to the needs of the learners and goals of education (Limniou et al., 2007; Domin, 2007). IBLW can either be guided or open (Schoffstall & Gaddis, 2007; Kirschner et al., 2004). Schoffstall & Gaddis (2007) contend that guided inquiry is a reasonable option to verification approaches. This is supported by Kirschner et al. (2004) when they propound that guided inquiry may even be more effective than open inquiry in learners since it presents less chances of learners acquiring misconceptions or incomplete knowledge. With guided inquiry learners have an opportunity to learn for themselves in an environment that is controlled and the teacher can give them guidance (Schoffstall & Gaddis, 2007).

Dudu and Vhurumuku (2012) and Hattingh et al. (2007) also used some kind of classification to what they referred to as inquiry in the studies that they conducted in South Africa. Hattingh et al. (2007) used a classification framework for science practical work which is composed of four levels of complexity. In the first and lowest level the teacher uses classroom demonstrations to help develop concepts as well as specimens found in the local environment for purposes of illustration during lessons. Learners' actions are limited to observing in order to gain conceptual understanding. In the second level the teacher uses classroom demonstrations during lessons while learners are observing. Learners perform 'cook book' practical work and communicate data collected by way of tables and graphs. In the third level the teacher plans the practical work in a manner that allows learners to learn by discovery. Learners perform guided discovery type of practical work in groups and they are expected to write scientific reports in which they develop conclusions based on the data collected. In the fourth level learners design and do their own 'open-ended' investigations. Learners are able to develop skills in experiment design that enable them to collect quality data. Data collected is used by learners to support competing theories and explanations.

In a study also conducted in South Africa by Dudu and Vhurumuku (2012) through examining the practices of two grade 11 teachers when teaching practical investigations, the authors used a classification framework based on teacher and learner roles during question posing, developing of procedures and finding of solutions while conducting inquiry activities in the science laboratory similar to the one propounded by Bretz and Fay (2008). In this study, according to the authors, the teachers faced some challenges in different ways as they engaged in the teaching of practical investigations which resulted in teachers and learners achieving inquiry in varied degrees but somehow fell short of making learners practice the highest form of inquiry. Stoffels (2005) conducted a study on the implementation of the Outcomes-Based Curriculum 2005 (C2005) which required teachers to abandon the traditional content-heavy textbook methods in favour of more inquiry-oriented approaches. However, the teacher under study converted the learner support materials provided into worksheets to be followed and decided not to make use of the suggested problem-solving experiments designed to be conducted by learners. According

to the findings the teacher did this in order to maintain control over learners in the face of learner disruptions and discipline issues, lack of resources, lack of mastery of certain strands of science and the intensification of workloads. These are some of the findings made by investigators as they studied about how teachers in South Africa facilitate practical work in the science laboratories.

The development of rubrics to characterise inquiry by using question posing, experiment procedure design and solution articulation is a very important development in giving more insights into attempts to define inquiry. This is a development in a scholarly terrain in which an all-encompassing definition of inquiry as it is applied in the science laboratory is elusive (Barrow, 2006). From the literature reviewed I have noticed three ways in which inquiry can be conceptualised.

First, inquiry has been conceptualised according to the actions that learners perform when they are participating in learning activities in the chemistry laboratory. These actions include posing scientifically oriented questions, forming hypotheses, designing and conducting scientific investigations, formulating and revising scientific explanations, and communicating and defending scientific arguments (Hofstein & Naaman, 2007; Limniou et al., 2007). Accordingly, if learners are engaged in any of these actions then they are considered to have participated in inquiry activities. The rubrics are also important in measuring the extent of inquiry practiced. This study is explicitly aligned to this way of conceptualising inquiry. Literature reviewed reveals a scholarly grey area in how teacher professional identity influences the facilitation of particular inquiry actions and not inquiry in general. This area is under researched.

Second, inquiry has been conceptualised through a constructivist lens which emphasises certain conditions that must be met to ensure inquiry learning. These include facilitating learner centred activities in which learners construct knowledge cooperatively in authentic environments like science laboratories. The first and second approaches of conceptualising inquiry are not in contradiction; however, the first approach specifies actions and allows us to measure the extent of learner autonomy allowed in the learning process.

Third, inquiry can be conceptualised by pitting it against ‘traditional’ teaching and learning methods in the science laboratory. This conceptualisation assumes that inquiry occurs when learners construct knowledge by discovering the scientific concepts and theories as they engage in practical work. This happens when laboratory work is structured in a manner that allows learners to inductively learn scientific concepts and theories. Accordingly, by using this way of conceptualising inquiry, laboratory work activities can either be inquiry-based or ‘traditional’ in terms of whether scientific concepts have been learned inductively or deductively. Inquiry is viewed as an end or outcome and not a process. Verification experiments become a ‘traditional’ way of facilitating laboratory work. It is important to note that this happens after restricting the definition of inquiry to when learners discover scientific concepts and theories. For the purposes of this study this definition was considered to be too limited. Barrow (2006) also observes that teachers interpret the concept inquiry in different ways. The scholarly gap arises on how to best conceptualise inquiry in the school chemistry laboratory.

Findings from literature suggest that if IBLW is successfully implemented the educational benefits could be quite significant.

2.5.2 Benefits of IBLW in school chemistry

According to Hofstein (2004) activities in the chemistry laboratory constitute a mode of learning, assessment and instruction for which teachers need knowledge, skills and resources to enable them to facilitate these processes. With inquiry approaches being embodied in national curricula for science education (Lustick, 2009; Bantwini, 2010), IBLW is one strategy through which inquiry can be implemented. The chemistry laboratory in the school can be used to promote student initiated and student directed learning in line with the theory of constructivism (Fay et al., 2007; Buntine et al, 2007). Learners are afforded opportunities to manipulate equipment and materials in order to construct their knowledge of phenomena and related science concepts (Lotter et al., 2006; Hofstein & Naaman, 2007) by coming up with explanations based on evidence (Lustick, 2009; Bradbury, 2010).

Through laboratory work the cognitive, affective and practical goals of science education can be achieved (Hofstein & Naaman, 2007). By engaging in laboratory work learners can gain understanding of the nature of science (NOS) and scientific literacy (Vhurumuku et al., 2006; Buntine et al., 2007). Abrahams and Millar (2008) affirm that learners find practical work enjoyable and exciting. The following technical and higher order thinking skills can be achieved through practical work in the laboratory: manipulation, observations, data collection, processing and analysis of data, interpretation, posing scientifically oriented questions, forming hypotheses, designing and conducting scientific investigations, formulating and revising scientific explanations, problem solving, teamwork, communicating and defending scientific arguments (Fay et al., 2007; Buntine et al., 2007; Limniou et al., 2007; Hofstein & Naaman, 2007).

Despite the immense potential portrayed here of how the practice of IBLW assists in achieving some of the goals of science education, the practice faces a number of challenges.

2.5.3 The challenges in the practice of IBLW

The reports on the practice have not all been positive (Hofstein & Naaman, 2007; Witteck, 2007; Cheung, 2007; Domin, 2007; McDonnell et al., 2007). One of the major concerns is that the achievement of the educational goals through practical work in the laboratory has been limited because of the failure to incorporate inquiry in the learning activities (Fay et al., 2007; Buntine et al., 2007; Cheung, 2007; McDonnell et al., 2007). The argument is that laboratory work conducted through traditional approaches mainly allows learners to verify known results (McDonnell et al., 2007; Domin, 2007). The benefits of laboratory work become limited in that little is achieved in understanding the nature of science, experimental design, critical analysis and sources of error (Abrahams & Millar, 2008; Limniou et al., 2007). Abrahams and Millar (2008) contend that teachers expect learners to understand scientific ideas from the observations made in the laboratory and yet they put little in place during the planning of the activities to ensure that this happens. Hofstein and Naaman (2007) observe that laboratory work can be unproductive and confusing if is practiced without a clearly thought out purpose. Cheung (2007) mentions the barriers to the successful implementation of IBLW in school chemistry to include lack of time,

teacher beliefs, lack of effective inquiry materials, pedagogical problems, management problems, large classes, safety issues, fear of abetting student conceptions, student complaints, assessment issues and material demands.

2.6 The South African landscape

This section discusses the findings from the literature reviewed on the influence of teacher professional identity on teacher practice in South Africa as well as the debates around school chemistry practical work.

2.6.1 School contextual settings in South Africa

As alluded to by Ogunniyi (2013), the apartheid era has seen South Africa forged into four distinct cultural groups namely 'Blacks', 'Coloureds', 'Indians' and 'Whites'. Laws were passed to outlaw racial mixing and education saw itself classified as 'White', 'Indian', 'Coloured' and 'Black' with children of particular races attending school separately in their areas of residence in urban areas which were also demarcated according to race (Selod & Zenou, 2003). The term 'Africans' may be used instead of 'Blacks' for affirmative action purposes (Ogunniyi, 2013). The separation of races was characterised by differential treatment of the groups in terms of per capita spending, class size and teacher quality (Selod & Zenou, 2003). The allocation of resources favoured White schools the most followed by Indian schools, Coloured schools and, last of all, African schools (Ogunniyi, 2013; Selod & Zenou, 2003). This made African schools suffer the worst effects of these segregation policies by ending up with overcrowded classrooms and the highest number of under- or unqualified teachers (Selod & Zenou, 2003). On overcrowding in classrooms, Onwu & Stoffels (2005) say that it results in lack of physical space for movement; reduced opportunities for all learners to participate actively in learning and therefore impedes efforts to meet individual learner needs for self-activity and inquiry, motivation, discipline, safety and socialisation; excessive workloads and unrevised homework; impersonalised teaching and teachers resorting to lecture methods and demonstrations.

On science education Lewin (1995) alludes to the notion that apartheid policies systematically neglected the needs and the rights of the disadvantaged masses in science

teaching and learning. Ogunniyi (2013) supports this by saying that learners from the different cultural groups ended up having different experiences with school science. Performance in science during the apartheid era was ranked in the order of Whites, Indians, Coloureds and then Africans. This may be attributed to the allocation of resources as mentioned by Selod and Zenou (2003). Generally for every R4 spent on a White child, R3 was spent on an Indian child, R2 on a Coloured child and R1 on an African child. However, in 1990 there was an important development to take note of which translated into the granting of rights to appoint teachers, decide on admission policies and to impose fees on the model C schools which resulted in their semi-privatisation (Selod & Zenou, 2003). These rights were also extended to all public schools as the restrictions on racial mixing were also abolished in 1996 (ibid). The abolishment of the restrictions may be seen as one of the efforts made through policy to promote racial integration which would see some of the schools becoming multi-racial.

2.6.2 The South African perspectives on the influence of teacher identity on teacher practice

Recent literature about teacher professional identity in IBLW and even about science on the South African landscape has been scantily available. Most of the literature used here deals with identity and other curriculum issues from which implied significance and relevance have been derived. South African teachers have been working in an education system characterised by constant reforms (Jansen, 2007; Msila, 2007; Parker, 2006, Bantwini, 2010). In 1994 the primary aim of the curriculum developers was to create a single national core syllabus which is representative and participatory in nature, free from racist characteristics (Bantwini, 2010; Department of Basic Education, 2011). 1997 saw the launch of OBE (Jansen, 2007; Msila, 2007; Bantwini, 2010; Stoffels, 2006). In 2002 came the Revised National Curriculum Statement with changes aimed at improving the implementation of OBE especially in impoverished areas (Bantwini, 2010; Msila, 2007; Jansen, 2007). Implementation challenges resulted in the review of the RNCS of 2002 in 2009 (Department of Basic Education, 2011). The RNCS and the National Curriculum Statement (NCS) 10-12 were amended and combined into the NCS Grades R-12 which took effect in January 2012 (ibid.). The NCS Grades R-12 embodies the Curriculum and Assessment Policy Statement (CAPS) which provides clearer specification of what is to be taught and learnt.

These constant changes and innovations around the South African National Curriculum Statement (NCS) translates in shifts on the nature of teacher practice and hence on teacher professional identity (Webb, 2009; Vanger et al., 2007; Stoffels, 2006; Bantwini & King-McKenzie, 2011; Jita & Vandeyar, 2006). It may be expected that this environment of constant change would promote the evolving nature of teacher professional identity to manifest significantly (Varghese et al., 2005; Upadhyay, 2009; Assaf, 2008). Parker (2006) points out that one of the major aims of the educational reforms is to transform the pedagogical identities working in the system. Stoffels (2006) contends that OBE requires a significant amount of pedagogical shift in response to a number of policy directives in post-apartheid South Africa. Weldon (2010) recommends the need to subject teachers to professional development programmes to reshape identities constructed during the conflict period.

The inquiry teaching and learning is a newly introduced phenomenon which came with the massive education reforms after 1994 (Bantwini, 2010). Vanger et al. (2007) observe that in Southern Africa, policy emphasis is on learner-centred education. Stoffels (2006) posits that OBE requires that teachers adopt different mind-sets and changed practices in line with constructivism and learner-centred teaching practices. Despite the embodiment of inquiry in the science curriculum, the implementation has not been all smooth running. Jita and Vandeyar (2006) observe that there is a gap between reform policy and teacher identities. Reform policies seem to take for granted that teachers will be able to effect the changes while they may not have the necessary experiences in line with the policy shifts (ibid). Stoffels (2006) points out that there has been little training provided for the teachers. Inquiry has been threatened by the continuation in the practice of traditional methods in the classroom by teachers (Webb, 2009; Vanger et al., 2007; Stoffels, 2006). Vanger et al. (2007) propound that studies reveal classroom practices largely dominated by teachers while learners silently copy notes from the chalkboards. Stoffels (2006) observes that, although teachers are in agreement with the general aims of OBE, their efforts on successful implementation are hampered by overwhelming administration burdens and increased workloads. Webb (2009) found that in South Africa science may be taught in

second and third languages which often results in traditional and teacher-centred strategies as evidenced by chorus repetitions at the expense of inquiry activities.

While most teachers have found the contextual factors like intensification of workloads debilitating to their performance, some teachers have been able to rise above the challenges drawing on their personal resources (Stoffels, 2006). Jita and Vandeyar (2006) recommend that the gap between policy and teacher identity should be addressed by uncovering teachers' prior experience with subject matter and then provide them with opportunities to learn and unlearn in the context of the introduced reforms. The significant role that teacher professional identity plays in the successful implementation of reform ideas (Bantwini & King-McKenzie, 2011; Bantwini, 2010; Jita & Vandeyar, 2006; Webb, 2007; Vanger et al., 2007), such as inquiry based strategies, is in line with findings made on the international landscape of teachers using their identities as filters in implementing change (Morgan, 2004; Keys, 2007; Coenders, 2010).

2.6.3 Chemistry practical work in South African schools

Mudau (2007) posits that the development of scientific inquiry in learners specified in the Learning Outcome Number 1 of NCS physical sciences should be achieved through practical work which is mainly expected to be conducted in the school science laboratory. The conducting of practical work has been be-devilled by a number of challenges. Ramnarian (2011) observes that practical work is characterised by lack of learner autonomy despite curriculum imperatives for learners to engage in inquiry-based practical work. Mudau (2007) says that some reports regard practical work in some South African schools as not being meaningful.

Onwu (2009) observes that the Learning Outcome Number1 has been neglected in the following ways: first, it is not conducted in the practical context but as multi-step calculations; second, scientific investigation has been diluted by problem-solving; and, third, practical skills are not adequately assessed. However, Ramnarian (2011) says investigations and experiments can be assessed as continuous assessment (CASS) tasks. Stoffels (2008) attributes the failure of reform-oriented strategies such as inquiry to the intensification of teachers' workloads resulting in them relying heavily on the textbook

method. Makgato and Mji (2006) and Makgato (2007) highlight lack of resources in some schools to impact negatively on laboratory activities.

Mudau (2007) found that some teachers use practical work to develop procedural knowledge in learners and neglecting content while others are keen on using practical work to support understanding by relying heavily on teacher demonstrations. Ramnarian (2011) points out that although autonomy may be transferred to learners teachers still play an important role of ensuring that learners remain on the track of inquiry by employing questioning techniques.

The findings from literature on the debates around teacher professional identity and the implementation of practical chemistry are in line with findings made internationally even though the contextual settings may not be the same.

2.7 Summary of findings

After a review of voluminous literature the following findings have been made. First, teacher professional identity is a field of research that has branched out from the major field of research based on identity theory (Luehmann, 2007; Zembylas, 2003). For that reason teacher professional identity is theoretically underpinned by principles and tenets that form the foundation of the identity theory.

Second, research on the identity construct is rich in attempts to construct and reconstruct the concepts that help to give it a comprehensive definition (Kelchtermans, 2005; Akkerman & Meijer, 2011; Zembylas, 2003). Major contributions in efforts to define the identity construct have been from the fields of psychology, sociology and philosophy, (Akkerman & Meijer, 2011; Korte, 2007; Hornesey, 2008). It can be concluded that the various definitions put forward demonstrate that identity has psychological, socio-cultural and philosophical foundations.

Third, research has revealed some of the major shapers of teacher identity to include teacher training and professional development, teacher narratives and discourses,

contextual settings, a sense of agency and teacher beliefs (Beauchamp & Thomas, 2009; Settlage et al., 2009). Professional training and development has the potential to alter the cognitive and affective dispositions of teachers (Korte, 2007), while contextual factors have the potential to inhibit or promote action (Milne et al. 2006). Through stories teachers are able to give accounts of their identity dispositions, authentic events and experiences in their professional lives and for this reason narrative research has become one of the major approaches when studying teacher identity (Beijaard et al., 2004). Teacher identities get constructed and reconstructed as teachers play out the roles particular to their practice in the teaching profession (Beauchamp & Thomas, 2009). Teacher identity is continually shaped by classroom practice which explains why we can speak of experienced teachers and less experienced teachers and, in turn, the nature of their experience can also inform their classroom practice. Teacher beliefs have been found to play a crucial role in how teachers cope with reform ideas such as inquiry-based instruction (Hick, 2008; Roehrig et al., 2007; Lotter et al., 2006). Hick (2008) propounds that teacher inquiry-based beliefs should be able to withstand the school site factors so that the teachers do not wind up teaching using traditional styles.

Fourth, literature has reached a consensus in that teacher identity is a multidimensional and dynamic entity (Akkerman & Meijer, 2011; Varghese et al., 2005). Identity can be fragmented into sub-identities which allow teachers to take up different roles as required by the circumstances. In response to contextual factors as well as internal factors encountered by teachers during practice, identity keeps evolving which prevents it from reaching an ultimate destination state in the process of its definition.

Fifth, the effective practice of inquiry-based instruction has been reported to face serious challenges because classrooms have been observed to be dominated by traditional approaches of teaching and learning (Vanger et al., 2007; Webb, 2009). IBLW falls under the pedagogical strategies that constitute inquiry-based instruction. In some instances the successful implementation of IBLW in school chemistry has been compromised. Cheung (2007) cites lack of time, teacher beliefs, lack of effective inquiry materials, pedagogical challenges, management issues, large classes, safety issues, fear of exacerbating student

misconceptions, student complaints, and assessment issues and materials to stand in the way of effective IBLW practice.

Sixth, inquiry in the laboratory in simple terms involves three steps which are formulation of question, elaboration of procedure and construction of solution (Bretz & Fay, 2008). Inquiry in the chemistry laboratory can be performed at different levels depending on the extent of learner control allowed during the learning process (Schoffstall & Gaddis, 2007; Bretz & Fay, 2008). Inquiry can now be classified in levels that differ in complexity. According to Bretz and Fay (2008), if inquiry is placed on a scale of 0 to 3 then level 0 will have the question, procedure and solution provided for the learners. In level 1 the question and procedure are provided for learners but the solution is learner constructed. In level 2, the question is provided for the learners but the procedure and solution are learner constructed. In level 3 the question, procedure and solution are learner constructed.

Seventh, the findings made on the international landscape on the practice of IBLW and how it interfaces with teacher professional identity are in line with findings made on the South African landscape. However, South Africa has unique contextual settings that include widespread reforms in education in the form of curriculum innovations (Jansen, 2007; Msila, 2007; Bantwini, 2010; Parker, 2006). The constant curriculum innovations call for constant teacher professional development exercises; therefore, professional development as one shaper of teacher identity may have a significant role to play. Some of the challenges that bedevil the practice of IBLW in the South African context include issues of language since science might be taught in second or third languages (Webb, 2009). Stoffels (2006) cites the overwhelming administration burdens and increased workloads on the part of teachers to be some of the contextual factors that discourage teachers as they try to implement inquiry-based strategies. The failure to sufficiently bridge the gap between reform policies and teacher identities has been pointed out by Jita and Vandeyar (2006) and Stoffels (2006) to be one of the contributing factors to poor implementation of reform ideas embodied in the curricula as is the case with inquiry-based instruction. In South Africa the contexts in which schools operate are also important to take note of. Just as the education system was classified into racial classes of White education, Indian education, Coloured education and Black education during the apartheid

era, the process of racial integration after independence still has resulted in different school contexts. Some of the school contexts are private, former model C, former Indian, former Coloured, African township, rural and even farm schools.

In conclusion, the multiple nature of teacher professional allows the practice of IBLW to be considered as an identity position in which the teacher plays the role of a pedagogical specialist (Lee, 2012; Akkerman & Meijer, 2011). The pedagogical expertise is crucial in the successful implementation of inquiry in the chemistry laboratory and on this Hofstein (2004:260) says that:

Teachers need knowledge, skills and resources that enable them to teach effectively in practical learning environments. They need to be able to enable students to interact intellectually as well as physically, involving hands-on investigation and minds-on reflection.

Considering the practice of IBLW to be an identity position implies that the pedagogical strategy shares the same theoretical underpinnings with the identity construct in the manner in which it is constructed and shaped. This has made it possible to use the identity theory as part of the framework on which the arguments in this study are based.

2.8 Theoretical framework

An identity theory was used as a theoretical framework. However with the existence of many strains of the theory depending on the field in which it is applied, the social identity theory was considered to be appropriate. Social identity theory was applied in the context of teacher professional identity as a theoretical framework for the study. The nature of the study allowed the use of inquiry-based instruction as a conceptual framework. Some of the basic tenets of the identity theory and the inquiry-based instruction as well as how the study proposed to make use of both the theoretical and the conceptual frameworks are described below.

2.8.1 Social identity theory

Since this study has to do with teacher professional identity it made sense to use an identity theory to organise the arguments made in this study. However, the review of a voluminous literature reveals the existence of several attempts to define and redefine identity theory as

a construct, (Hornsey, 2008; Korte, 2007; Zembylas, 2003; Kelchtermans, 2005; Akkerman & Meijer, 2011). This study made use of some and not all of the social identity theory tenets.

2.8.1.1 Basic tenets of the social identity theory

The social identity theory as a construct is discussed here according to the perspectives of authorities from the literature reviewed for this purpose, some of which are Korte (2007), Huddy (2001), Fielding et al. (2008) and Reicher et al. (2008). This is important to point out because, according to Korte (2007), the social identity theory shows its weaknesses as follows. First, authorities do not define the social identity theory in the same manner which makes it confusing to the reader. Second, authorities from different disciplines view the social identity theory with biases. Psychologists may be seen to place emphasis on psychological factors in their contributions to the social identity theory (Huddy, 2001). Proponents of socio-cultural perspectives like Varghese et al. (2005) may be seen to place emphasis on socio-cultural factors. Those involved with professional training and development may be seen to be focusing on conceptual frameworks that have to do with theories of planned behaviour (Gado, 2005) and those working on the development of political identity may be seen to be placing emphasis on political factors (Reicher et al. (2005). Third, Korte (2007) propounds that the social identity theory may make coherent explanations of past behaviour but it is difficult to use it to predict future behaviour.

Reicher et al. (1995) view the social identity theory construct as a complex system consisting of at least two major sub-systems which are the personal identity and social identity. Personal identity corresponds to those attributes that uniquely identify an individual (Reicher et al. (1995) and social identity refers to the identity dispositions acquired by individuals when they become part of a group or groups (Korte, 2007; Reicher et al., 1995; Fielding et al., 2008; Huddy, 2001). Huddy (2001) agrees by saying that the social identity theory has its origin in cognitive and motivational factors. Fielding et al. (2008) and Korte (2007) contribute by saying that individuals develop part of their self-concepts or identities through becoming part of a group. The different authorities used here are in agreement that individuals develop a social identity when they join a group.

Using the social identity theory allows this study to make an assumption that teacher professional identity is a social identity position acquired by teachers as they become part of the body of professional teachers. Tajfel and Turner (1979) propound that individuals join groups because they would have made a decision to do so through a process of social categorisation. Individuals who join groups also share norms and attitudes of other group members through a process of social identification and still hold their own self-concept through a process of social comparison (ibid.). This study focused specifically on physical sciences teachers who practice IBLW in school chemistry as a sub-group. The implication of being a member of this group is that the use of laboratory work as a teaching strategy is informed by the norms, values, beliefs and knowledge that underpin the identity of the social group (Korte, 2007; Reicher et al., 1995). Through a social identity theory lens I examined the ways in which physical sciences teachers facilitate question posing, experiment design and solution articulation when they are practicing IBLW in school chemistry. Korte (2007) explains that changing to a group-based identity is accompanied by a corresponding change in motives, expectations, affective connotations, background knowledge, beliefs, norms and values to match that of the group. It is important to note that physical sciences teachers are also members of other social groups as might be determined by the contexts in which they teach. Belonging to these other social groups may or may not have bearing on the way they play their roles as members of the physical sciences teachers who practice IBLW in school chemistry. Also of importance to note is the notion that the physical sciences teachers practiced IBLW as members of other social groups like when they were still secondary school learners, students at colleges or any other previous positions they may have occupied that have to do with laboratory work. All this forms part of their background experiences that they have to negotiate as they become members of professional physical sciences teachers who practice IBLW.

The basic tenets of the social identity theory at this point of the discussion are outlined in the context of the study as well as apply to the context of teacher professional identity. The social identity theory proposes the following tenets to be inherent with teacher professional identity. First, Korte (2007) propounds that psychology defines identity as a cognitive construct which is significantly laden with affective dispositions. The affective dispositions include emotion (Zembylas, 2003; Prosser, 2006) and motivation (Lasky,

2005) as well as the values and beliefs upheld by individuals (Keys, 2010; Nakedi & Rollnick, 2010). The interplay between the cognitive and affective manifestations is seen as an individual's personal traits that give him/her a unique and enduring personality (Korte, 2007).

Second, the concept of identity acquires a social nature when individuals seek to belong to the various social groups and assume different social roles (Hornsey, 2008; Korte, 2007). Teachers belong to the teaching profession as a social group. Belonging to this social group allows them to take up different roles in other social groups such as school organisations, communities of practice and classroom practice. Varghese et al. (2005) and Vygotsky (1978) highlight the influence of socio-cultural settings on behaviour in adopting and adapting to social roles. For these reasons identity comes out as multifaceted and an identity disposition accords with the situation (Huddy, 2001). The dynamic nature of identity becomes pronounced as socio-cultural settings are characterised by widespread reforms (Assaf, 2008; Upadhyay, 2009; Milne et al., 2006).

Third, professional development and training play a significant role in teacher identity formation (Malderez et al., 2007; Edwards & Blake, 2007; Taitelbaum et al., 2008; Lotter et al., 2006). Teacher training and teacher professional development allow teachers to participate in communities of practice such as described by Wenger (1998). Korte (2007) propounds that learning alters the individual's set of skills and knowledge and this applies to teachers as they participate in professional training and professional development programmes.

Fourth, insights into teacher identities can be elicited through the teachers' accounts of their personal and professional experiences. These are teacher stories (Burns & Bell, 2011; Lee, 2012; Beijaard et al., 2004) that Luehmann (2007) posits that are embodied in the interpretations and narration of experiences. It is possibly for this reason that one major focus in teacher identity research makes use of narrative research as a methodological approach (Beijaard et al., 2004).

Fifth, a sense of agency results in teachers having an affinity to certain roles and behaviours as determined by the social identities they have assumed. As explained by Fielding et al. (2008), upon becoming a member of a group an individual's behaviour becomes group-based and is informed by the norms and values of the social group. Teachers practice IBLW in school chemistry because they are members of a social group of teachers who are reform-minded and employ inquiry-based strategies. Teachers assume their roles in a manner that makes them take up the identity of the social group by behaving in a manner that advances the particular sense of agency.

At this point an attempt is made to justify why the practice of IBLW in school chemistry will be investigated using a teacher professional identity lens. Leuhmann (2007) and Zembylas (2003) point out that professional identity has emerged as a subfield in the theory of identity. This theoretical standing underpins the link between the practice of IBLW and teacher identity.

2.8.2 Identity theory as a lens to investigate the practice of IBLW in school Chemistry

Considering the position that teacher professional identity may be shaped from the teachers' own perspectives of how they define themselves and their practice (Lasky, 2005), teacher narratives are able to elicit the interplay between identity and teacher practice (Burns & Bell, 2011; Beijaard et al., 2004; Lee, 2012; Zembylas, 2003; Settlage et al., 2009; Beauchamp & Thomas, 2009). As Beijaard et al. (2004:121) put it "A story to live by provides a narrative thread or story-line that educators draw on to make sense of themselves and their practice."

The reference to the multiplicity of teacher professional identity is evident in much of the literature (Akkerman & Meijer, 2011; Beauchamp & Thomas, 2009; Forbes & Davis, 2008; Tsui, 2007; Morgan, 2004; Beijaard et al., 2004). The implication of the multiplicity of teacher identity is that it is composed of sub-identities (Tsui, 2007; Morgan, 2004; Akkerman & Meijer, 2011). One way of fragmenting teacher identity is to view it as consisting of professional identity, situated identity and personal identity (Smit & Fritz, 2008; Akkerman & Meijer, 2011). The sub-identities can be described as role identities which originate from the contexts and relationships that the teachers find themselves in during the process of executing their duties (Tsui, 2007; Forbes & Davis, 2008; Beijaard et

al., 2004; Akkerman & Meijer, 2011). The sub-identities may exist in conflict and the teacher plays the active negotiator who has to manage the contradictory interests of the identities to keep them in balance (Morgan, 2004; Tsui, 2007; Prosser, 2006; Predetti et al., 2008). Prosser (2006) observed that teachers are embroiled in tensions that arise from social, historical and institutional pressures on what is the right way to teach and what is the right sort of teacher. This now raises questions on how teacher identity is sustained (ibid.).

One fragmentation of teacher professional identity alluded to by Akkerman and Meijer (2011) is to consider that a teacher is a subject matter expert, a pedagogical expert and a didactical expert. It is upon this assumption that the practice of IBLW is considered to be a role identity in which the teacher becomes a pedagogical expert. Hence, to investigate the influence of teacher professional identity on the practice of IBLW is, in essence, to study the shaping of the role identity of a teacher as a pedagogical expert in IBLW. This investigation was conducted through a teacher identity lens by studying the dynamic interplay amongst the various components that constitute the totality of identity. Day (2007) explains that the sub-identities are closely interwoven and exist in mutual interplay even if the coexistence may be in conflict (Tsui, 2007).

Lasky (2005:901) propounds on how teacher professional identity influences teacher practice in the following manner:

Individual capacity is what an individual brings with him or her to the school setting and instruction. It includes personal commitment, a willingness to learn about instruction and to view learning as on-going, and substantive knowledge about reform ideas...It also encompasses individual beliefs, identity, values, subject area and pedagogic knowledge, past experiences with reform...teacher emotional well-being...and professional vulnerability.

Through teacher narratives it was hoped that this study would illuminate the interface between teacher professional identity and the practice of IBLW in school chemistry.

2.8.3 Inquiry-based instruction

Inquiry in this section will be applied to the context of a chemistry laboratory. According to Hofstein (2004) learners engaging in IBLW ask questions and hypothesise, plan

experiments, conduct the planned experiments, analyse results, ask further questions and present the results in a scientific way.

Inquiry is rooted in the theory of constructivism in which the process of teaching and learning is learner-centred and takes into account the learner's own ways of meaning making since the construction of knowledge happens in the mind of the learner (Hunter et al., 2010; Eick & Reed, 2001; Wink, 2010; Lotter et al., 2006). Eick & Reed (2001:402) propound that:

Constructivist learning theory supports inquiry by placing the focus of learning on student ideas, questions, and understanding and not teacher delivery of content.

The next section discusses the basic tenets of inquiry-based instruction, the role of inquiry-based instruction in chemistry education and its relationship with teacher professional identity.

2.8.3.1 The basic tenets of inquiry-based instruction

Since constructivism exists in various forms (Boghossian, 2006) it becomes imperative to identify the form of constructivism compatible with the IBLW that is being referred to in this study. The IBLW in this study is based on the principles of social constructivism as a learning theory. For that reason the following tenets become inherent to the inquiry-based instruction described here. First, the learner or communities of learners actively construct knowledge and the process has to occur in the mind of the learner or minds of learners (Boghossian, 2006; Miller & Miller, 1999). Second, construction of knowledge is achieved through learners' experiences in authentic environments resulting in unique and multiple meanings for participants (Doolittle & Camp, 1999). However Miller and Miller (1999) point out that it is important for learners to reach a consensus amongst the group members or through consistency of results as they construct meaning to avoid cases of reaching false conclusions. Third, learning is relevant resulting in learners developing behaviours that make them viable for further education, work and everyday life in general (Doolittle & Camp, 1999). Fourth, learners are encouraged to take considerable control of their learning while teachers play the important role of facilitating and guiding the process of learning and instruction (Schoffstall & Gaddis, 2007; Kirschner et al., 2004). Fifth,

learners engage in science activities from the posing of the question or problem, devising of the procedure or method and the construction of the solution (Bretz & Fay, 2008). Sixth, learning acquires a social nature as it is characterised by collaboration, cooperation and communication amongst the learners

This characterisation of inquiry-based instruction helps to lay down the fundamental principles upon which the values, norms, beliefs, expectations, background knowledge, motives and affective connotations of the social group of teachers who practice IBLW in school chemistry are based in this study. As teachers practice IBLW they are expected to operate within the confines of the behaviour that makes them identifiable with the group in a way propounded by Reicher et al. (1995:177):

To be a group member, then, is to define oneself as a member of the social category and for members of groups perception operates at the social categorical level. This is not only a matter of characterizing out group members in terms of self-stereotyping such that individuals adopt the understandings and characteristics associated with the intergroup category. Thus the values and beliefs that underpin behavioural choice, the norms which are held as relevant, who will be influential and what messages will gain influence are all dependent upon definition of the social category in question.

2.8.3.2 The role of inquiry-based instruction in school chemistry

Inquiry teaching and learning strategies are embodied in national curricula (Eick & Reed, 2001; Barrow, 2006; Bantwini, 2010; Mudau, 2007; Onwu, 2008). The Department of Basic Education (2011:8) outlines that:

Physical sciences promotes knowledge and skills in scientific inquiry and problem solving; the construction and application of scientific and technological knowledge; an understanding of the nature of science and its relationships to technology, society and the environment.

In chemistry education inquiry comes as a philosophy guiding the teaching and learning processes as well as a teaching and learning strategy (Barrow, 2006; Wink, 2010).

2.8.3.3 The relationship between inquiry-based instruction and teacher professional Identity

According to the multiplicity nature of teacher professional identity, Eick and Reed (2001:412) posit that in order for teachers to practice inquiry in classrooms they should have a well-developed “inquiry role identity”.

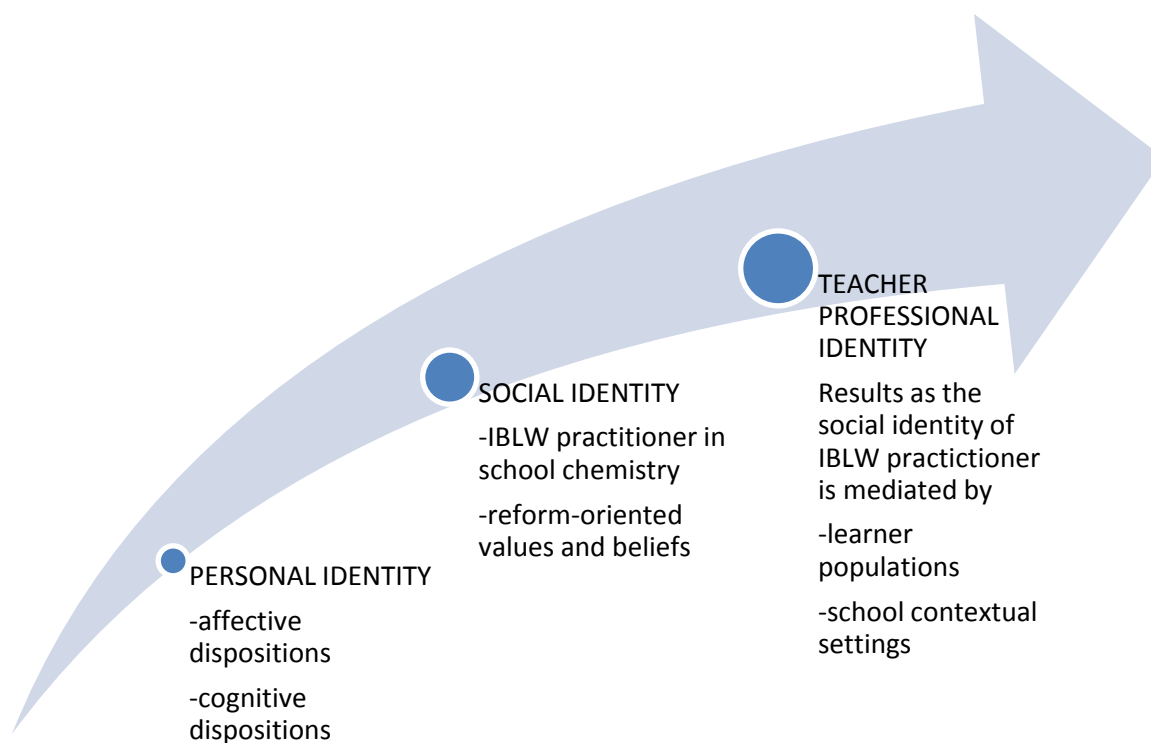
Teachers who practice reform ideas have student-centred beliefs which stem from teachers' personal histories (Eick & Reed, 2001; Hick, 2008). Teachers' core beliefs do not arise from school site factors; however, beliefs should be able to withstand the school site factors so that the teachers do not wind up teaching in traditional ways (Hick, 2008). This can be supported by work done by Roehrig et al. (2007) who classified reform curriculum implementers as traditional, mechanistic and inquiry-based implementers. On this Lotter et al. (2006) posit that teachers' epistemological views of science influence how they conduct and portray science in the classroom.

It is important to note that inquiry in this study interfaces with teacher professional identity as a philosophy guiding chemistry education, a pedagogical strategy and a reform-oriented approach. The inquiry-based instruction is also considered to be a teacher role identity.

2.8.3.4 Summary of the theoretical framework

The assumptions made during the proposition of this theoretical framework are founded upon the roles played by personal identity, social identity and contextual settings in framing teacher professional identity. The framework recognises the psychological, socio-cultural and contextual connotations in the shaping of teacher professional identity. A teacher's professional identity is defined by the teacher's personal identity disposition, and the norms, values, beliefs, expectations and the knowledge systems of the social group of teachers who practice IBLW in school chemistry, as well as by the contextual settings in which the school is situated. Although it may be assumed that by joining a group of physical sciences teachers who practice IBLW in school chemistry the teacher takes up an identity associated with the group which, in this case, has to do with the practice of inquiry-based strategies, this identity is mediated by personal identity and the school cultural settings. Hence the totality of teacher professional identity in this study is explained upon these assumptions. The figure below makes an attempt to capture the essence of how the theoretical framework supports the arguments made in this study.

Figure 2.2 Teacher professional identity in the practice of IBLW in school chemistry



2.9 Conclusion

The practice of IBLW in school chemistry is considered as a teacher role identity in this study. Hence by investigating the influence of teacher professional identity on the practice of IBLW is, in essence, examining the shaping and sustaining of that particular identity position in chemistry teachers. Literature revealed that teacher identity is influenced and shaped by factors that are within the individual teacher as well as factors that stem from the school settings. A social identity theory was used as a theoretical framework together with inquiry-based instruction as a supporting conceptual framework. Narrative methods played an important role in this study in shedding some light on the interplay between these factors and the practice of IBLW in school chemistry.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

In this chapter an attempt is made to give a detailed description of the research design and methodology. This is done by way of discussing the basic features of a research methodology which include the meta-theoretical framework; the methodological paradigm; the research strategy of inquiry; sampling techniques; data generation procedures; data documentation, analysis and interpretation; quality measures and ethical issues, as well as the limitations of study. Also described is a pilot study which was conducted, including its purpose and how it assisted in shaping the research design and methodology of this study. The following is a table summarising the research design and methodology before they are discussed in detail.

Table 3.1 An outline of the research methodology

Title	The influence of teacher professional identity and the practice of inquiry-based laboratory work (IBLW) in school chemistry	
Epistemological paradigm	Social constructivism	
Methodological paradigm	A qualitative approach	
Research design	Case study, narrative inquiry	
Selection of participants	Purposive sampling	Seven grade 10-12 physical science teachers practicing inquiry-based laboratory work in the teaching and learning of school chemistry. 1 teacher drawn from a former model C, former Indian, former Coloured schools and 2 teachers from African and private schools. Grade 10-11 learners who are taught by these teachers and participate in the inquiry-based laboratory activities also become research participants.
Pilot study	A pilot study in one school and one teacher was conducted to test whether the data collection instruments were generating sufficient and relevant data as well as testing whether the process of analysing data is appropriate for the	

	data collected.
Data collection methods	Semi-structured interviews; Focus group interviews; Document analysis Observations
Data documentation	Field notes; Researcher journal; Audio recordings; Transcriptions
Data analysis	Narrative analysis and Content analysis
Ethical considerations	Researcher as a non-participant observer, informed consent and voluntary participation; confidentiality and anonymity of research participants; protecting participants' from harm
Quality criteria of the study	Confirmability, Credibility, Transferability and Dependability

The discussions are made in such a way that I was able to justify the epistemological, ontological, methodological and axiological decisions made and give a detailed report of how data was collected.

3.2 Meta-theoretical framework

In this inquiry meaning making was viewed through a social constructivism framework. In social constructivism, researchers seek to make meaning of the meanings other people have of the world around them (Patton, 2002; Cresswell, 2007). These meanings have a public element whereby individual subjects have to reach consensus on what is considered as truth (Boghossian, 2006) and that reality is constructed through human activity (Kim, 2001). Research conducted under this epistemological position relies mostly on the participants' views. I entered the research field as a non-participant observer. Insights on the interface of teacher professional identity and the practice of IBLW were elicited through planned human activities which were undertaken by the research participants and the researcher. The human activities alluded to were the data collection activities which allowed me to interact with the research participants. Collaboration in meaning making and construction of knowledge was achieved.

The use of interviews to elicit narratives allowed participants to actively take part in the construction of what is known about how teachers practice IBLW in school chemistry. I was also an active participant in the construction of reality in the process of data generation because my voice was heard through the field notes made from observations and the

reflections in the research journal. I collaborated with the participants to generate data for the research in the form of narratives. The observed laboratory activities were another form of human activity that served as a platform for the teacher and learners to construct the reality which was sought by the research question of how teacher professional identity interfaces with the practice of IBLW in school chemistry.

The data on how teacher professional identity interfaced with the practice of IBLW in school chemistry could only be best provided by the teachers themselves since they are the ones who can narrate stories of their experiences and they may be able to explain why they do the things they do in the practice of IBLW. Throughout all the stages of this research study, the collaboration between me and the research participants in the construction of meaning became a value and an underlying assumption. In social constructivism humans construct knowledge about reality and not reality itself whereby a singular, stable and fully knowable reality is not attainable (Patton, 2002). As a result of that the meanings made about a particular reality, according to Cresswell (2007), are varied and multiple. Researchers' interpretations have an element of bias since they flow from their personal, cultural and historical backgrounds (ibid).

The notion that teacher professional identity is a social, evolving and multiple construct (Beauchamp & Thomas, 2009; Beijaard et al., 2004; Upadhyay, 2009; Varghese et al., 2005; Akkerman & Meijer, 2011) fitted well with the ontological position that realities are multiple and socially co-constructed (Boghossian, 2006). Social constructivism was one of the appropriate perspectives to understand teacher identity. Culture and context were taken into account as attempts were made to understand teacher activities in the process of incorporating IBLW in school chemistry. The construction of knowledge was based on this assumption (Kim, 2001).

For readers to understand discussions during the analysis and interpretation of findings they should know the lens through which meaning making was conducted. This is one research in which research participants were given a voice. It relied mostly on the participants' views. Patton (2002) and Cresswell (2007) point out that social constructivists seek to make meaning of the meanings other people have of the world around them.

Similarly, I sought to make meaning of the meanings teachers had in the interface of their teacher professional identities with their practice of IBLW.

In this study meaning making was a social activity which was undertaken by the participating teachers and their learners as well as the researcher. In the construction of meaning it was the voices of teachers, to a large extent supported by their learners and my voice as I wrote and reported on the research findings. Teachers expressed their perceptions, beliefs and experiences through narratives. Learners supported the teachers by narrating the experiences that they have had with laboratory work. I reported on observations I made during data collection. I reorganised the meanings teachers and learners made of their experiences with laboratory work. Literature also speaks to the findings of the study. These four voices collaborated and cooperated in a bid to establish the essence and the substance of the fundamentals of this research as expressed through the findings.

Patton (2002) posits that in social constructivism a singular, stable and fully knowable reality is not attainable which results in meanings made of a particular reality to be varied and multiple. For this reason, readers of these research findings may continue the process of knowledge construction by making their own interpretations of the meanings expressed by the four major voices speaking in this study. It is through the ontological position that realities are multiple and socially constructed that the findings of this study should be understood.

3.3 Methodological paradigm

Hanson et al. (2005) mention that primary importance should be placed on the research question more than the method, the theoretical lens or the paradigm that underlies the method. With the research question in mind considerations were made on which research paradigm should be used to conduct the research. The epistemological, ontological and methodological considerations were made with the ultimate aim of finding how best to get insights into how teacher professional identities interface with the practice of IBLW in school chemistry. The qualitative research paradigm is anchored in multiple constructed

realities that depend on researcher's world view and that research is influenced by values (Onwuegbuzie & Leech, 2005).

With the research question in mind I had to come up with the most appropriate research paradigm for this study by reviewing literature on similar studies. A study was conducted by Cheung (2008) using a quantitative approach to measure teacher professional identity dispositions of Hong Kong teachers by developing a professional identity scale with 19 items. The scale utilised self-ratings by teachers on the items of the professional teacher identity scale. For this study Cheung (2008) relied on the views of the teachers on the manifestation of the phenomena under study since they were asked to self-rate themselves on various professional identity issues. I had an opportunity to get insights into the phenomena under study by using the views of the teachers as they were the ones living the experiences of what constitutes teacher professional identity. The professional teacher identity scale with 19 items that deal with issues on teacher identity was the main data generating tool in the study. Using quantitative methods Cheung (2008) was able to get results that the author was able to generalise on Hong Kong teachers. This study was not for generalising but to gain deeper understanding of the shaping of teacher professional identity of a few teachers in the different school situations that they found themselves in. This was achieved by taking contextual factors into account; bearing in mind that context is important in the shaping of professional teacher identity (Varghese et al., 2005). This study is firmly situated in five different contextual settings as historical determined by years of apartheid and post-apartheid policies in South African education.

Another study which was conducted in Mpumalanga, South Africa, was taken into consideration. Hattingh et al. (2007) conducted a study looking into some factors influencing the quality of practical work in science classrooms. A mixed method approach to research was used. This allowed them to use both the quantitative approach and the qualitative approach paradigms by employing a survey, case studies and classroom observations. What is important to highlight here from the findings is that teachers do not always do what they claim to do in questionnaires about how they conduct practical work in school science. This highlights one of the disadvantages of relying upon the information provided by teachers solely in case studies without allowing the researcher to get access to

the research sites for purposes of conducting first-hand observations and other interactions that allow the researcher to acquire in-depth and comprehensive insights on the manifestation of the phenomena under study. Triangulation through the use of varied data collection tools is one of the important things to incorporate in case studies.

Upon deciding on the appropriate research paradigm to use in this study, I realised that literature reviewed is saturated by studies that point out the factors that have the potential to shape teacher professional identity which, in this case, would be the teacher who practices IBLW in school science. The other realisation made from literature is that IBLW as a practice comes not in one form (Bretz & Fay, 2008) but is varied in nature for reasons rooted in teacher professional identity which is the focus of this study. Based on the above realisations and the research question, the purpose of this study calls for in-depth and close-up examination of how teachers make decisions when practicing IBLW in school chemistry. A qualitative approach to the study was eventually designed for this research to focus on the grey area that exists on how the aspects of teacher professional identity bring about the varied ways in which IBLW is practiced.

A qualitative approach was used in this research based on the tenets outlined by Devetak et al. (2010). First, the approach was inductive, constructivist, interpretative and exploratory. I embarked on an exploratory journey to get in-depth insights into the interface of teacher professional identity and the practice of IBLW in school chemistry. The journey was exploratory in that, while from literature reviewed one is able to explain the shaping of teacher professional identity dispositions such as that of reform-oriented teachers who are able to incorporate inquiry practices in teaching and learning, one still needs to understand how and why the professional identity dispositions of individual teachers bring about the varied ways in the practice of IBLW. Second, the world was viewed through the eyes of the participants. The research participants in this study were the teachers and their learners. Third, the approach took into account and described the context. Fourth, the approach emphasized the process and not the final results. Fifth, the approach was flexible in that concepts and theories were developed as outcomes of the research process. As alluded to earlier on during this discussion, one of the main reasons for the choice of a qualitative approach to this study is that it provided an opportunity to gain deeper

understanding of the phenomenon of interest (Hanson et al., 2005; Johnson and Onwuegbuzie, 2004).

3.4 Research strategy of inquiry

There are a wide variety of ways in which to conduct qualitative research. Devetak et al. (2010) say that in qualitative research it is possible to combine different kinds of research like case studies and narratives. The qualitative approach in this study was in the form of a case study in which narrative research was applied.

3.4.1 Case study

Literature reviewed reveals that case studies in research are not used for the same purposes. Here are some of the ways in which researchers can make use of case studies. Denzin and Lincoln (2005) and Flyvberg (2011) posit that a case study is a choice of what is to be studied by defining the unit of study as well as the context. Cresswell (2007) says that a case study is a methodological choice as it allows the use of multiple sources of data such as interviews, observations, documents and artefacts among others (Kyburz-Gruber, 2004; Yin, 1981, Eisenhardt & Graebner, 2007) in studying an event, a programme, or an activity using one or more than one individual (Cresswell, 2007). Kyburz-Gruber (2004) and Yin (1981) contend that using a case study is to provide the research with a strategy of inquiry.

Yin (1981) says that using a case study is a choice of a research strategy that researchers make over other research strategies like an experiment, a history and a simulation among others. Yin (1981) further clarifies that the use of a case study neither implies the use of a particular type of evidence since it can be used for both qualitative and quantitative research paradigms nor implies the use of a particular data collection method. Corcoran et al. (2004) postulate that a case study can accommodate a variety of research designs, data collection techniques, epistemological orientations and disciplinary perspectives. In this investigation I used a case study as a research strategy of inquiry under a qualitative research paradigm in which narrative research is applied as a method.

Cresswell (2007:73) says that, “case study research involves the study of an issue explored through one or more cases within a bounded system”. This can be a study of an event, programme or activity. In this case study the phenomenon under study was the interface of teacher professional identity with the practice of IBLW as a teaching and learning strategy in school chemistry using more than one individual (Cresswell, 2007). Seven teachers and some of their learners participated in the study. Yin (1981) explains that a case study examines a contemporary phenomenon in its real life context where the boundaries of the context and the phenomenon are not clearly evident. This is applicable to this study since factors like school environment, nature of learner population, the impact of colleagues and school administrators play a part in the shaping of teacher professional identity (Beauchamp & Thomas, 2009).

Cresswell (2007) describes some ways by which case studies may be distinguished. First, case studies may be classified according to the size of the bounded case as in whether the case involves one individual, several individuals, a group, an entire programme or an activity. In this study the case study involves several individual teachers and the interface between teacher professional identity and the practice of IBLW as teaching and learning strategy as the phenomenon under study. Case studies according to Cresswell (2007) and Yin (1993) may also be classified based on the intent of the case analysis. Based on intent there is the single instrumental case study, the multiple or collective case study and the intrinsic case study (ibid). Cresswell (2008) explains that the single instrumental case study is a study that provides insight into an issue. This study is an example of a single instrumental case study which focuses on an issue. The multiple case study results when several cases are used to provide insights on one issue while the intrinsic case study is used to study unusual cases which present unique characteristics (Cresswell, 2007; Cresswell, 2008).

A review of the literature reveals yet another way in which case studies may be distinguished. There is the descriptive case study, the explorative case study and the explanatory-causal case study (Yin, 1981; Yin, 1993; Kyburz-Grabner, 2004; Macnaghten and Myers, 2004). Explorative case studies are used by researchers when they are not quite sure of what to expect in terms of relevant categories, perspectives, and links among

other aspects of emerging themes (Macnaghten & Myers, 2004). In this study the case is both descriptive and explorative. Descriptions of how teachers practice IBLW in school chemistry in the different school contexts form part of the case study report. The report contains insights on why teachers do the things they do when practicing IBLW as a teaching and learning strategy. Although the review of literature may provide general insights on why teachers behave the way they do when using inquiry strategies, this study looked closely at the practice of IBLW in school chemistry in five different school contexts in South Africa. At the start of the investigation, I was uncertain as to which aspects characterising the interface between teacher professional identity and the practice of IBLW would distinctly come out as relevant.

3.4.2 Narrative inquiry

Cresswell (2007) defines narratives as written or spoken texts describing events or actions which are chronologically connected in an individual's life. Chase (2011) says narratives can also be in visual texts besides the usual oral and written texts. Narrative inquiry relies on narratives. Cresswell (2007) outlines the roles played by narratives in research. First, narratives which are texts and discourse can be the data collected by means of the relevant data collection tools. Second, narratives can be a mode of inquiry in qualitative research. Third, narratives may refer to the phenomenon under study (Beijaard et al., 2004). Fourth, narratives can be used as a method in research beginning with stories of experiences told by participants with researchers providing ways for analysing and understanding the stories. For this study, narratives were used as both qualitative data and method embedded in a case study as a research strategy of inquiry.

Teacher stories have the power to shape teacher professional identity (Burns & Bell, 2011; Lee, 2012; Smit & Fritz, 2008; Zembylas, 2003; Settlage et al., 2009; Beauchamp & Thomas, 2009). Fieldman (2005:47) says this about narrative research,

It is ultimately an opportunity for educators to raise significant questions about learning and teaching in relation to teacher histories, bias, experiences, traditions and personal preferences. In this sense then we might understand better the paradoxical relationship between the dilemmas and delights of professional learning.

Chase (2011) points out that, narrative research is a subtype of qualitative inquiry which has an interest in life experiences as narrated by those who live in them. The task of the researcher is to make sense of those narrated life experiences by constructing and communicating meaning (Merriam, 2002). Sikes and Gale (2001) propound that narratives provide links, connections, coherence, meaning and sense. Narrative research can be in the form of life stories, life histories, personal documents, and documents of life, life writing, personal accounts, narrative interviews and personal narratives, among other forms (Casey, 1996). However Cresswell (2008) points out that personal experience stories are what are used in education because the narrative study is not about accounts of entire lives alluding to the notion that the accounts can be individual or social. These accounts may be contained in diaries, letters, autobiographies, field notes made from naturally occurring conversations and in-depth interviews (Chase, 2011).

In this study the narratives were generated through conducting semi-structured interviews with teachers, focus group interviews with learners, keeping a research journal and writing field notes on observations made as well as from naturally occurring conversations. Digitally video-taped practical laboratory lesson proceedings facilitated by the teachers provided narratives in this study. As I transcribed the video tapes I narrated how IBLW was facilitated for learners. Therefore much of the data collected was in the form of narratives.

Cresswell (2007) outlines the following milestones that the researcher goes through when conducting a narrative research. First, the researcher should be able to make a convincing argument about how the research problem can be pursued through narrative research. Since narrative research is about capturing life stories and experiences (Cresswell, 2007; Burns & Bell, 2011), this study used narrative research as a method. By applying narrative research in the case study it assumed that the data collection process is rooted in stories of experiences elicited from the research participants. The researcher then selects ways of analysing so that meaning may be constructed from these life experiences. Studying the interface between teacher professional identity and the practice of IBLW in school chemistry, is about getting insights on teaching and learning experiences as lived by the teachers and their learners.

Second, the researcher has to carefully select research participants with stories to tell. For this, study physical sciences teachers who practice IBLW in the teaching and learning of school chemistry had stories to tell. Their learners who participate in the IBLW activities in the chemistry laboratory had stories to tell. In this research I also had stories to tell about my experiences and the experiences of the participants because I kept a research diary and developed field notes from observations.

Third, the researcher has to capture information about the context of the stories by situating them in an individual participant's or group participants' historical, cultural, school and even personal contexts as described by the biographies. In this study it was important to depict clearly the historical and cultural contexts of the schools as well as the personal biographies of the teachers that led to defining personal identities and professional experiences and practices that painted a picture of teacher professional identity. Situating the study contextually is in line with the use of a case study as a strategy of inquiry (Cresswell, 2008; Flyvberg, 2011). It is also in line with the choice of the qualitative research paradigm. The results of the study are not meant to be generalised but to be described as a phenomenon in context (Kyburz-Grabner, 2004).

Fourth, after collecting the stories the researcher reorganises them for the purposes of retelling them in what Cresswell (2007:519) terms "restorying". This is done by analysing the stories for fundamental elements that make up the story such as time, place, plot or scene followed by rewriting the stories in chronological sequence. The chronology may be depicted either by stories having a beginning, middle and an ending or by stories having a past, present and a future (Cresswell, 2007).

Fifth, the process of collecting narratives is achieved through collaborative efforts between the researcher and the research participants (Cresswell, 2007). Participants are actively involved in the generation of the narratives. The researcher and participants help each other to give meanings to the stories and they also have an opportunity to learn and change from the encounter. This is in line with the epistemological underpinnings in this study of social constructivism which posit that reality is constructed through human activity and does not exist before its construction through social encounters such as the narration of the

stories and the meaning making that follows (Kim, 2001). Insights on the interface between teacher professional identity and the practice of IBLW in school chemistry were brought to light through my collaboration with the chemistry teachers and their learners.

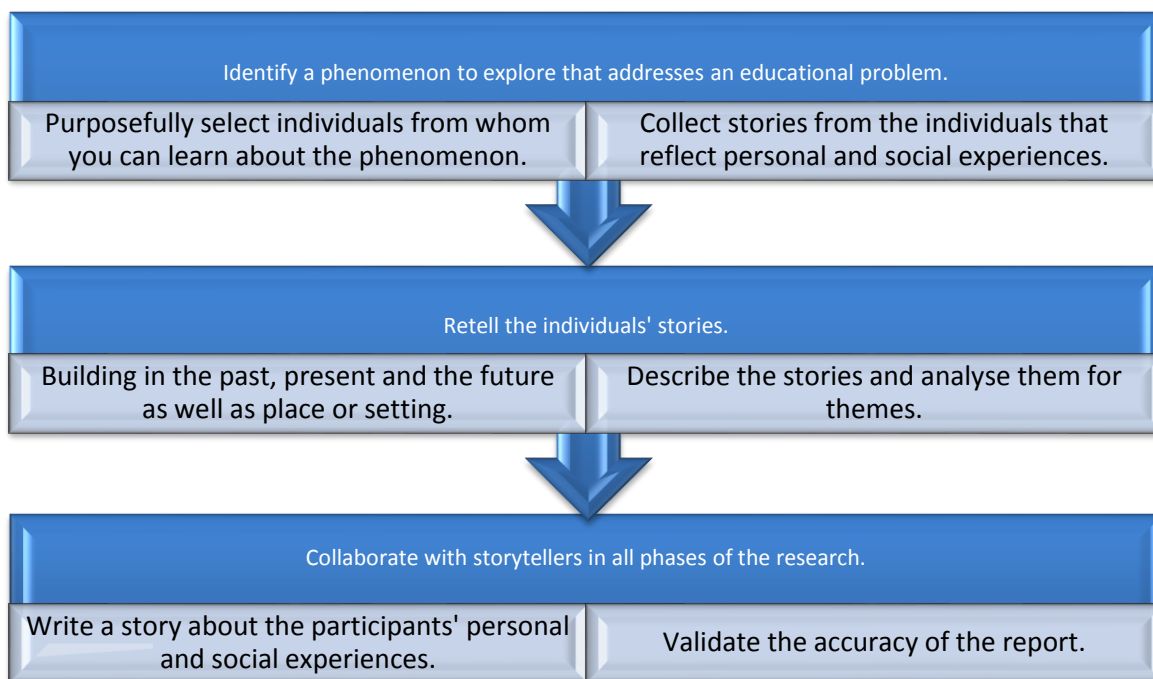
The use of narratives as a method of inquiry is not without challenges. Cresswell (2007) points out the following challenges to be taken note of by the researcher before embarking on a research journey making use of narratives. First, for the research to be meaningful the researcher needs to collect extensive information about the participant. This has serious implications on time factors and data gathering tools used. Enough time should be allowed for the research in order to collect acceptable quantities of qualitative data to allow for meaningful data analysis and interpretation. The choice of data collection tools to be used also determines the extent to which relevant data is collected. For this study, it was hoped that the use of semi-structured interviews for physical sciences teachers, focus group interviews with their learners, observation resulting in field notes, keeping a research journal, worksheet analysis and direct lesson observation of teachers facilitating IBLW activities in school chemistry would elicit extensive information on the participants. It was also hoped that the drawing of participating teachers from seven schools from five different socio-cultural contexts in South African schools would allow for the collection of extensive information on the phenomenon under study.

Second, the contexts of the participating individuals' lives and experiences need to be understood fully. The use of a case study as a research strategy of inquiry ensures that contexts are fully described because cases are bound in contexts and boundaries (Flyvberg, 2011). The use of the social identity theory as a theoretical framework for this study also highlights the important role played by contextual factors in teacher professional identity formation (Varghese et al., 2005). The description and understanding of contextual settings were paramount for this study.

Third, it is pointed out that the researcher needs to expertly uncover the individual's experiences from the information gathered extensively through the stories. For this reason the researcher needs to come up with appropriate data analysis procedures in order to achieve the unravelling of the phenomenon.

Since the method for this research study was determined to be narrative research, the steps were set out clearly. The figure below provides a comprehensive step by step description of the methodology.

Figure 3.1 The process of conducting narrative inquiry



Source: Adapted from Cresswell, 2007

In this study I collected stories of experience in the practice of IBLW from the physical sciences teachers mainly through the semi-structured interviews and casual conversations that were captured in field notes. The focus group interviews with learners also contributed in the building of the stories of the teachers' experiences. The lesson observation of the laboratory activity facilitated by the teachers for the learners helped me to have first-hand experience of the teacher experience story. In the same way the worksheet analysis provided more insights into the teacher experience on how laboratory work practice is conducted. The field notes and journal reflections afforded me the opportunity to contribute to the teacher experience stories through the recording of observations made on the research sites as well as the opinions, thoughts, hunches and sentiments as I reflected on the data collection activities. I hoped that through using all

these data collection tools I would successfully construct the teacher experience stories in what constitutes the narrative research employed in this study.

Yin (1981) describes two pitfalls that are faced by researchers when applying narratives in case studies. First, researchers have to make the most of note-taking and narrative writing when analysing data within a case study. The observation is made that researchers have a tendency to develop elaborate narratives from such items like interviews and log entries in research diaries. It is pointed out that unless the study calls for the publishing of such narratives the researcher does not have to go through such a laborious task of developing elaborate narratives from raw data but should rather use notes to precisely summarise the captured data. It is these notes that the researcher uses to develop narratives around the fundamental issues underlying the case study. In the process, integration is ensured by assembling qualitative evidence that addresses the same issues and topics. For purposes of illustration, the sections of interviews that discuss the role of contextual settings in the way in which teachers practice IBLW in school chemistry are discussed together. In this study note taking was used to make summaries of raw narrative data generated from the various data collection tools. I then utilised these notes to develop narratives that were around the crucial topics and issues that underlie the case study, thus ensuring integration of evidence in the process.

Second, Yin (1981) points out that in case study reporting lengthy narratives are used. Writers should aim to avoid a situation where the reports have no predictable structure and are difficult to write and read. The case study should be set on a clear theoretical and/or conceptual framework so that the discussions are ordered and easy to follow for the readers.

3.5 Selection of site and participants

I used purposive sampling techniques to select school sites and research participants. Teddle and Yu (2007) allude to the notion that purposive sampling is done in qualitative research with the research question in mind by ensuring that relevant information is obtained during data collection which otherwise could not be obtained from other choices.

A revelatory case sampling was used in this study which falls under sampling special or unique cases because the schools have to be from particular environments and the teachers have to be practicing IBLW as a teaching and learning strategy in school chemistry (Teddlé & Yu, 2007).

The selection of school sites in the Further Education Training (FET) phase and participants was prompted by the need to get rich and revelatory information in the process of answering the research question (Yu, 1994; Eisenhardt & Graebner, 2007). First, the study for purposes of triangulation had to be conducted in South African secondary schools from five different contexts as determined by their socio-cultural backgrounds. These five secondary school contexts are former model C, former Indian, former Coloured, township and private.

Second, the schools should have had a functional physical science laboratory where teachers were able to facilitate IBLW activities for their learners in school chemistry. Third, the teachers had to reveal that they practiced IBLW with their learners and be willing to be observed while they were practicing. To identify the schools and participants during the site and participant selection process I visited a number of schools with letters addressed to principals and teachers introducing myself and outlining the purpose of the study. By doing this I also hoped to secure permission from the school administration and teachers to conduct research at the school. Through the letters and casual conversations that resulted I explained that I intended to work with physical sciences teachers who practiced IBLW as a teaching and learning strategy in school chemistry. From the encounter I was able to establish the context of the school, whether the school had a functional physical sciences laboratory and whether the teacher was comfortable with being observed while he/she was facilitating an IBLW activity with the learners.

Since the initial stages of this study there has always been the question of how the teachers who practice IBLW in school chemistry were going to be identified. I came up with two possible ways in which to identify the teachers. One of the two ways which appeared to be more attractive to me in the early stages of the study was the conducting of professional development exercises for the participating teachers. The professional development would

be on how to practice IBLW in teaching and learning of school chemistry. This would ensure that the teachers would be capacitated to practice IBLW and therefore the issues on how to identify teachers who practice IBLW would be cleared and explained. The idea of professional development is in line with the notion that professional development is one way used to shape teacher professional identity (Coenders, 2010; Stolk, 2010). It was assumed that after the professional development exercise I would begin to collect data which would reveal the interface between teacher professional identity and the way they practice IBLW.

A review of the literature earlier on in chapter 2 of this study had already revealed that although teachers may attend the same professional training and/or professional development programmes, they do not practice IBLW in the same way (Bretz & Fay, 2010). A review of the literature had also established that the practice of IBLW can be placed on a continuum where it can be ranked from simple to complex (ibid). However, when I was ready to conduct the professional development exercises there were a number of practical and logistical challenges that stood in the way of the process. First, it proved daunting to identify a cluster comprising of a former model C, former Coloured, former, Indian, township and private schools. The idea of using one cluster of schools was to ensure easy accessibility by using the schools' existing structures so that it would be possible for them to gather at one point. Another challenge was whether all the teachers in one cluster would agree to be research participants. If I had to identify participants first from different contexts, I would still face challenges of finding a venue for the professional development at every teacher's convenience. This would imply taking the teacher away from his/her working place. I considered that in the face all the challenges put together, overcoming them would require more time and financial resources than I had available.

The second option, which proved more feasible, was to undertake an exploratory approach of identifying teachers who are practicing IBLW in school chemistry. This was done in two ways. First, I approached possible candidates and from the casual conversations as I explained the purpose of the study in order to secure the teachers' consent to be research participants, the teachers were screened. If at all I was made to believe that the teacher was practicing IBLW when actually he/she was not, I would not use the data collected from that teacher. This is why the process was exploratory. Second, I acted on

information obtained through word of mouth from colleagues. The cases of teachers identified through word of mouth were such that their practices were well known throughout their community of practice because they were already actively involved in programmes to promote the practice of IBLW in school science.

This exploratory option was more practically feasible because once a teacher was identified I would not waste time but collect data right away. The result was that the process of sampling more teachers went on simultaneously with the process of data collection from the teachers who had been identified already. The exploratory option had an advantage of identifying teachers who had established teacher professional identities in the practice of IBLW over the option of making all teachers to go through a professional development exercise. Recruitment of teachers through conducting a professional development exercise might not have yielded participants who had been engaging in IBLW before and it would have been difficult to establish whether the teacher professional identities that resulted were transitory or established in this current study.

Seven grade 10-12 physical science teachers were purposefully selected for this study. One teacher was selected from a former model C, one from a former Indian school and one from a former Coloured school. However, two teachers were selected from two African schools and two teachers from two private schools. This methodological position was taken as a result of reflection and a hunch on my part on the impressions I got after collecting data from these school contexts. I felt that allowing for comparisons of findings made in similar contexts would enrich the process of data analysis and interpretation as well as enhance the quality of the findings. This is in line with the use of a research journal as one of the data collection tools in which researcher reflections and hunches are part of the data collected. This is also in line with me being partly a participant observer sometimes (Punch, 2005). I conducted the study with seven teachers from seven schools drawn from five different contexts. Some of the grade 10-12 physical science learners who were taught by the participating teachers also became part of the participants. Learners who took part in the laboratory activity lessons I observed and those who participated in the focus group interviews formed part of the participants.

3.5.1 Teacher profiles, purposive sampling techniques used and school contexts.

This section describes the profiles of the seven teachers who participated in this research. The teachers are referred to in this study using pseudonyms and the schools are only described by their contextual settings. The names and locations of the schools are withheld in order to ensure their anonymity.

Jane is a Caucasian female teacher working in a former model C school. I got in touch with Jane on one of the school visits I made searching for possible research participants. On approaching the school authorities I was asked to leave the research support letters with administration and write Jane an email which I did immediately. Jane responded positively to the email the same day and even invited me to come and conduct the interviews and laboratory activity observations without delay since she had some laboratory activities prepared already. The learner population in the school is constituted of girls who are from multi-cultural backgrounds. However, from my perspective White and African girls constituted a majority.

Tendai is an African female teacher working in a former Indian school. I finally secured Tendai as a participant in the research after numerous visits to the school because each time I failed to meet the person who had authority to grant permission for the research. I had to make the numerous visits because the option of finding other former Indian school contexts was limited since there were only just a few as compared to other contexts. Efforts made in other former Indian school contexts had not yielded the required results. Finally, research permission was granted. I was now able to use both email and text messages to arrange for when to conduct the interviews and observe the laboratory activities. The learner population of the school is constituted of both boys and girls from multicultural backgrounds. However I observed that learners of Indian and African backgrounds are in larger proportion than their White and Coloured counterparts.

Jimmy is a Coloured male teacher working in a former Coloured school. I secured Jimmy as a research participant on one of the school visits I made while searching for possible research participants. Just like the former Indian schools, I was aware that there were few former Coloured schools to approach. The research permission was granted immediately

by the school authorities and Jimmy volunteered to participate in the research so I did not have to approach the teachers to secure participants. I was able to use phone calls and text messages to arrange for the day that was convenient to conduct the interviews and observe the laboratory activities. The learner population of the school is constituted of both boys and girls from multicultural backgrounds although I observed that the Coloured learners are more numerous than their African, Indian and White counterparts.

Kabelo is an African male teacher working in an African school set in a township. I recruited Kabelo as a research participant during one of the school visits to scout for possible research participants. I secured research permission after presenting the research support letters to the school authorities. The school authorities introduced me to Kabelo who agreed to be a research participant. Through phone calls with Kabelo I managed to secure an appointment to visit the school to conduct the interviews and observe the laboratory activities. The learner population of the school is constituted of boys and girls of African ethnic backgrounds only.

Melusi is an African male teacher working in an African school set in a rural area. I recruited Melusi as one of the research participants after acting on information obtained through word of mouth. After Melusi agreed to be a participant in the research, he then secured research permission from the school authorities on my behalf by presenting them with the research support letters. I communicated with Melusi through emails, phone calls and text messages until we were able to agree on a convenient date on which the interviews and laboratory activity observation would be conducted. The learner population of the school is composed of boys and girls from African ethnic backgrounds only.

Betty is a Caucasian female teacher working in a private school. I secured Betty as a research participant through word of mouth. She was recommended by colleagues as a teacher who practices IBLW as a strategy in teaching and learning. Through emails I managed to have her agree to be a research participant. She, in turn, secured the research permission from the school authorities on my behalf. Through the emails we arranged when I could visit the school to conduct the interviews and observe the laboratory activities. The learner population of the school is constituted of boys from multicultural

backgrounds. However, I observed that White learners are significantly more numerous than learners from other cultural groups.

Farai is an African male teacher working in a private school. I sent an email to the head of the science department in the school to ask for permission to conduct research in the school after the school was recommended to me by colleagues. I received a positive response through email and was given an email address of the teacher who was to be a participant in the research. We used emails, phone calls and text messages for communication until a day was agreed upon to conduct the interviews and observation of the laboratory activities. The learner population of the school is mostly African although other racial groups are also there in small numbers.

It can be noted at this point that word of mouth referral is an effective way of securing research participants who are a rich source of data. This meant that I had to focus more on finding ways of getting into contact with people who can make the referrals from their communities of practice. Getting connected to people in the relevant communities of practice is important. However, a researcher should also be prepared to go out to scout for research participants without acting on any information previously received. This option was also very important in this study because four out of the seven research participants were secured this way. The option of just going out to search for a research participant by making school visits has its implications on the budget and the time intended for the research. The researcher has to make adjustments in the budget by allowing for more resources to cover mainly transport costs and other miscellaneous costs. The research plan has to allow for the time to embark on that exploratory process of selecting research participants. The researcher may not know whether the process will take longer than anticipated. This was a cause for considerable anxiety for me. However, what transpired was the process participant identification and selection ran simultaneously with the process of data collection and everything was completed within the time-frame planned for data collection.

3.6 Data collection methods

The nature of qualitative data collected in this study can be placed in four categories which are observations, interviews, documents and audio-visual materials (Cresswell, 2008). This study employed semi-structured interviews, focus group interviews, lesson observation, field notes, and worksheet analysis and a research journal as data collection tools. The semi-structured interviews were conducted with physical science teachers. The focus group interviews were used with learners who were taught by the participating teachers. I also observed a lesson in which the teacher was facilitating IBLW in school chemistry. The worksheet that the learners used during the laboratory activity was also analysed if available. I engaged in observation all the time that I was on the research site. This is unlike the conducting of interviews which were done at appointed times. Therefore, even if I was engaged in the collecting of other forms of data, such as the audio-visual materials at the research site, observation was still on-going. From the observations field notes were made. I also kept a research journal.

The employment of semi-structured interviews, focus group interviews, field notes, and a research journal and lesson observation generated narrative data in the form of notes, summary of interviews, word-for-word transcripts and single words, brief phrases and full paragraphs from open-ended questions.

3.6.1 Semi-structured interviews

Punch (2005) regards interviews as being the main data collection tool in qualitative studies for they allow researchers to elicit people's perceptions, meanings and experiences, definitions of situations and constructions of reality. Interviews can be classified into structured, semi-structured and unstructured (Punch, 2005). All these types of interviews can involve one individual or group of people being interviewed. This classification can be pitted against the classification made by Mulhall (2003) whereby interviews are seen as being structured, focused or semi-structured and unstructured. The classification may vary from author to author. The interviews used in this study draw from all these types of interviews.

In structured interviews the researcher develops categories *a priori*. The interviewer plays a neutral role while asking the questions (Punch, 2005) but should have significant knowledge about the issues in the interview schedule (University of Portsmouth, 2010). The unstructured interviews are open-ended and in-depth in which neither the exact question asked nor the responses made are pre-determined (University of Portsmouth, 2010). In this study semi-structured interviews were used for teachers. The interviews incorporated aspects from both the structured and the unstructured interviews. They were structured in the sense that the general topics for discussion were determined *a priori*. The content of the interviews was divided into three sections as shown in Annexure H. The first section deals with biographical information of the teachers as well as their previous educational and professional experiences with IBLW in chemistry. The second section deals with the teachers' current experiences with IBLW as a strategy used in the teaching and learning of school chemistry. The third section situates the teachers in the chemistry laboratory while they are facilitating IBLW and it deals with the pedagogical, content and knowledge issues in the classroom.

The interview schedule came with predetermined questions which served as a guide for the interviewer because the interview was conducted in the form of a discussion in which the questions could be adapted to suit the situation and the schedule was flexible since some questions might be omitted and others added to the schedule during the interview. The responses by the respondents were not predetermined as they were encouraged to narrate their stories of experience including all aspects that they felt were relevant in answering the questions. The questions were open-ended and probed for in-depth responses. The respondents were given a voice to make interpretations of their experiences and communicate meanings that they make of the way they practice IBLW in school chemistry. They were given the platform to explain their behaviour in the practice of IBLW in line with social constructivism. One-on-one, semi-structured interviews were used with teachers. The interviews were in part focused towards the aspects defined by the theoretical and conceptual framework. The interviews were also open-ended and in-depth in nature as teachers were allowed to tell their stories and everything that they considered relevant to the issues raised by the interviewer.

3.6.2 Focus group interviews

Creswell (2008:226) points out that, “Focus groups can be used to collect shared understanding from several individuals as well as to get views from specific people”. In this study the focus group interviews were used to collect some views from learners about how teachers facilitate the practice of IBLW in the teaching and learning of school chemistry. The use of focus groups was in line with social constructivism whereby knowledge is socially constructed by cooperation, sharing ideas and reaching a consensus (Kim, 2001; Boghossian, 2006). The interviewees in this case were learners of the same teacher participating in the same laboratory activities and working as groups.

Macnaghten and Myers (2004) contend that focus groups can be used to discuss topics that people could talk about to each other in their lives but however don't . In the same way, the use of IBLW as a teaching and learning strategy may not be what learners talk about most often but may be made to do so through facilitated focus group interviews. Kitzinger (1999) says that although focus group interviews may not be good for eliciting biographical information from individuals, they may, however, be used to examine how knowledge and ideas develop and operate within a given cultural context. Focus group interviews are also used to fill in the gaps exposed by other data collection tools (Kitzinger, 1999). In this study the use of focus group interviews with learners served the purpose of triangulation with what was revealed by observations and teacher interviews.

The focus group interviews were also semi-structured (Punch, 2005). The structuring was in the sense that the discussions were divided into two sections with broad topics (See Annexure I). The first section has questions that seek to get insights on the learners' current experiences with IBLW in school chemistry with their teachers. It was hoped that among other things focus group interviews with learners would also provide insights on previous experiences of how IBLW was facilitated that might not be revealed during teacher interviews and lesson observations. The second section situated the learners in the chemistry laboratory conducting IBLW facilitated by the teacher. The interview questions sought to establish their experiences while engaging in inquiry activities. The questioning sought to establish the roles played by the learners and their teacher in the three stages that constitute inquiry according to Bretz and Fay (2008) which are question posing, procedure

development and the finding of solutions. Questions were asked in such a manner that learners collaborated to come up with the position of the group on the issue. My role as a researcher during group interviewing was more of a facilitator and moderator (Punch, 2005).

3.6.3 Observations

Cresswell (2008:221) says that “Observation is a process of gathering open-ended, first-hand information by observing people and places at a research site.” Berg (2007) concurs with Cresswell (2008) by saying that observation is a way of measuring behaviour by watching people, events, situations or phenomena in natural settings. The advantages of using observation as a data collection tool stem from these definitions. Berg (2007) points out the advantages of observation by saying it has its strength in allowing phenomena to be observed in natural settings; therefore, the researcher is able to get first-hand information and the information obtained is based on behaviour and this cannot be obtained by any other procedure. Berg (2007) is also quick to outline the disadvantages of using observation by saying that it cannot be used for behaviours that cannot be seen and that information may have the problem of meaningful organisation as well as it is time consuming and costly to conduct on large sample sizes. Mulhall (2003) and Punch (2005) classify observation as being structured and unstructured. Structured observation is associated with positivistic research whereby observation schedules consist of taxonomies developed from known theory (ibid). Mulhall (2003) continues by associating unstructured observation with interpretive research whereby the researcher has no preconceived notions upon entering the research field. Cresswell (2008) mentions that the researcher may undertake the observation process either as a participant observer or nonparticipant observer. Other authorities like Punch (2005) and Mulhall (2003) contend that the role of the researcher may not be clear cut into being either participant observer or non-participant observer but that observation can be placed on a continuum on which it transits from non-participant on one end to complete participant observer at the other. Mulhall (2003) further clarifies the roles played by the researcher during observation.

First, a researcher may play the role of a complete observer who does not interact with the research participants and have his/her role concealed from participants. Second, the

observer may be a complete participant in the social activities at the research site and have his/her role concealed from the research participants. Third, the researcher may be a participant observer who also conducts interviews and makes his/her role known to research participants. Fourth, the researcher may engage in prolonged observation as a participant observer and have his/her role known to the participants. This is significant in this study because, although my role was that of a non-participant observer in general, there were times when I played the role of participant observer when I was conducting interviews.

Most of the time, I was a non-participant observer who undertook intermittent observation alongside interviewing and the role was not concealed from the research participants.

3.6.4 Field notes

Field notes are obtained from observations. Cresswell (2008) and Mulhall (2003) point out that the researcher should design some means of recording field notes from observations made. Researchers are encouraged to record both descriptive field notes and reflective field notes (Cresswell, 2008) by giving descriptions of places, activities, people and events as well as hunches, ideas and themes that begin to emerge from the observations. For purposes of organisation I used the following template to record field notes.

Table 3.2 Template to record field notes

Field notes made during school visits	
Observational field notes	Laboratory activity, interview or routine visits to the school
Setting	Classroom, science laboratory, staffroom and so on.
Observer	Self
Role of observer	Non-participant observer
Time and date	
Length of observation	
Description of phenomenon	The researcher records the description of activities as they unfold noting the time of events as they happen and keeping the research question in mind.
Reflective notes	This is where the researcher records hunches, insights, themes and so on.

Source: Adapted from Cresswell (2008)

Literature reveals that a research journal can also be referred to as a reflexive journal (Smith, 2001; Ortlipp, 2008) or may be alluded to as a research diary (Nadin & Cassell, 2006; Duke, 2012). In this study the research journal was kept in the manner described by Nadin and Cassel (2006). It consisted of an A5 lined book which worked as a diary. Entries were made in the journal after every visit to the school, making sure that every entry was made on a new page and started with biographical information on the school and the participants. Entries were of reflections on the interview experiences with teachers and focus group interviews with learners, naturally occurring conversations, lesson observations of laboratory activities and other observations made on site. I reflected on how well the interviews had gone, the emerging themes and my feelings throughout. According to Ortlipp (2008), Nadin and Cassell (2006) and Hannan (2006) the researcher regards the data collection process as a social encounter in which she has to record her own personal feelings and reactions, frustrations, opinions, experiences and assessment of life and work in the field.

The use of a research journal in this study is rooted in the functions that it serves. First, the research journal serves as a composition tool (Smith, 2001). I generated narrative data by writing texts of my reflections in the form of feelings, experiences, opinions and assessments. Second, Smith (2001) points out that keeping a journal helps researchers to become more organised by keeping track of their experiences during the data collection process. Third, keeping a research journal creates time, space and contexts within which the researcher practices critical self-reflection (Nadin & Cassell, 2006; Cresswell, 2008). The researcher gets the opportunity to think through the manner in which the research is being conducted (Smith, 2001; Ortlipp, 2008; Nadin & Cassell, 2006) thereby allowing researcher to record the research methodology, content and even theoretical frameworks in continued efforts to work them out.

Smith (2001), Ortlipp (2008) and Nadin and Cassell (2006) propound that applying reflexivity in journal keeping has allowed researchers to make adjustments to research designs, methods and approaches taken by recording and questioning methodology and content. This is supported by Devetak (2010) who points out that, qualitative approaches are flexible and that the emphasis is on the process and not the final results. Fourth, Ortlipp (2008) posits that researchers work against a backdrop characterised by raging

debates on how much researcher influence is acceptable in qualitative research. It follows that applying reflection in journal keeping allows for transparency. Transparency is achieved and ensured if the researcher describes his/her experiences, opinions and feelings giving readers close accounts of what transpired as the research was being conducted.

3.6.5 Documentary data

This study also utilised documentary data from the worksheets that were in some cases issued to learners for use during the laboratory activity. I hoped that the worksheet instructions might give me some insights on how IBLW is conducted based on what the learners are expected to do. It is important to note that the worksheets were used only where they were available. In some cases they were not available.

In this study the worksheet was considered to fall under the type of data called 'documentary data' (Punch, 2005; Cresswell, 2008). Punch (2005) describes documents as a rich source of data and alludes to the notion that they are often neglected by researchers. These documents include diaries, letters, essays, personal notes, biographies and autobiographies, institutional memoranda and reports amongst others (ibid).

The research journal in this study used in conjunction with interviews, documentary data and observation was important for triangulation (Punch, 2005) which results from using a multiple of instruments to generate the same type of data.

3.7 Data documentation

Schutt (2011) says that documentation of data may be done by jotting down notes in the field or during an interview, by reconstructing the original comments and feelings as well as texts transcribed from audiotapes and videotapes. A research journal is also useful for recording qualitative data. A research journal can be used to condense, summarise and integrate data as well as for recording the insights and ideas as the researcher generates them (Spiggle, 1994). Documentation of data is important because it helps the researcher to keep track of growing volumes of notes, tapes and documents; it provides the researcher with a way of developing and outlining the analytic process and encourages the on-going process of conceptualisation and strategising on data analysis (Schutt, 2011).

Documentation may be regarded as the first analytical step (ibid). Data documentation was a very significant part of this research study. Transcribing audio-taped interviews was a time-consuming and rewarding in the reconstruction of data. I made use of computer software that converted voice to text. I simultaneously listened to the recorded interviews and repeated the words spoken by interviewees. The software picked up my voice and converted it to a word document. By personally transcribing the audio-taped interviews, I had a chance to relive my data collection experiences and enhance the data analysis and interpretation process.

The data collection process started during the time I was still selecting research participants. This was because the process of teacher profiling started during that period and I had to make important decisions of whether teachers were to be selected or left out depending on whether they practiced IBLW or not. I utilised observation which generated field notes and I made entries in the research journal of the school visits recording my experiences. The successful identification of the participating teachers gave way to the main data collection phase whereby I conducted interviews with the teachers, observed laboratory activities in which the teachers facilitated IBLW activities and conducted focus group interviews with learners.

After completing the main data collection process I sat to process the data until I developed the individual teacher stories in a process of “restorying” according to Cresswell (2008). I took the developed stories back to the teachers for verification through conducting a last set of interviews with them. I took this opportunity to pose follow-up questions on areas that needed clarification. After this the process of data collection was complete and the data was ready for final analysis and interpretation.

3.8 Data analysis and interpretation

In an attempt to show how qualitative data analysis is different from quantitative data analysis Schutt (2011) describes important features of qualitative data analysis. First, the emphasis in qualitative data analysis is on meaning in the data collected rather than the numbers that result from quantifying phenomena. However, it is important to note that

categorisation and counting produces quantitative data from texts. Second, qualitative data analysis is through rich descriptions of phenomena and contexts unlike the measurement of particular variables in quantitative data analysis. Third, for qualitative data analysis significant amounts of data are collected in a few cases because the study has to be detailed and in-depth. For the current case study the collection of significant amounts of data was achieved by using several instruments which are teacher interviews, focus group interviews with learners, lesson observation, and worksheet analysis and research journal and field notes.

The use of seven teachers drawn from five different contexts helped to enrich the data collected by capturing as much information as possible on the manifestation of the phenomena of interest. Punch (2005:194) points out that there are several ways to analyse qualitative data and explains why it is like that:

Qualitative research concentrates on the study of social life in natural settings. Its richness and complexity mean there are different ways of analysing social life, and therefore multiple perspectives and practices in the analysis of qualitative data: ... The different techniques are often interconnected, overlapping and complementary, and sometimes mutually exclusive....

Punch (2005) emphasises that different analytic tools can be applied to the same body of qualitative data because the approach allows for data to be looked at from different perspectives. However, Berg (2007) says that the actual analytic techniques used in most of the qualitative analytical approaches are similar. The author gives a standard set of analytic activities in qualitative analysis in order of general sequence. First, the data is collected and made into texts which may be field notes or transcripts. Second, codes are analytically developed or inductively identified in the data and are assigned to sets of notes or transcript pages. Third, codes are transformed into categorical labels and themes. Fourth, categories help in sorting out data by identifying similar phrases, patterns, relationships as well as commonalities and disparities. Fifth, the sorted data is examined to isolate meaningful patterns and processes. Sixth, identified patterns are discussed in light of previous research and theories in order to make a small set of generalisations.

I had two methods of data analysis in mind for the data collected in this study which are narrative analysis and content analysis. Therefore a decision had to be made between

narrative analysis and content analysis based on appropriateness. For this reason the following discussion will focus on some aspects of content analysis and narrative analysis which assisted me in settling on the method of analysis used in this study.

3.8.1 Content analysis

White and March (2006) say that content analysis is based on quantified analysis of recurring, easily identifiable aspects of text content. The aim of content analysis is to describe the phenomenon by coming up with concepts or categories from the data (Elo & Kungas, 2007). In presenting results the use of numbers and/or percentages may be employed in simple tabulations and cross-tabulations to show relationships or the researcher may resort to description of details through textual presentation (White & March, 2006). The findings of the phenomenon under study are presented in the form of a narrative (ibid). Hsieh and Shannon (2005) describe the following steps of what they term 'conventional content analysis'. First, the researcher gets immersed in the data by reading the data word by word meanwhile making notes of his/her impressions. Second, codes are derived and labelled resulting in the division of the text into content categories and sub-categories. Third, the categories will be useful for organising data while connections among the content categories are established. Content categories are classified as central, supportive or distracting. Fourth, the relevant theories and other research findings will be addressed in the discussion section of the study.

There are some things that content analysis cannot do. Prasad (2008) alludes to the notion that content analysis which restricts itself to counting the individual units and their frequency of occurrence, for example, the number of times a certain word appears, may fail to grasp the essence of significance with which these words or texts are used in the data analysed. Prasad (2008) also says that the inferences made in content analysis are limited to the content of the text only in such a way that symbols are coded according to the attribution given by the researcher which may not correspond to the attribution given by the research participants and the consumers of the study conducted. The epistemological standing of this study highlights the importance of making sure that there is continual collaboration in the construction of meaning between the research participants and the researcher. At this point the discussion turns to what constitutes narrative analysis.

3.8.2 Narrative analysis

Analysis of narratives is no longer restricted to literary studies alone but it has found its way into human sciences and practicing professions (Riessman, 2003). It is important to point out that narratives are not appropriate for studies that involve large numbers of nameless subjects (ibid). Punch (2005) propounds that most qualitative data naturally occurs as narratives. The stories in this study were told both by the participants and the researcher. Schutt (2011:339) says narrative analysis is “A form of qualitative analysis in which the analyst focuses on how respondents impose order on the flow of experience in their lives and thus make sense of events and actions in which they have participated.” It is at this point that the decision has to be made on the method of analysis to be used. Narratives shape teacher professional identities (Akkerman & Meijer, 2011; Beijaard et al., 2004). Therefore, individual teacher stories were crucial in this study. For this reason content analysis was used in conjunction with narrative analysis in this study for this provided a platform to analyse the teacher stories by giving them prominence. The use of teacher stories of experience with the practice of IBLW empowered them by giving them a voice in the process of construction of realities in this study. This was also in line with the epistemological underpinnings of the study.

Riessman (2003) alludes to the notion that there exist several forms of narrative analysis whereby analysis can be personal or organisational among other forms. For the purposes of the study it is appropriate at this point to discuss the different typologies that fall under personal analysis of narratives by Riessman (2003). According to Riessman (2003) personal analysis of narratives can be performed in the following four ways. First, there is the thematic analysis which places more emphasis on what is said during story-telling than on how the stories are told. After gathering the stories conceptual groupings are created from the data. The creation of conceptual groupings is useful for theorising across a number of cases by finding common thematic elements across research participants and events. Second, Riessman (2003) speaks of structural analysis in which the emphasis of the analysis is on the way the stories are told. Thematic analysis is still there although the use of language is of paramount importance as it is treated more seriously than the content. Structural analysis in personal analysis of narratives is more suitable for detailed case studies and comparison of several narratives accounts and is not suitable for a large

number of case studies. This analysis is meant to build theories that relate to the language and meaning.

Third, Riessman (2003) speaks of interactional analysis where the emphasis is on the dialogue process in which the storyteller and the questioner jointly participate in conversation as they co-construct the stories. However, attention is still paid to thematic and structural analysis. The transcripts made from this type of conversations include the contributions of both the storyteller and the questioner in the dialogue making sure that other aspects of talk such as pauses and any stammering are incorporated in the transcripts. Although Riessman (2003) mentioned that the aim of outlining this typology is not to place the types of analysis in order of rank; however, readers are able to notice that that thematic analysis is simpler and involves fewer actions in terms of analysis than structural analysis. In turn, interactional analysis is on a higher level since it incorporates both thematic analysis and structural analysis. This becomes more evident when Riessman (2003) points out that, although interactional analysis involves more in terms of what to analyse, it still falls short in representing the unspoken word such as gestures and gazes as what happens with videotapes. For this reason, Reissman (2003) further discusses a fourth type of personal analysis of narrative, the performative analysis. The focus of analysis is on performance. Storytelling is regarded as a performance and the interest of analysis is beyond the spoken word. The storyteller captures the attention of the audience by both language and gesture through telling and doing. All the aspects of thematic, structural and interactional analyses are evident in performative analysis.

For this study, even though videotapes were used, the emphasis was on content. The narratives are utilised in order to elicit content in the interface between teacher professional identities and the teacher practices of IBLW in school chemistry. The focus is not on the narratives themselves but they are just a means to an end. For this reason thematic analysis is considered to be the most appropriate if the purposes of study are put into perspective.

Review of literature reveals that different authorities have made efforts to help the novice researcher as well as other readers on how to conduct narrative analysis (Friedl & Friedl, 2002; Blom, 2010; Huynh & Rhodes, 2011). Friedl and Friedl (2002) summarise the steps

in the process of narrative analysis as follows. First, the researcher immerses him/herself in the data by reading the original texts. Second, the literary and literal translation of data is made in the language used in conducting the research. Third, the texts are divided into macro and micro units, for example, a larger narrative may be subdivided into episodes which in turn may be divided into scenes. Fourth, a summary will be made based on the ideas reflected by the narratives based on events and the participants. At the end of data analysis the interpretation that follows should allow the study to answer the question on how teacher professional identity interfaces with teacher inquiry practices in the school chemistry laboratory. However, for a novice researcher who has never engaged in qualitative analysis of data, questions may still arise on what is actually done in all those steps. At this point illustrations of how to conduct narrative analysis with concrete examples that the researcher can follow become very useful.

Some authorities such as Blom and Nygren (2010) make an attempt to make the reader go through the steps involved in narrative analysis by making use of concrete examples. According to Blom and Nygren (2010), in narrative analysis the researcher first engages in naïve reading of the original narratives to grasp a superficial idea of the events. However the meanings are yet to be unveiled. Second, Blom and Nygren (2010) say that naïve reading is followed by structural analysis whereby questions about what, how, who and hence are answered. The third step is comprehension in which the researcher tells a new story by producing material of naïve understandings of the original narrative texts and material on conceptual codes from the structural analysis process. Blom and Nygren (2010) propose a fourth step which the authors call appropriation. Appropriation results after reading the comprehension products of the analysis. The reader is able to make the comprehension one's own become changed and discover new possibilities. The reader may be someone else other than the researcher. Blom and Nygren (2010) is quick to point out that appropriation may not always occur.

Huynh and Rhodes (2011)'s step by step outline of how to conduct narrative analysis helps to give the novice researcher more insights into what goes on in narrative analysis. They suggest that narratives from the data collection tools such as interviews and a research journal should be transcribed with line numbers with the interviewer's side issues removed. After this the researcher reads the transcripts with the research questions in

mind, making notes on a side column making reference to the line numbers. Using the notes the researcher creates stories in first person and past tense describing the plots, scenes and characters making sure the events are arranged in chronological order. The stories are taken back to the participants for member-checking. Member-checking results in the creation of a new document for each of the stories and the documents must still contain line numbers. The sentences and paragraphs are analysed by asking what the sentences and paragraphs are about and writing notes in a running column. This is repeated until the meaning of the story runs alongside.

The notes of meaning are then changed to categories and codes. The categorisations and codes should now be taken for peer review or taken to be reviewed by the supervisor. Categories inherent to each individual story are developed into a typology. The final step sees the researcher developing an across subject analysis of the relationship between codes and typologies with classification or attributes. For this study the steps in narrative analysis developed by Huynh and Rhodes (2011) were very useful because they give more detail to things unknown and not yet experienced by a novice researcher.

Table 3.3 Steps undertaken during the process of narrative analysis

STEP	ACTION
Transcripts	The audio-taped interviews with teachers and learners, video-taped lessons, field notes and research journal are developed into transcripts corresponding to each individual teacher.
Note-taking	The researcher reads the transcripts and makes notes on them with the research question in mind.
Re-telling the teacher stories.	Researcher develops a narrative to retell the story of each individual teacher beginning with biographical information with all the events of the teacher experiences arranged in chronological order.
Member-checking	The stories developed by the researcher are taken back to the teachers to make sure that the data was captured accurately.
Re-developing the teacher stories.	After member-checking the teacher stories are re-developed into final drafts.
Note-making	The researcher repeatedly reads through the teacher stories and makes notes until the meanings begin to emerge and run alongside.
Categories and codes	Data is tagged or labelled in the process of coding and developed into categories.

Supervisor/peer review	The codes and categories are taken to the supervisor and/or peers for review.
Typology development	Themes inherent to each individual story are developed into categories.
Analysis	A cross subject analysis of the relationship between codes and typologies with attributes is conducted.

Source: Adapted from Huynh and Rhodes (2011)

The steps in narrative analysis show that analysis is a systematic process and not a haphazard one. As Spiggle (1994) says, proceeding systematically ensures that all possible leads are uncovered. This is why the researcher should keep records of the analysis process in the form of memos, journals, charts or other documents in which data is condensed, summarised and integrated on one hand and inferences in the form of insights and ideas on the other hand (ibid). Besides proceeding systematically and keeping records, the researcher should also report on how analysis was conducted. It is common practice for researchers using qualitative approaches to report their procedures for collecting data and to submit their conclusions to informants, auditors and peers for them to assess the trustworthiness of the study (Merriam, 2000; Spiggle, 1994). However, Spiggle (1994) observes that researchers comparatively communicate less about their analytical procedures and suggests that investigators may report explicitly and briefly on the volume of text that they worked with, the number of times they read the texts, and how they modified previous interpretations based on subsequent readings and on the procedures used as well as how data was reduced, fragmented, managed, reconstructed, stored and retrieved for analysis.

While reviewing literature on data analysis as a novice researcher in this study, terms like ‘coding’ and ‘categorisation’ still made me to ask questions as to exactly what they are. Spiggle (1994) says that the analytic process is constituted by analytic operations like categorisation, abstraction and comparison among other processes. At this juncture it becomes important to briefly describe what each of the analytic operations entails. Cresswell (2008) says that literature about what constitutes coding is confusing; however, the author says it is when researchers put tags, names or labels against pieces of data which may be individual words or chunks of data of different sizes. Coding begins the process of analysis and continues throughout the process and is done in order to be able to attach

meaning to data, index data for storage and retrieval and to form a basis for more advanced and subsequent coding which is categorisation (ibid).

Spiggle (1994) says categorisation is still a process of coding because it involves classifying and labelling units of data by identifying passages of any length as belonging to, representing or being an example of a more general phenomenon. Cresswell (2008) says there are two types of codes which are descriptive codes and inferential codes. In qualitative approaches researchers do not generally determine the units of analysis *a priori* as happens with quantitative approaches but categorise data on the basis of its coherent meaning. Cresswell (2008) goes on to provide examples of how to go about the process of coding from raw data which is quite useful to novice researchers who still need to grasp the essence of what coding is. On 'abstraction' Spiggle (1995) says that it builds on categories by going beyond the identification of patterns in the data through grouping previously identified categories into more general, conceptual classes. This is achieved by incorporating more concrete categories that share certain common features into fewer more general ones. Comparison is about exploring differences and similarities across incidents within the data by noting general similarities in the specific empirical instances in the data and labelling them as representing the same categories during the process of categorising. According to Spiggle (1994) there are more analytic operations besides the ones discussed here such as dimensionalisation, integration and iteration.

3.8.3 Data interpretation

Spiggle (1994:500) describes data interpretation as:

...playful, creative, intuitive, subjective, particularistic, transformative, imaginative and representative. Interpretive insights often spring from serendipity. I propose no guidelines for the use of interpretation. The development of researcher-as-interpreter cannot depend on learning techniques and mechanics. Interpretive insights, especially creative ones, spring from mental activities, some of which are not accessible to the interpreter.

Cresswell (2008) describes interpretation in qualitative research as the process whereby the researcher makes efforts to make some larger meaning about the phenomenon based on personal views, comparisons with past studies or both. Spiggle (1994) propounds that while analytical procedures manipulate data, interpretation makes sense of data through

more abstract conceptualisations by transferring meanings across texts, objects or domains. Cresswell (2008) points out that interpretation appears in the final section under headings like 'Discussion', 'Conclusions', 'Interpretations' and 'Implications'. According to Cresswell (2008) the researcher in this final section should discuss a review of major findings and how the research questions have been answered, personal reflections of the researcher about the meaning of the data, personal views compared or contrasted with literature, limitations of the study and suggestions for future research.

Spiggle (1994) postulates on what is done by the researcher during the process of interpretation. The author points out that during interpretation investigators seek to do three things. First, investigators make attempts to grasp meaning from the research participants' view point. This understanding forms the basis of any subsequent meaning making. It is important to note that interpretation of others' experiences is subjective since no two investigators have the same previously acquired experiences that serve as a springboard in trying to understand other people's experiences in line with the epistemological standings in this study of social constructivism.

In this study I made an attempt to grasp the meanings of teachers on how their teacher professional identities interface with their practice of IBLW in school chemistry. Second, investigators endeavour to seek patterns in meanings through recognition of resemblances in meanings across contexts, situations, projects and individuals by identifying parallel structures, similar themes, recurring elements, and common concerns across various incidents for an individual. This is very significant in this study because research participants are drawn from different contexts and for each of the two contexts out of the five, two teachers have been selected. Third, investigators seek to decipher cultural codes during interpretation in what Spiggle (1994) says is how symbolic forms, rituals, traditions and cultural codes affirm and reproduce cultural themes and culture. For this study the aim was to determine the way of doing things in the practice of IBLW in school chemistry which may constitute cultural patterns.

3.9 Pilot study

Simon (2011) and Teijlingen and Hundley (2001) say that pilot studies are used for pre-testing particular research instruments and as a trial run in preparation for a major study. Pilot studies are conducted in order to develop and test the adequacy of research instruments, assess the feasibility of the full study, establish whether the sampling technique is effective, assess the proposed data analysis techniques and to train the researcher in as many elements of the research as possible (Teijlingen & Hundley (2001). In this study I applied the proposed data collecting tools in one school in order to uncover potential problems and issues that may arise. The general aim of the pilot study was to structure effective interview and observation protocols which would be able to generate the intended data. I also intended to use the pilot study to gain experience in the use of a research journal and field notes as data collection tools. The pilot study also afforded me an opportunity to decide on a more appropriate data analysis procedure.

The pilot study was conducted in a township school with one teacher. I identified a grade 11 teacher using purposive sampling techniques acting on information obtained through word of mouth from a physical sciences subject specialist. Through the subject specialist I was able to establish that the school in which the teacher works has a functional science laboratory and learners are made to engage in inquiry activities through conducting experiments in the science laboratory. I recognised that word of mouth was going to be one of the techniques that I would employ when conducting purposive sampling of teachers. The teacher was approached through the principal of the school who had granted permission for the pilot to be conducted in the school on condition that the teacher was comfortable with it. The principal summoned the teacher so that he can introduce me to him. After explaining the purpose of the research the teacher had no objection to being a participant of the research. A one hour interview was conducted with the teacher after school. The proceedings of the interview were audio-taped.

A date was set after this interview on which I would come to observe the teacher while facilitating IBLW in school chemistry. On the set date I observed a one-hour laboratory session of the teacher and a class of 35 learners of mixed boys and girls. The proceedings

of the lesson were video-taped. The lesson observation was followed by a focus group interview with six learners (Cresswell, 2008) comprising four girls and two boys who had participated in the observed lesson. The interview was audio-taped. The group interview lasted for ten minutes of the possible anticipated 30 minutes because the interviews were done after school and it was not possible to take much of the learners' time. However, all the aspects on the interview schedule were tabled for discussion. Meanwhile I was engaged in continual observations which were recorded as field notes and also kept a research journal to keep track of the data collection process by way of recording events, plans of action and reflections.

The following section describes how the pilot study assisted me to see how the instruments were generating data by giving a summary of the pilot results. This is done by retelling the story from the teacher's narrative and doing the content analysis of the data collected through all the instruments.

3.9.1 “Restorying” the teacher narrative

Tebogo is a 44 year, African, male physical science teacher with six years of teaching experience. He obtained a BSc in Agricultural Sciences and a PGDE for teaching physical sciences. He was exposed to laboratory work during his secondary school years, the technical college and the teacher development workshops he attends as a professional teacher. These are the three experiences that he claimed contributed to his knowledge of laboratory work. He mentioned that during the time that he attended secondary school and technical college the science examinations that he sat for were divided into a theory examination and a laboratory practical examination. He claimed he had to work hard to prepare himself sufficiently in order to pass the laboratory practical examination as well. He believes, however, that his exposure to practical laboratory experiences can still be improved to be in line with the current technological advancements and discoveries in science. Despite feeling this way he thinks the preparation that he got is sufficient for him to implement the curriculum for his learners. He feels that the following challenges are in the way of laboratory practice. First, the classes are overcrowded and it makes learners to wait for a long time before they can have their turn of hands-on experience in the laboratory. Second, he said the workload that he has is huge for meaningful practice of

laboratory work. Third, he said the reagents and equipment are in short supply in the laboratory; therefore, he ends up doing demonstrations most of the time. If they are to conduct experiments with learners, however, they have to break the classes into manageable groups which results in them having to do extra lessons after school and on Saturdays sometimes. He said that when they conduct lessons after hours learners are already suffering from fatigue. He understands that under the current conditions if he wants to practice laboratory work he has to improvise.

He said he conducts two laboratory experiments in a year for the purposes of continuous assessment. He said for every topic they could still do a practical which will bring it to 1-3 laboratory experiments in a month although it is not always possible. He believes laboratory experiments are of utmost importance in teaching and learning because he said they help learners understand as they are exposed to authentic learning experiences. He said that if learners are given the necessary support through laboratory work they show understanding. He mentioned other challenges that he faces during the time of conducting the experiments with learners. He said he has to deal with disciplinary issues with learners breaking the laboratory safety rules because they are unruly and they vandalise the laboratory at every opportunity. He pointed out that the teacher has to constantly move around to monitor the learners to make sure they are not misbehaving. The time is never long enough to complete the experiments properly. His feelings are captured in the following quote when he said:

I would like to see the school replace the reagents that are expired and a laboratory that is better equipped. I want to see lower numbers of learners in classes so that we can be able to put them in a laboratory at the same time. I would like to see laboratory time extended from thirty minutes to one hour periods so that whenever we want to do practical work we can manage. I would like the science teachers to be given lower number of classes and lower loads. Learners can also help the situation by being more serious with their studies.

During an experiment the teacher takes the materials and equipment himself from the shelves to the learners' working posts. He does this because he is afraid that the learners will damage them. He provides a worksheet for learners to use during the experiment. He makes sure the learners are observing the laboratory safety rules. There are no protective clothing articles like gloves, goggles and laboratory coats; therefore they have to be more

careful. As part of the preparation he would have given the learners a theoretical background concerning the experiments to be conducted.

For the experiment the teacher provides the aim of the experiment as well as the procedure and materials. Learners formulate a hypothesis, follow the provided procedure and they give the solution of the problem in the aim of the experiment. He guides the learners to follow the stages of the scientific method as they conduct the experiment which provides him with the opportunity to teach learners the scientific method. He feels he has sufficient knowledge of content and that he is making maximum use of the materials at his disposal.

Table 3.4 Emerging themes from the pilot study

Teacher interview	Learner interview	Lesson observation	Field notes	Worksheet	Research journal (reflections)
1. Classes too large		Laboratory crowded	Laboratory crowded		Teacher finds it challenging to manage the classes
2. Laboratory time not enough to complete all the activities	Learners do the write-ups after the experiment in their own time	Learners were not able to do the experiment write-up within the time frame of the experiment	Write-ups are done after the experiment in their own time		
3. Learners work in groups to conduct the experiment	Learners work in groups to conduct the experiment	Learners work in groups to conduct the experiment	Learners work in groups to conduct the experiment		
4. Laboratory activities are not that frequent	Laboratory activities are not that frequent				Learners do not have frequent hands-on experience of laboratory work
5. Teacher gives learners a worksheet with the aim of the experiment, material and procedure	Learners receive worksheet	Learners use worksheet as they are conducting the experiment		Worksheet contains steps to follow	Procedure is provided for learners
6. Teacher demonstrates steps to follow	Teacher demonstrates steps to follow	Teacher demonstrates steps to follow	Teacher demonstrates steps to follow	Worksheet contains steps to follow	Learners prefer that the teacher demonstrates before they can conduct the experiment
7. Learners formulate the hypothesis	Learners formulate the hypothesis	Learners formulate the hypothesis	Learners formulate the hypothesis	Learners formulate the hypothesis	Learners formulate the problem of the experiment in the form of a hypothesis
8. Learners give solution to the problem when they analyse, interpret and draw conclusions as contained in the write-up of the experiment	Learners give solution to the problem when they analyse, interpret and draw conclusions as contained in the write-up of the experiment	Learners give solution to the problem when they analyse, interpret and draw conclusions as contained in the write-up of the experiment	Learners give solution to the problem when they analyse, interpret and draw conclusions as contained in the write-up of the experiment	Learners give solution to the problem when they analyse, interpret and draw conclusions as contained in the write-up of the experiment	Learners give solution to the problem when they analyse, interpret and draw conclusions as contained in the write-up of the experiment

About the data collected from the pilot study, Simon (2011) says that it should not be included in the main study to avoid contamination. Contamination can also be as a result of including the pilot study participants in the main study and collecting new data from them (Teijlingen & Hundley, 2001). However, data from pilot studies can be combined with data from main studies if the data collection tools and sampling techniques did not change (Thabane et al., 2010). Based on this, data from the pilot in this study could have been combined with data from the main study. The sampling techniques and data generating tools used in the pilot were the same as those used in the main study. I did not combine the pilot data with data generated from the main study because of the reasons that propelled me to conduct the pilot in the first place. I regarded myself as an inexperienced researcher who needed to go through some form of preparation before embarking on a journey that would take me through the main study. Conducting interviews and lesson observation involved multitasking skills. I simultaneously audio/video recorded proceedings and stayed focused as I made observations and asked questions. I wanted to familiarise myself with the terrain and know what to expect to avoid nasty surprises (Baptista Nunes et al., 2010). I decided not to include the pilot data because I considered it might not have been effectively and optimally collected because I was still exploring my capabilities and abilities in using the data generating tools.

The teacher narrative which resulted from the semi-structured interview successfully yielded some personal identity characteristics of the teacher according to the interview protocol. The personal identity characteristics are important in that I was able to profile the teacher according to personal academic and teaching experiences, perspectives in IBLW and the way it is practiced, beliefs and the way contextual settings are promoting or inhibiting the practice of IBLW. The focus group interview helped to provide data on how the teacher and the learners practice IBLW by complementing and confirming the data obtained from the teacher interview.

The lesson observation provided me with first-hand information on how IBLW is practiced by both teachers and learners. The lesson observation also yielded data on contextual settings to confirm what came out from the interviews and any other issues that I might be able to observe. The field notes were important for taking note of all observations in an

organised way just as the journal was important in capturing my reflections and thoughts which form part of the data in this research.

During the lesson observation I realised that the worksheet that the teacher may provide for the learners was another data collection instrument that I could use. Worksheet analysis revealed the roles of the teacher and learners in the formulation of questions, procedures and solutions for the laboratory activity that they conduct. This was very important in this study because the roles taken by teachers and learners in question posing, procedure formulation and solution giving determine how they practice IBLW.

The worksheet that was used in the experiment that the learners conducted contained the aim of the experiment. Learners used this aim to formulate a hypothesis which they would then disprove or approve during the analysis and interpretation of data recorded during the experiment. The work sheet also contained the list of materials to be used, steps to be followed and a diagram of the apparatus. This is very significant as it clearly provides the learner with the procedure of the experiment. The teacher even went a step further in making sure that the learners are equipped with the knowledge of the procedure by conducting a demonstration of how to follow the steps in the worksheet.

The solution to the problem of the experiment was not contained in the worksheet. However the learners were expected to use data collected from the experiment to display results, analyse, interpret and draw conclusions which they would submit as a write-up to the teacher. This is an indication that learners are expected to provide the solution. Worksheet analysis together with the other data collection instruments used enhanced the triangulation efforts made to ensure the trustworthiness of the data.

The results of the pilot study gave me the confidence to proceed with the main data collection process using the six data collection tools which are the semi-structured interviews with teachers, focus group interviews with learners, lesson observation of laboratory activity, field notes, research journal and worksheet analysis. The aim was to be able to get insights into the interface between teacher professional identity and the way teachers practice IBLW in school chemistry.

3.10 Quality measures

Riege (2003) propounds that despite the advantages of the case study method, its reliability and validity may be questionable since the researcher has more direct personal contact with the organisations and people examined. To ensure that the researcher refrains from subjective judgements in a way that might jeopardise the results and findings of the study, reliability and validity tests should be incorporated in the research by way of employing appropriate techniques which correspond to the research design (ibid). In order to put in place quality measures the researcher should employ techniques to ensure that the research process passes construct validity, internal validity, external validity and reliability tests in quantitative research. The corresponding tests for qualitative research are confirmability, credibility, transferability and dependability respectively (Riege, 2003).

Riege (2003) outlines techniques as tests to ensure the four quality measures. First, confirmability which corresponds to construct validity in quantitative research is ensured by using multiple sources of evidence, establishing a chain of evidence and having key informants review the case study report. Meriam (2002) says besides using multiple sources of data for purposes of triangulation, multiple investigators can also be employed to confirm emerging findings as well as giving a detailed account of the methods, procedures and decision points while conducting the study. Sufficient time should be spent collecting data in order to elicit adequate information, as well as taking data and tentative interpretations back to the research participants in a process called member checking to ensure that they are plausible (ibid).

Second, credibility which corresponds to internal validity in quantitative research is achieved by doing a within-case analysis and even cross-case pattern matching for multiple case studies, do explanation building and make sure that the findings and concepts are systematically related. Meriam (2002) mentions that conducting peer review and examination on the process of the study is one way of ensuring that emerging findings are congruent with the raw data and tentative interpretations.

Third, transferability which is a quantitative equivalence of external validity would be ensured by replicating in multiple case studies, defining the scope and boundaries of

reasonable analytical generalisation for the research and comparing evidence with existing literature. Meriam (2002) suggests the researcher presents enough description to contextualise the study so that readers may be able to determine the extent to which their situations match aspects of the study for purposes of transferability. Utilising maximum variation by purposefully seeking variation or diversity during sample selection to allow for greater range of application of the findings by consumers of the research also ensures transferability (ibid). In this study participants are purposefully selected from five different historical contexts as defined by South African history for the same reason.

Fourth, dependability which corresponds to reliability in quantitative paradigms is achieved by examining and documenting the process of inquiry and clarifying the researcher's theoretical position and biases. Shenton (2004) says that triangulation reduces the effects of researcher bias. Meriam (2002) also suggests that conducting peer review and examination of the study will ensure dependability.

Taking steps to address issues on credibility, transferability, dependability and confirmability ensures the trustworthiness of a qualitative research (Shenton, 2004). In this study deliberate efforts were made to incorporate quality measures at every stage of the research process. As a starting point the nature of the study already had some important issues of quality measures taken care of. First, the research used six different data collection tools, namely, teacher interviews, focus group interviews with learners, lesson observations, field notes, worksheet analysis and a research journal to ensure triangulation and help confirm emerging themes. This, together with member-checking, ensured confirmability of research findings. The research also was undertaken in five different contexts to ensure variation and diversity which together with detailed descriptions of the contexts in the case study ensured transferability. Most importantly, I used literature to familiarise myself with steps I should take to incorporate quality-ensuring measures throughout this study and I understood perfectly well that failure to do so would compromise the successful completion of a trustworthy thesis.

3.11 Ethical issues

Meriam (2002) posits that a good qualitative research is one that is conducted in an ethical manner. In the early stages of the research project the researcher should be able to establish whether the research is worth conducting, demonstrate expertise and competence to conduct the study in question, obtain informed consent from participants and be able to determine the costs and benefits involved (Punch, 2005). As the research is being conducted the researcher should clear issues that have to do with safety of participants, trust and honesty, privacy, confidentiality and anonymity (ibid). Even after the study has been completed Punch (2005) points out that the researcher still has to deal with issues that have to do with the integrity and quality of the study, establish who owns the data and conclusions and the use and misuse of data.

The real names of the schools and teachers were not used in the write-up of this research; instead I assigned pseudonyms to teachers. The identity of the teachers has been kept anonymous. Ensuring the anonymity of teachers is in line ensuring that the teachers and the schools would be protected when the results are published in the research write-up or any other publishing forum. The teachers and the schools would not want to have their privacy compromised. First and foremost I secured ethical clearance from the University of Pretoria. I then secured permission from the Gauteng Department of Education. Armed with the ethical clearance and the support letter from the Gauteng Department of Education, I went on to apply for support letters from the Education District Managers for Tshwane North and Tshwane South.

I used the letters of support from the District Managers to approach the school principals. In the schools principals and teachers signed letters of consent. Since I observed lessons and conducted focus group interviews with some of the learners who are under 18 years of age, it was also necessary for me to obtain consent from their parents/guardians. Learners were given letters of assent to sign and consent letters to be signed by their parents/guardians. The data collected from the schools was used solely for the writing of the thesis of this study and for research presentation in academic forums and can be accessed only by myself and my supervisors.

3.12 Limitations of the study

This was a qualitative study and, therefore, the results cannot be generalised to a larger population because they are unique to the participants and contexts in which the study was conducted. Spiggle (1994) propounds that interpretive research hinges on developing the researcher-as-instrument whereby the researcher serves as an instrument in observations, selection of participants and analysis and interpretation of data. Riege (2003) says that the qualitative approach to research makes it vulnerable to questions that can arise on issues of reliability and validity. There would always be the risk of the researcher influencing the research findings due to personal biases although this was minimised by ensuring dependability, confirmability, transferability and credibility.

3.12 Conclusion

This study was conducted using qualitative methods rooted in a social constructivist worldview. An instrumental case study approach was used as a research strategy in which narrative research methods were incorporated. The case study is about the interface between teacher professional identity and the practice of IBLW in school chemistry. The research participants were seven purposefully selected teachers and some of their learners from five different contexts. The five contexts are former model C, former Indian, former Coloured, African township and private schools. Semi-structured interviews, focus group interviews, lesson observation, field notes, worksheet analysis and a research journal were the instruments used for data collection. Analysis of the data was done through narrative and content analysis methods. The development of the data collection tools and data analysis methods was enhanced by conducting a pilot study to test the instruments and familiarise myself with the scope of the research process. The study was conducted in such a way that the quality measures of confirmability, credibility, transferability and dependability as well ethical considerations for protecting research participants and sites from harm were scaffolded into the research design.

CHAPTER 4

FINDINGS OF THE STUDY

4.1 Introduction

The findings of this study are presented in this chapter. Efforts have been made to give thick and detailed descriptions of the findings that emerged from the study. Findings are organised as emerging themes as teacher professional identity interfaces with the practice of inquiry-based laboratory work. The following broad themes have emerged:

- (i) Theme 1: Teacher personal identity expressions in IBLW.
- (ii) Theme 2: Contextual settings and learner populations interface with teacher IBLW professional identity positions.
- (iii) Teacher IBLW professional identity positioning.

The themes are sub-divided into sub-themes and categories. The main data sources were the participants' narratives and my field notes hence frequent verbatim quotations are used to give the reader a first-hand experience of the findings. Chapter 3 of this study justifies why data was collected from five different contexts, that is, a former model C, former Coloured, former Indian, African and a private school. It follows that on presenting the findings the contexts from where the data was collected are indicated.

The findings reveal four teacher professional identity positions for the seven teachers who participated in this study. The findings made on each teacher are presented separately because it is important to take the contextual settings into account. An attempt to present a discussion on how teacher professional identity interfaces with the practice of IBLW in the schools is also made for each teacher.

Tables and figures have been used to present summaries of the emerging themes. Table 4.1 and Figure 4.1 present a summary of emerging themes for the entire study. Tables and figures summarising each theme are subsequently used as each theme is discussed.

4.2 Important points to take note of when reading this chapter

- In South Africa secondary school chemistry is offered as part of physical sciences (chemistry and physics) as a subject.
- The data collected may not be only for chemistry but for physics as it is part of physical sciences.
- The laboratory activities observations made were both for chemistry experiments and physics experiments. Five laboratory activities were chemistry experiments and two were physics experiments.
- Efforts were made to capture narratives of teachers and learners verbatim; however, in some instances some parts were rephrased without changing the meaning to enhance comprehensibility.
- The presentation of findings is organised in emerging themes, sub-themes and categories; however, some of the findings may not be general to all the participating teachers since identity shaping is particular and individual in some instances

4.3 The seven participating teachers in the study

Jane is a 45 year old, female teacher of Caucasian origins. She has 20 years of experience in the teaching of physical sciences. She holds a Diploma of Education and is currently studying for a Bachelor of Education Honour's degree. She teaches in a former model C girls' high school. The girls are from multicultural backgrounds although White and African girls form the majority of the learner population. Jane's narratives echo how the beliefs that she acquired from her previous experiences interface with the contextual settings to bring about a position identity in the way she facilitates IBLW for learners. She negotiates an IBLW teacher identity which reflects both her beliefs and the school contextual settings.

Jimmy is a 48 year old, Coloured, male physical sciences teacher. He has 17 years' experience of teaching physical sciences. Jimmy holds a Bachelor of Science degree in Education. He teaches in a former Coloured school. The learner population of the school is composed of both boys and girls from multicultural backgrounds. However, Coloured learners constitute the majority of the learner population. Jimmy's narratives reflect a

teacher who negotiates an IBLW teacher professional identity through contextual settings characterised by lack of materials in his past experiences with IBLW and other overwhelming school setting challenges.

Tendai is a 40 year old, African, female physical sciences teacher. She has 15 years' experience of teaching physical sciences. Tendai holds a Diploma in Science Education as well as an Honours degree in Environmental Science. She teaches in a former Indian school. The learner population of the school is composed of both boys and girls from multicultural backgrounds. However, Indian and African learners constitute the majority of the learner population. Tendai merges her previously acquired beliefs with perceptions that she forms when interpreting the curriculum document and the school settings in terms of challenges and favourable conditions for the practice of IBLW to develop her teacher identity position.

Kabelo is a 43 year old, African, male physical sciences teacher. He has 16 years' experience of teaching physical sciences. Kabelo holds a Diploma in Science Education. He teaches in an African township school. The learner population is constituted of both boys and girls from African cultural backgrounds only. Kabelo negotiates an IBLW teacher identity position in the wake of the beliefs that he developed about practical work when he was in teachers' college and the realities of his school context.

Melusi is a 33 year old African, male teacher who works in an African rural school. He holds a Bachelor's degree in Science Education. The rural school is one of the seven disadvantaged schools to which he offers his services. He works to engage learners in laboratory activities. He has seven years of experience as a science teacher. The learner population of the school is constituted of both boys and girls from African cultural backgrounds only. Melusi negotiates an IBLW identity position that he can use in all the different schools that he works by using the special training that he got to prepare him for this kind of work.

Betty is a 50 year old, White, female physical sciences teacher. She has 23 years' experience of teaching physical sciences. Betty holds a Bachelor of Science and an

Honours degree in Chemistry Education. She also holds a Master's degree in Chemistry Education. She works in a private school. The learner population is constituted of boys only. The boys are from multi-cultural backgrounds although White boys form the majority of the learner population. Betty negotiates an IBLW teacher identity position by using the confidence that she gained from her previous experiences and how she thinks the boys should be made to engage in laboratory activities.

Farai is a 36 year old African, male physical sciences teacher. Farai has 15 years teaching experience as a science teacher. Farai holds a Bachelor's degree in Science Education although he first attended a teachers' college where he obtained a Diploma in Science Education. He works in a private school. The learner population is constituted of both boys and girls. The boys and girls are from multicultural backgrounds although those of African cultural backgrounds constitute the majority of the learner population. Farai negotiates an IBLW teacher identity position in the wake of strong beliefs that he has on the incorporation of laboratory work in the teaching and learning of physical sciences and the realities of his school contextual settings.

Summary of emerging themes

A summary of emerging themes have been organised in a diagram and a table to help understanding. The summary also includes sub-themes and categories that were generated during the process of data generation.

Figure 4.1 Overview of themes

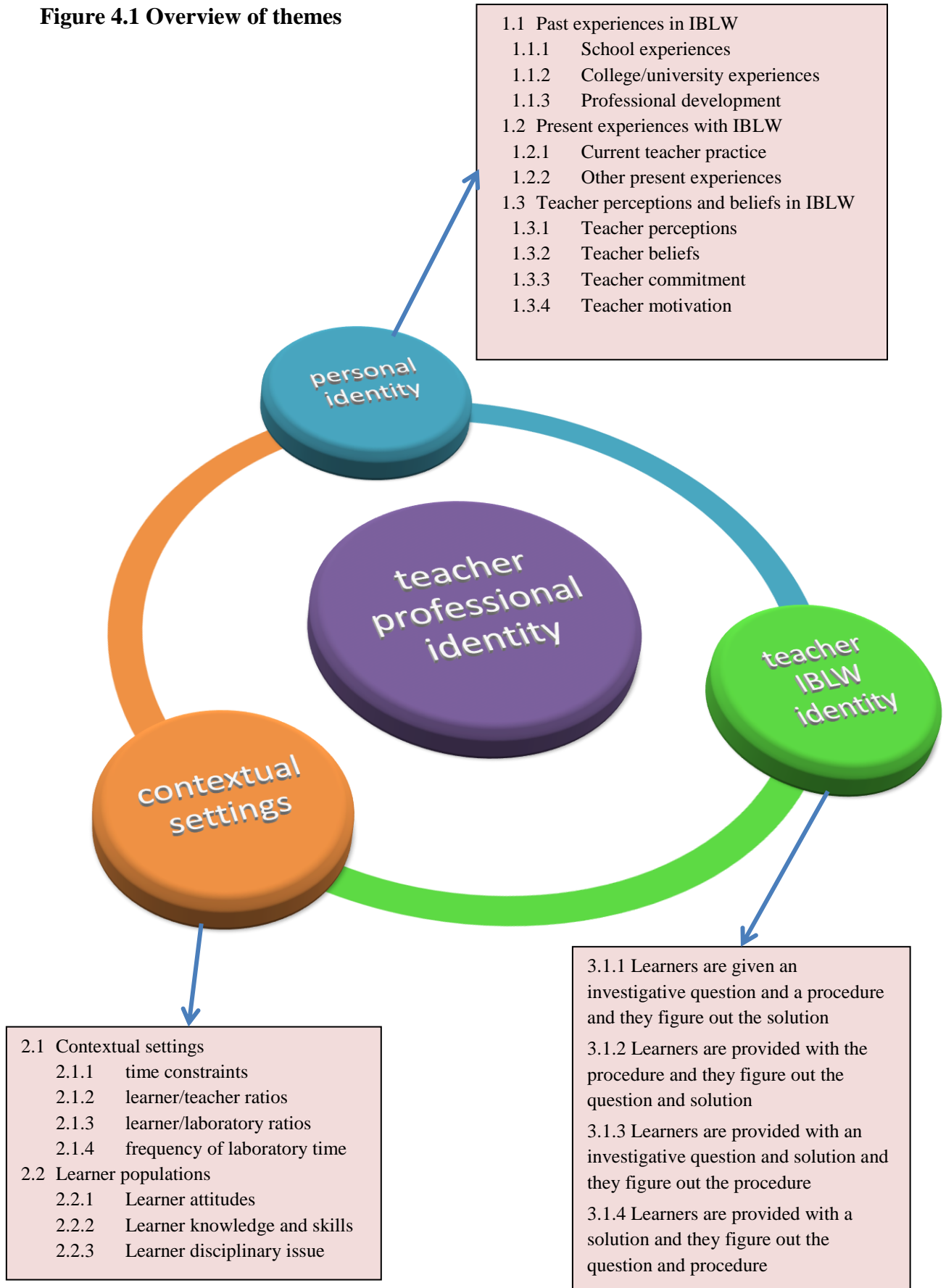


Table 4.1 Summary of emerging themes

Secondary research questions, themes, subthemes and categories			
Secondary research questions	Themes	Subthemes	Categories
How do personal identity traits influence teacher identity positions in IBLW practice?	Theme 1: Expressions of teacher personal identity positions	Subtheme 1.1: Past experiences with laboratory work	Category 1: School experiences
			Category 2: College/university experiences
			Category 3: Professional development experiences
		Subtheme 1.2: Present experiences with laboratory work	Category 1: Current teacher practice in IBLW
			Category 2: Other experiences with IBLW
		Subtheme 1.3: Teacher perceptions and belief systems in the practice of IBLW	Category 1: Perceptions on IBLW reflected on teacher practice
			Category 2: Teacher belief systems shaping IBLW practice
			Category 3: Teacher belief systems that fail to have an impact on the IBLW practice
			Category 4: Teacher commitment
			Category 5: Teacher motivation

Secondary research questions	Themes	Subthemes	Categories
How do contextual school settings influence teacher identity positions in IBLW practice?	Theme 2: Contextual settings and learner populations	Subtheme 2.1: Contextual settings	Category 1: Time constraints
			Category 2: Learner/teacher ratios
			Category 3: Learner/laboratory facilities ratios
			Category 4: Frequency of laboratory work engagement
		Subtheme 2.2: Learner populations	Category 1: Learner attitudes towards laboratory work
			Category 2: Learner knowledge and skills in IBLW
Category 3: Learner disciplinary issues			
What are the teacher professional identity positions in the practice of IBLW	Theme 3: Teacher professional identity positions in IBLW	Subtheme 3.1: Learners are given the investigative question and procedure and they figure out the solution	Category 1: Jane from a former model C school
			Category 2: Jimmy from a former Coloured school
			Category 3: Melusi from an African rural school
			Category 4: Betty from Private school (I)
		Subtheme 3.2: Learners are given the procedure and they figure out the investigative question and the solution	Category 1: Kabelo from an African township school
			Category 1: Tendai from a former Indian school
		Subtheme 3.3: Learners are given the investigative question and solution and they figure out the procedure	Category 1: Farai from Private school (II)
			Category 1: Farai from Private school (II)
Subtheme 3.4: Learners are given the solution. They figure out the investigative question and procedure	Category 1: Farai from Private school (II)		
	Category 1: Farai from Private school (II)		

4.4 Expressions of teacher personal identity positions

This theme captures how teachers express their personal identity positions in relation to the practice of IBLW. The theme is further divided into the following subthemes: 1.1) past experiences with laboratory work; 1.2) present experiences with laboratory work; 1.3) teacher perceptions and belief systems in the practice of laboratory work. Figure 4.2 provides a summary of the subthemes in theme 1 while Table 4.2 gives a summary of the subthemes and categories in theme

Figure 4.2 Expressions of teacher personal identity positions

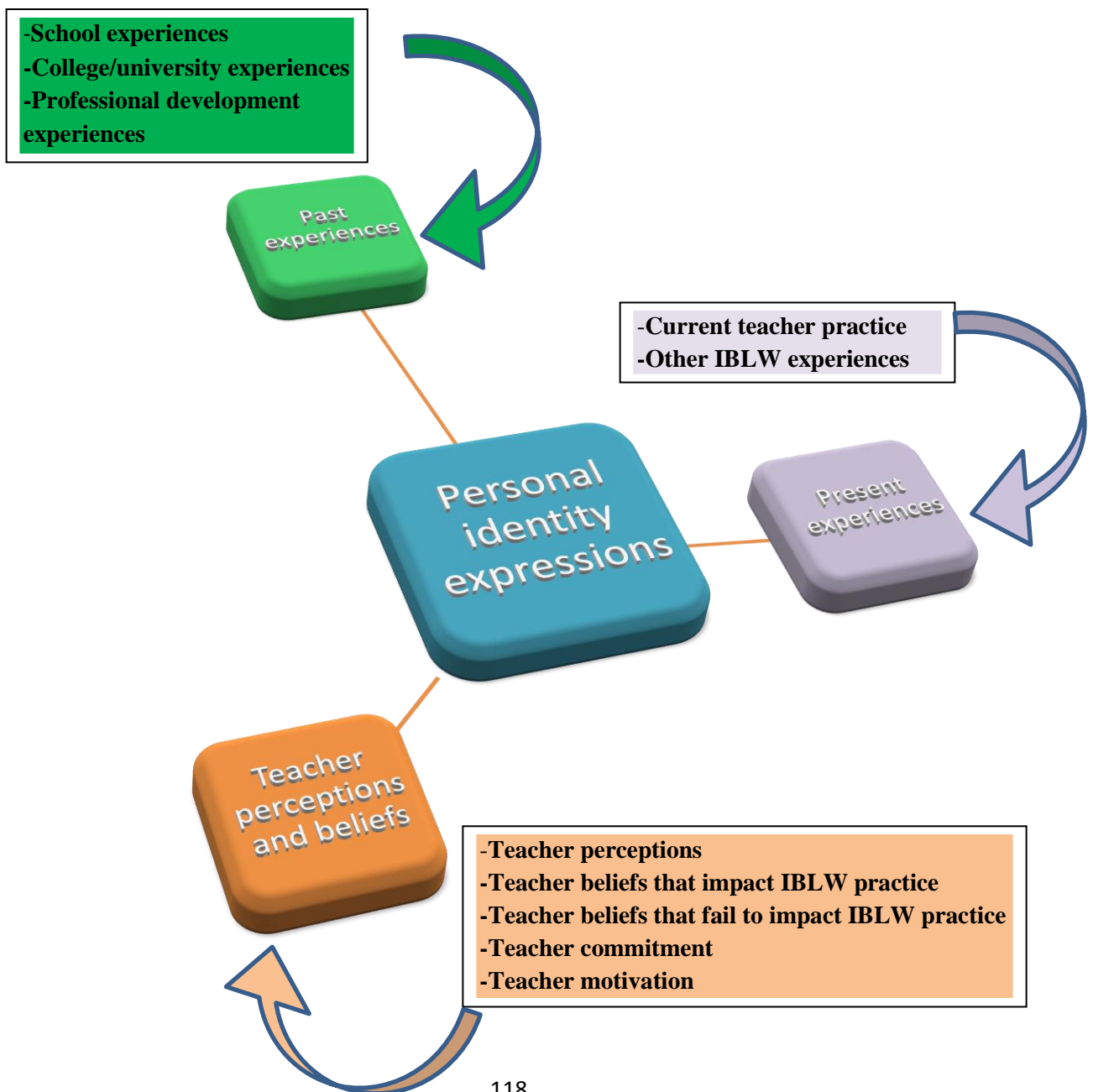


Table 4.2 Inclusion and exclusion data indicators for Theme 1

Expressions of teacher personal identity positions		
<i>When I was a learner the reason why I did science is because I just wanted to be in the lab I wanted to be with the apparatus I wanted to have my hands on anything that is inside there so already I was somebody who was already decided that what-ever that needs to be done I had to do it. Farai (Private school)</i>		
Subtheme 1: Past experiences		This subtheme focuses on the teachers’ exposure to IBLW from past experiences
Subthemes and categories	Inclusion indicators	Exclusion indicators
Category 1: School experiences	<ul style="list-style-type: none"> • This category includes data on teachers’ school experiences with laboratory work • Data on any impressions that may have resulted from the school experiences is also included 	<ul style="list-style-type: none"> • This category excludes data on teachers’ other experiences with laboratory work
Category 2: College/university experiences	<ul style="list-style-type: none"> • This category includes data on teachers’ college/university experiences with laboratory work • Data on impressions that may have resulted from the college/university experiences is included 	<ul style="list-style-type: none"> • This category excludes data on teachers’ other experiences with laboratory work
Category 3: Professional development and training experiences	<ul style="list-style-type: none"> • This category includes data includes instances where teachers undergo professional development exercises on how to facilitate IBLW for learners. • This also includes data on when they attend training exercises on how to conduct certain experiments 	<ul style="list-style-type: none"> • This category excludes data where teachers attend professional development exercises for other curriculum issues
Subtheme 1.2: Present experiences with laboratory work		This subtheme focuses on the IBLW experiences that teachers are currently engaged in.
Category 1: Current teacher practice in IBLW	<ul style="list-style-type: none"> • This category includes data of how the teachers’ current teaching practice helps to shape their identity position in IBLW • This includes data on how they practice IBLW with their learners. 	<ul style="list-style-type: none"> • The category excludes data on other teaching practices that the teachers may be engaged in.

Category 2: Other present experiences with IBLW	<ul style="list-style-type: none"> • This category includes instances where teachers engage in other IBLW experiences • This data also includes data from instances where teachers are engaged in training other teachers in IBLW practice 	<ul style="list-style-type: none"> • This category excludes data on current teaching practice and professional development
Subtheme 1.3 : Teacher perceptions and belief systems in the practice of IBLW		This subtheme focuses on the significant beliefs, perception, commitment and motivational that teachers have in IBLW
Category 1: Perceptions on IBLW reflected on teacher practice positions	<ul style="list-style-type: none"> • This category includes data on how teachers view practices on laboratory work • The category also includes data on how teachers interpret the syllabus on aspects of laboratory work 	<ul style="list-style-type: none"> • This category excludes data on teachers' perceptions on the practice of IBLW that fail to reflect on how they facilitate laboratory work for learners
Category 2: Teacher belief systems shaping IBLW practice	<ul style="list-style-type: none"> • This category includes data on the belief system of teachers that significantly shape teachers' teacher identity 	<ul style="list-style-type: none"> • This category excludes data on other teachers' beliefs that do not shape their IBLW teacher identity
Category 3: Teacher belief systems that fail to have an impact on the IBLW	<ul style="list-style-type: none"> • This category includes data on teachers' beliefs on the practice of IBLW that fail to manifest in their laboratory practice with learners. 	<ul style="list-style-type: none"> • This category excludes data on teachers' beliefs that reflects on the way they facilitate laboratory work for learners
Category 4: Commitment	<ul style="list-style-type: none"> • This category includes data on actions undertaken by teachers in the face of challenges to promote the practice of IBLW 	<ul style="list-style-type: none"> • This category excludes data on what teachers think might be done to overcome challenges in the practice of IBLW but however fail to put it into practice
Category 5: Motivation	<ul style="list-style-type: none"> • This category includes data on internal forces that drive teachers to align themselves with a certain IBLW teacher identity position • This category also includes data on the positive outcomes that they achieve through their IBLW practice 	<ul style="list-style-type: none"> • This category excludes data on external forces that drive teachers to align themselves with certain IBLW practices • This category excludes data on other unintended and undesired outcomes that teachers achieve through their IBLW practice

4.4.1 Past experiences with laboratory activities

The subtheme captures teachers' narratives on their past experiences with laboratory work. The subtheme is organised in the following categories: (i) school experiences, (ii) college/university experiences and (iii) professional development experiences.

4.4.1.1 School experiences

Three of the seven teachers were never exposed to laboratory work activities when they were in school. These are Kabelo (African), Jimmy (Coloured) and Betty (White). They learned science without engaging in the practical component of science. Jimmy and Kabelo lament the fact that they did not experience laboratory work in school. They feel that they have been somehow disadvantaged since they did not have the basic knowledge and skills on laboratory work as they pursued tertiary education. Kabelo looked back and made an attempt to describe the way he was taught science in school:

When I was still at school everything was done theoretically. Everything was done theoretically and then they would talk about substances like sodium chloride but only saying that sodium chloride can be found in the homes. Other substances like calcium carbonate and potassium permanganate they would tell you that they are also found at home and may even give the names in our own local languages.

Jimmy explained that they could not engage in laboratory work activities at school because of a lack of laboratory facilities, equipment and materials. Learning was achieved through the descriptions that were given of scientific phenomena. He said, "It was just theory. We'd just visualise or imagined some of the things that were happening because of lack of equipment."

Betty remembered that she had no exposure to laboratory work at school and did not elaborate much on the reasons why science was taught that way. Betty said, "I think when I was at school we didn't do laboratory work. There was no laboratory work when I was at school."

Jane (former model C), Tendai (former Indian), Melusi (African rural) and Farai (private) all acknowledge having had exposure to some of form of laboratory work when they were in school. Jane and Tendai were proud to say that their laboratory engagement at school

was on a frequent basis. Jane disclosed that she had frequent exposure to laboratory work when she said; “The school that I attended the teachers allowed us to do a lot of practical work.”

Tendai’s revelations of school experiences suggest that she thinks that her school experiences were better than those that her learners are experiencing now. She believes that she has what she calls a ‘solid foundation’ in the practice of laboratory work because of her school experiences. With voice full of pride Tendai’s said, “I don’t know how to put it. At school if we did practical work it was twice a week.”

Melusi revealed that although he did not have exposure to laboratory work during the first four years of his secondary schooling, he was finally exposed to laboratory work in the last two years of his six years of secondary school. He said, “At least I had the ‘A’ level experience where I got to do practical work.” Melusi compared and contrasted his school experiences with his learners experiences by observing that the science content that he covered when he was in school was more detailed than the concepts that his learners should cover now. However, he revealed that the equipment that he is using for laboratory work with his learners is more technologically advanced than the equipment they used during his school days:

In terms of the content that we covered at advanced level, the content was much more detailed than what these learners are doing. But then in terms of instruments,... and maybe it being very modern, these ones that I am using are more modern than what we used before and I believe they are even more accurate and more sensitive because most of these apparatus that we use, we use soft wares so it’s like we are moving away from the traditional conventional apparatus.

Farai even remembers how he developed a love for practical work and got motivated and excited by laboratory work when he was still in school. He even developed long term ambitions that had to do with laboratory work activities. Farai’s exposure to laboratory work activities is evident:

When I was a learner the reason why I did science is because I just wanted to be in the lab I wanted to be with the apparatus I wanted to have my hands on anything that was inside there so already I was somebody who had already decided that what-ever it takes I had to do it.

4.4.1.2 College/university experiences

The teachers' college/university experiences in laboratory work activities were limited for Jimmy and Farai. Jimmy's exposure to laboratory activities was limited during the time that he was studying for his Bachelor of Science degree at university. This compounds the fact that he never had school experiences with laboratory work. He feels that his laboratory work experiences when he was at university were not meaningful enough to prepare him as a science teacher:

It was only done when it was the period for practical work. We were not very much exposed to practical work. It was more theory than anything else. The emphasis was on theory than practical. We would only go there just to get the mark on practical.

With this limited exposure to laboratory activities Jimmy had to forge a relationship with one university lecturer during the time he was doing his teaching practice so that he could receive the mentoring that he needed for him to be able to facilitate laboratory activities for learners:

Fortunately when I was doing the method of physical sciences and you do that in your fourth year, I built up quite a good relationship with a physical science lecturer... so then if I wouldn't have something at school I would go to the university and he'll give me the apparatus to use.

Farai went to teachers' college and later to university having developed an interest in laboratory work from school. He saw this as an opportunity to be exposed more to laboratory work activities. His expectations were not met; that is why he considers his college and university experiences with laboratory work to have been limited. Farai reflected on how limited his teachers' college exposure to laboratory work was:

When I went to college it was slightly different because you would find that they would have what you call prescribed experiments for certain courses and stuff like that. You wouldn't do most of the things because they would tell you that most of the things you did them in high school but there were other experiments that they would say we know these ones you didn't do so you have to do them but all the same it wasn't as rigorous as it was in high school.

When Farai went to university he was expecting to be engaged in more hands-on activities in laboratory work. This was not to be. He explained why he considers the laboratory work experiences that he went through at university to be limited. At university it was not hands-on:

When I went to university for a bachelor's degree in education it was more on pedagogy and content because they would tell you, having been at teachers' college and having been in high school doing science most of these experiments you know them but we would have time to interact with the stuff mainly for the purpose of coming up with probable problems that may come up or that would surface when learners are doing such experiments.(Farai, private school)

Jane (former model C), Kabelo (African, township), Tendai (former Indian), Melusi (African rural) and Betty (private) remember their college and university laboratory experiences as having been very meaningful. Jane mentioned the name of the university that she attended in a way that reminds the listener that it is a reputable university. She further emphasised that the class was very small which had positive implications on her hands-on and first-hand experience of laboratory work. Jane said, "We were a very small class so we did everything that we could on practical activities."

Tendai considers herself to have received a solid foundation in laboratory work because she said she continued to have meaningful exposure when she went to a teachers' college. About her teachers' college experiences in laboratory work Tendai said, "We were doing a lot of practical work at college. Let me say throughout all my learning experiences..."

Kabelo was first exposed to laboratory work activities when he was at teachers' college. He was aware that he was disadvantaged because of his school experiences that lacked practical work. He and others who had no school experiences with laboratory work were a bit apprehensive and anxious at first each time they would be practicing laboratory work:

I started experiencing that in tertiary but now we were having a problem in handling those apparatus because we never had chance to touch them at school so we were afraid to touch them because we didn't even know how to handle some of them because we never had chance to touch them in high school. So we were afraid to touch some of them because we didn't know how to handle them (Kabelo, African township school).

Kabelo considered the exposure that he had at teachers' college to be meaningful. He liked and appreciated this new experience with science. He narrated his college experiences with pride and satisfaction:

At the University at least we conducted experiments every time. I was in the TC the former TC where experiments were conducted every time. I enjoyed the

laboratory sessions. All materials were there everything was there in the lab. It was hands-on every time. I never came across a lesson where they would say there are no materials each and every time the materials would be there.

Melusi also remembered his exposure to laboratory work activities as having been significant. He described his university experiences with laboratory work by comparing and contrasting them with his present practice as he facilitates laboratory work activities for his learners:

At University of course the apparatus could compare with these ones that we are using now because some of the things there were automated. We would use machines and not the manual way though of course it was a maybe a few years back but then at least the standard was higher than secondary school.

Besides not having experienced laboratory work while she was in school, Betty believes she had the necessary exposure when she attended tertiary education. She considered her university preparation in laboratory work to be adequate and satisfactory for her to be able to facilitate practical work for her learners:

My exposure is okay and I am comfortable in the laboratory. I did a Bachelor of Science when I was at university I did an Honours degree in Chemistry so we did a lot of practical work. I was at university of... I don't know if it was different from others but we did a lot of practical work during my studies (Betty, private school).

4.4.1.3 Professional development experiences

Jane (former model C), Tendai (former Indian), Kabelo (African township) and Melusi (African rural) alluded to having attended workshops recently for professional development or training on matters related to laboratory work. Jane and Tendai have had similar experiences. Their schools received donations of laboratory kits with equipment and materials for use even in situations where laboratory facilities are not available. The people who donated the laboratory kits asked teachers to attend workshops on the use of the materials and equipment. Tendai explained how the laboratory kits could be used even in classrooms:

Of late I have attended a workshop; there are new kits that they make for convenience for places that do not have proper laboratory facilities like personally the other challenge is that this is not a proper laboratory setting if you look at the work benches. I have gone for training on how to use the micro kits and you discover that they can actually work even if you don't have Bunsen burners they actually work as a miniature laboratory (Tendai, former Indian school).

Jane revealed that she has benefited in terms of professional development on how to facilitate laboratory work for learners from the support she received from both the Department of Education and the organisations that donated laboratory kits:

We receive a lot of support from national and from our district office. On this Saturday again they have teacher training for the boxes to make sure you know how to use them because some people are very scared.

She also said:

The people who gave us the boxes have done some sessions with us on in-service training in conducting laboratory practical work. They are also the people presenting it now on Saturdays. So the district has notified us of these sessions they tell you about the box, they tell us how to do certain practical activities and what is the best option and what are the expected results and things like that.

Kabelo has been able to attend professional development exercises organised by the Department of Education on how to facilitate and perform some experiments. The teachers are afforded the chance to familiarise themselves with certain experiments in the syllabus and also discuss experiments that present challenges for them:

For professional development we are having some sessions with the Department of Education. They organise some sessions where we perform experiments, not all the experiments but some of the experiments which they think they are problematic in teaching. However professional development during this year, we have never had any. That was only last year when we went for workshops. This year they've not yet organised workshops for us.

Melusi has had a different kind of professional development. He underwent a two weeks intensive training before he started his work as a teacher who is solely assigned to facilitate laboratory work for learners. The training was to familiarise him with the experiments that learners are expected to conduct as well as the use of the specialised and technologically advanced equipment that he has to make use of. The training was also to enable him to be able to facilitate experiments for learners even in conditions where there are no laboratory facilities:

When I joined...there was actually two weeks intensive training focusing mainly on experiments using the apparatus troubleshooting and of course the uniqueness of these apparatus, what about them and all those things naming them, how to connect them and precautions to take so I can say that was an exposure that at a professional development level that I got beyond university.

Jimmy from a former Coloured school does not always attend some of the professional development exercises in the form of workshops for teachers because of his involvement with the School Improvement Plan (SIP) in which the teachers conduct extra lessons for learners on Saturdays. He said, however, that if he feels he needs professional support on certain topics, he is free to ask for help from the physical sciences subject advisor:

Our facilitator from the Department she supports us a lot. She is available any time if there may be a need. If there may be a practical that I need assistance with, she comes, she is quite available, and she's helpful, very supportive she quite understands.

However, Jimmy realises that it is his responsibility to make sure he knows how to meaningfully engage his learners in laboratory work. Therefore he was quick to point out how he takes charge of the process to make sure he stays competent:

The support may not be enough but I don't expect her to do everything she only guides us and from there I take it a step further. That is how I will grow. I cannot expect the facilitator to help me in everything. I cannot always say Madam I can't do this practical come and help me, that way I won't grow. Before I go to her I consult with a colleague. If a colleague here cannot assist me I go to the neighbouring school but she is my last option.

At Betty's school learners are examined under the Independent Examinations Boards. They have no obligation to attend any professional development exercises that are organised by the Department of Education. Betty feels they are competent enough and do not need any support from outside. The school caters for learners who come from high income backgrounds who can afford to pay very high fees that are out of the reach of the general populace. That makes the school self-reliant and independent. Betty describes the circumstances that result in her not experiencing professional development on laboratory work in school clusters when she said:

We don't get any support because our school is part of the IEB (Independent Examinations Board) and write the IEB matric exams. Once a year they have a conference, subject conference that we go to. We have a department of four teachers that teach physical sciences. We stimulate each other. We organise each other so that what we do here is what we want to do. I feel we are well-trained and we know our science so we don't feel that we need any help at the moment.

Farai also teaches in a private school which is not exactly the same as Betty's school. The learners write exams that are administered by the Department of Education. For this reason

they may feel obliged to attend workshops organised by the Department of Education. He said that unfortunately most the workshops have been only on theory development. He said, “We do professional development here and there but it's not that often...but mainly it was for theory development.”

4.4.2 Present experiences with laboratory work

This sub-theme captures teachers’ narratives on their present experiences with laboratory work. The sub-theme is organised in the following categories: (i) current teacher practice in IBLW and (ii) other teacher experiences with IBLW.

4.4.2.1 Current teacher practice in IBLW

Teachers narrate how their current engagement in laboratory work as a teaching and learning strategy assist in defining teacher identity positions in IBLW. This is done by explaining how they make laboratory work a priority in which learners are hands-on.

Jane (former model C) has her laboratory practice dominated by teacher demonstrations because she cannot manage to have the learners conduct the experiments themselves because time does not permit her. She manages to conduct the teacher demonstrations so that the learners can observe scientific phenomena and to help her explain the scientific phenomena. Jane painted a picture of how she practices laboratory work when she said the following:

I would like to do more but the syllabus is extremely full so we just have to do some of our things as a demonstration because there is no time, but whenever we have a lesson somewhere we try to put a practical in even if it's boiling water or to give the measurements so that the girls can stay up to date. Quite a few of them will go into engineering and things like that so we have to do practical work and develop that skill for them.

Jane further expounds by revealing that if learners are to conduct experiments she first teaches the theory pertaining to the practical activities. This works as a way of preparing the learners for the practical activities to make sure the learners manage to conduct the experiments successfully because they are meant for assessment:

We first do all the theory that is relevant to the practical and then a week before the date of the actual practical they get the instructions clearly set out and also what you expect of them like which write-up should they have and whether it's

a full write-up, is it just observations. On the day of the practical you put them in groups. We don't do that before the time because they kind of decide that this one is right I am going to work with this one I am not going to do preparation.

Jane's learners confirmed that the laboratory activities that they conduct are mainly for assessment and they wished they could be given an opportunity to conduct other laboratory activities that are not meant for assessment. These sentiments were echoed when the learners said the following:

I think if we could do more of them but not all of them for assessment it will be a more relaxed environment and everybody won't be stressing to do it perfectly so that we can get good results.

They also said:

I think it's chaotic when we know we will be doing experiments. Everyone is frantic and all, so it's like that thing of maybe we should do them more often. They shouldn't be once and for marks because it gets chaotic when it is like an investigation.

Other insights into Jane's current practice are reflected in what the learners reveal. Although the laboratory is fairly well equipped, there are instances where there are insufficient materials for certain experiments. When the materials are insufficient, learners are made to form large groups and the learners feel that they do not benefit sufficiently in such activities. Chelsea said:

With the light bulbs it was like seven of us per table. It's not a bad thing but just some people don't get to handle the apparatus as much as others. They don't get a feel of it and also we don't know what is everywhere so we can't do like quality control and to make sure everybody's results are on point. But sometimes I understand why we have to be in such big groups because there is not enough like apparatus and stuff but smaller groups would be nice to work in.

For Jimmy (former Coloured school), his narrative reflects the level of learners' hands-on experience in the laboratory. From the narrative it can be deduced that he conducts teacher demonstrations most of the time. Jimmy observed that learners are reluctant to participate actively in the conducting of the experiments. Learners seem to take up a passive role in the practical activities. All this was reflected when he said:

We are about to finish the electrolytic reactions but children don't see the chemistry behind it. They just see like magic happening there in front. They are

not in a culture of observing things and write down things that they observe, write down what you smell. They just sit there and watch. It's just a watching thing. There is no actually that interest to say the educator is doing this why is there a colour change why is there a gas forming. They just think it's a miracle.

Whenever the learners have to conduct experiments Jimmy has to provide them with the necessary support for the exercises to be successful. He explained that he gives more guidance to lower grades and less support to learners who are in higher grades. Jimmy described the extent of guidance and support that he provides his learners during laboratory practical activities:

However for the Grade 10s like I said I guide them most of the time I do maybe 60% even up to 80% if it is necessary of the practical work myself and the learners will do the rest and gradually we expect them to do more. From grade 11 I will do less and they will do more. In grade 12 you do absolutely nothing we only give them the instruction sheet and they go and do the practical activity. That is the support that I give to my learners.

Tendai (former Indian school) believes that besides acquiring a solid foundation in laboratory work practice in school and at college she is also continuing to develop professionally in the practice. Teaching science provides her with an opportunity to do more laboratory work activities. She also realises how her learners are benefiting from the process by way of being motivated to learn science and improving their understanding of scientific concepts. Tendai described her laboratory practice and her observations when she said:

Now here at school I am doing more because I discovered that when I do more practical work the kids get more interested so some of the practical activities I am even trying them here. I find that I even try some practical activities here that I never did at school. They enjoy. I capture their attention and I keep them coming back for more. With practical work I just told myself discovery is the best way for them to learn. They are able to understand more I think from the practical work.

Tendai makes laboratory work an integral part of the process of teaching and learning science. She makes her learners actively involved in the preparation of materials and equipment before experiments can be conducted. Tendai allows her learners to engage regularly in the handling of materials and equipment in the laboratory as they conduct experiments. The essence of Tendai's current practice in laboratory work was captured

when she described the priority that she attaches to practical activities and the role that she hopes they will play in the process of teaching and learning:

And we also don't have a lab assistant to prepare the chemicals and equipment in advance so a lot of time is spent on preparation but I am also in some instances involving them in preparing some of the reagents so that they get used to the names and looking for the names and handling the equipment. I think when they do the practical activities especially themselves they are more interested in learning the theory; they can confirm the theory that we are doing (Tendai).

What stands out about Kabelo's (African township) laboratory practice is the incorporation of computer technology to help him supervise the learners and for the learners to be able to observe from any part of the laboratory any demonstrations he may conduct of experiments. The conditions allow for him to conduct more demonstrations of experiments than laboratory activities in which learners are hands-on. However laboratories are usually overcrowded:

They want to see themselves on the screen. They are not going to play because I can play it again and I tell them if you do something wrong, if you steal or whatever I am going to play it again and it is capturing each and every one of you so at least it minimises some of the things like stealing like playing... They can also see what is happening even if they are far away from the screen without coming close (Kabelo).

The importance of the incorporation of technology in Kabelo's laboratory practice is also noticed by learners. They realise how the incorporation of technology is assisting them when they are engaged in laboratory work. Besides being able to observe scientific phenomena and instructions from the teacher projected on the screen, they are also able to collect results from one experiment that is being conducted in front by a few learners. The learners said:

When we interact we have the projector and we have the apparatus of the experiment so that we are able to conduct the experiment, because some people they believe things, they believe theories when they see them, so when it's theoretical when we are in class you can't understand it because they are talking using bombastic words like Boyle's law and Charles' law and all that but then if you see it in practice that's when you can understand.

Kabelo pointed out that he uses laboratory activities in two ways. He may use experiments to consolidate or verify scientific phenomena that he has already taught the learners as theory. He may also use the experiments to introduce new content to learners before he can

develop the concepts theoretically. He explained how he prepares himself and the learners for the laboratory activities that they conduct,

Before conducting an experiment there are some pre-activities that we do like yesterday I had to introduce Boyle's law and Charles Law and Gay Lussac law. Before we do experiments we teach them the theory and explain some concepts and then the next day now we will perform the experiment based on what we have discussed in the classrooms. However there are other experiments that you can just do without much preparation for examples when I am teaching waves.

Melusi (African rural school) works in seven schools focusing on facilitating laboratory activities for learners from Grades 10-12. He is able to conduct experiments with learners in schools where there are no laboratory facilities because he makes use of laboratory kits that he carries with him in his car. The laboratory activities that he conducts with his learners are already prepared in the form of work sheets. The worksheets have activities and suggested methodologies that he and his learners can follow. The work sheets have three parts which start with a theory section to make sure learners are ready to conduct the experiments. The second section involves the step by step execution of the experiments and the last part has got questions that assist learners to reach the conclusions of the experiment as well as help them to consolidate their understanding of the scientific concepts. Insights on Melusi's current laboratory practice were reflected when he said:

I cannot say there is a specific method to follow because what happens is that there are worksheets there and the worksheet obviously as you have seen it has got two to three sections. Section A has got theory so maybe method wise if you want to follow their worksheet as it is then it will be theory followed by experimental setup and then executing the experiment and then doing the write-up and conclusion.

Melusi observed that his learners are in a better position to conduct the experiments if he makes sure they are taught the theory first. Sometimes he has to go out of his way to teach theory, something that is supposed to be done by the learners' physical sciences teacher in the school. He also realises that learners need his guidance and support in everything that they do during the experiments:

I've realised that when you take that approach where you give them two or three pointers around that topic and now go to the experiment most of them they easily relate the practical activity that they are doing with the theory. Then what I have observed also is that they need guidance all the way through of course with the exception of a few outstanding learners. When you show them

the first and the second steps, they can easily relate to the rest (of the steps) and complete it.

The learners corroborated what Melusi observed about the learners' need to familiarise themselves with the concepts of the topics before they can engage in a laboratory activity:

Being taught the theory over and over again, the theory part of that particular I don't know subject or topic. Being taught the theory part, our teachers assisting us in understanding the theory part before we actually do the practical (Lebogang).

For Betty (private school) and her learners, practical work in science is a regular component of teaching and learning. Learners have to be taught to independently handle materials and manipulate equipment in the laboratory because they have a number of practical examinations in the year in which the support from the teacher is very minimal. The place of laboratory work at Betty's school in the process of teaching and learning is pivotal because learners are also examined in that component. This was reflected when she said:

They do practical exam. The Form 3s (Grade 10s) do it twice a year; the Form 4s (Grade 11s) and Form 5s (Grade 12s) do it three times a year.

As Betty prepares her learners by making them engage in laboratory work activities, she tries to make sure the learners master the scientific method by assessing how they write hypotheses for experiments, collect data and reach the conclusions of the experiments they conduct. Betty also uses the experiments to consolidate learners' understanding of scientific concepts because they are able to get first-hand experience of scientific phenomena. There is evidence that she usually provides them with the investigative question of the experiments. Here is a detailed account of how Betty engages her learners in laboratory work. The extract gives a summary of how the question is posed and solution of the experiment is reached:

On evaluating their ability we do it in different ways at different times. Sometimes when they do a practical activity I just assess the conclusion. There is another practical that we will do next week where I will give them sodium chloride of different concentrations and then ask them, 'Does the conductivity increase as the concentration increases?' Then I make them write a hypothesis and get the data and draw the conclusion based on what they measure (Betty).

The following extract from Betty's narrative demonstrates that, although theory is taught before the learners can engage in corresponding laboratory work activities, the learners do not necessarily have the solutions to the investigative questions of the experiments. They may get those solutions only after conducting the experiments:

I had taught them everything about the ionic compounds and that there are ions and free electrons in metallic compounds and all that. That was not enough. They were still confused about it, so what they measure and what they see is quite different from the pictures that they had in their heads so it's a way of getting rid of the misconceptions allowing them to understand what's really happening so it's very invaluable.

Farai (private school) is aware that after he teaches his learners the theory before conducting the experiments, they may already know the solutions to some of the investigative questions. However, he believes that he can still engage his learners in some forms of inquiry even though the experiments are now for verification and confirmation of theory. He seeks to engage learners in trying to figure out what is not known to them which is the experiment procedure. Farai is of the opinion that one way that he can meaningfully engage his learners in laboratory work under these conditions is to ask them to design experiments to obtain desired and known results. Farai's narrative gave insights on his general approach in the way he facilitates laboratory work for his learners:

They know the result that they are supposed to get, but they have to get it practically. It forces them to do it the right way and they can't cheat because they know what they are supposed to get and they know you know what they are supposed to get. If you realised earlier on I would tell them, 'You have done the experiment you have collected the gas but as long as the gas doesn't produce a positive test then something is wrong and you have to re-do it (Farai).

According to the learners Farai also employs problem-based experiments where at the end of the activities learners are supposed to give solutions to the problem. The learners remembered one that they did in physics on kinetic friction. One learner explained:

We had to put a shoe on a tile. Okay we were given a scenario where a lady had tripped. She was walking and she apparently fell and hurt herself. She sued the supermarket where she was walking saying that they didn't use the correct surface on the tiles. She said they were wet and they didn't put the sign. They said let's test the friction of the shoe on that specific tile to see if it's the shop's fault or it was the shoe so we tested the shoe on different tiles (Thapelo).

It is evident that Farai makes sure he structures the laboratory activities in such a manner that learners are allowed to figure out some things for themselves. Some learners are not happy with such an approach because they believe the teacher should give them clear instructions on how they should conduct the experiments. One learner's narrative is full of displeasure in the way they are made to conduct experiments:

I think I would enjoy it if maybe the teacher helped us out a bit more, if he gave us a bit more guidance I would enjoy it a lot better.

Another learner seems to understand why Farai makes them engage in laboratory work using that approach of leaving them to figure out some things during experiments. She tried to make him see why the teacher facilitates laboratory work in that way:

Can I just say something from his point of view? If you get something wrong when you try for the next time you know you are not supposed to do those things. Like if I tell you what to do now then you are going to cram what you should do and then that's the only perspective that you have but if you guys get it wrong then you know I am not supposed to do this. That's why they don't give us guidance (Grace).

For Farai, just like for other teachers, practical work may mean teacher demonstrations or activities in which the teacher conducts the experiments. He conducts more teacher demonstrations than facilitating activities in which learners are hands-on. He uses these demonstrations in three ways. First, he introduces them to new content. Second, he may use his demonstrations to help him develop the scientific concepts and, last, he may use the demonstrations to verify theory. Farai explained three ways in which he uses laboratory work in the process of teaching and learning:

I normally do it in two ways or basically in three ways. In some cases I use the practical activity as a way of introducing the learners to a concept so that they get to question why did that happen. The other way is to introduce a concept and then conduct an experiment during the progression stage of the lesson or alternatively you hold the lesson and then conduct verification experiments.

Farai's laboratory work practice is also characterised by the incorporation of computer technology. The incorporation of technology assists him in ensuring that learners are able to collect data from an experiment that he might conduct by observing it from a screen. He says for him it is important that the learners may at least be able to collect results that they can analyse and draw conclusions from although they may not be able to be hands-on in the handling of materials and the manipulation of equipment:

If we realise there is not enough apparatus I can just do a demonstration in class and then we use the projectors to collect the information and then they analyse the results but what's important to me is that they have to know how they are collecting the information and then they decide on their own how they analyse and interpret that information that is what is important to me.

4.4.2.2 Other present experiences with IBLW

Jane (former model C school) and Farai (private school) are engaged in developing other teachers on how to facilitate laboratory work for learners. They are actively engaged in providing support to teachers in their school clusters. They sometimes function as facilitators in professional development workshops that are sponsored by non-governmental organisations that support schools by way of donating laboratory materials and providing professional support. Jane and Farai are capable of taking these mentorship roles in the professional development forums. Jane shared some of her experiences:

Just yesterday (a representative from the non-governmental organisation that sponsors the school) phoned me to ask if I can give him some practical activities that I have done at school because he would like to use real life practical work examples. I emailed him the practical activity so that when they do the training with the teachers they don't just do it as theory but as real practical activities that can be done in the classroom.

Jane provides mentorship even outside of the professional development exercises. Other teachers are able to consult with her on how they can conduct certain laboratory activities with their learners. Jane described her other laboratory practice experiences:

I say in our district we work very closely with schools from Soshanguve, inner city schools because we mark together at the end of the year, so yesterday again we had someone coming to our school from another secondary school asking, 'How did you do the practical (activity)?' I will print it or I can email it to him and he can just change it a little bit so that each teacher can support the other one so we are very much in it.

Farai, realising that the workshops that they were facilitating for his school cluster were focusing only on theory and ignoring the practical aspects of science, took the initiative to conduct professional development exercises on laboratory work for teachers. He was not happy to realise that learners may be made to learn science without them engaging in the practical work. For him the teaching and learning of science without engaging in practical work is not proper and tantamount to cheating the system. Farai explained how he works with teachers to give them professional support:

We do professional development here and there but it's not that often. I was the one who used to conduct workshops for teacher development around here. I started doing teacher development workshops in 2009 but mainly it was for theory development and then we proposed that maybe if we can incorporate the practical. That is why we had to champion such move and lately with the current CAPS syllabus, it's emphasizing more on practical work which is a good thing.

Farai's commitment to see teachers teach science in a proper way goes beyond his classroom practice and the professional development exercises. He realised that some teachers may find it challenging to plan some meaningful laboratory work activities for their learners. He had to come up with another way of ensuring that teachers may be able to successfully engage in laboratory practice. Farai is currently involved in a project to produce a workbook of laboratory experiment activities that can be used by both teachers and learners:

Right now I am working on a document. It's a workbook for the CAPS syllabus for experiments. Not all schools can get these apparatus. There are certain schools that are deep down in the rural areas, poor schools to be specific they are not coping so we are trying to improvise and come up with a strategy whereby we design a kit which is a low-cost lab kit but producing the best results by the standards.

Tendai is new in her school. On arriving at her new school she realised that the culture of laboratory work practice was not well established. This did not deter her from doing what she believes to be how science should be taught, that is engaging learners in laboratory work activities. This has resulted in her taking up the role of mentoring her colleagues who might have been finding laboratory activities challenging. Tendai is now engaged in mentoring other teachers in her school on how to facilitate laboratory activities for learners:

For the moment I am the one who is driving the experiments, conducting the drive because after I do it the other kids see it, that is, those who are taught by other teachers. My kids will say our class did this and that and the other teachers will come as you saw in the morning someone was still trying to get assistance on something.

She also said, "I am leading the way for others; because I enjoy experiments I find it necessary that I must do them."

4.4.3 Teacher perceptions and belief systems in the practice of IBLW

This sub-theme captures teachers' perceptions, beliefs, level of commitment and motivational factors in the practice of IBLW. The sub-theme has been organised in the following categories: (i) teacher perceptions on IBLW reflected on teacher practice; (ii) teacher belief systems shaping IBLW practice; (iii) teacher beliefs failing to have an impact on IBLW practice; (iv) teacher commitment to IBLW practice; and (v) teacher motivation in the practice of IBLW.

4.4.3.1 Teacher perceptions on IBLW reflected in teacher practice

Some of the teachers have strong views that are quite significant when it comes to laboratory work.

Jane (former model C school) is able to make some decisions on how she is going to implement some of the subject policies. Even though the CAPS syllabus comes with prescribed experiments that teachers must facilitate for their learners, she is able to realise that some of the experiments are not suitable to be conducted under the conditions prevailing in her laboratory. She even feels confident enough to take up the matter with the responsible people in the Department of Education telling them that she is not going to let her learners conduct those experiments. Jane reveals some of her views on some of the policies in the CAPS syllabus on laboratory work in the following narrative:

One of the practical activities that they wanted us to do and I refused to do that is to determine the boiling point of oil, now boiling oil will start burning. I am not willing to do that with my girls. It is prescribed that we should do it but the equipment we have is just not efficient we do not have the equipment for that. So I have spoken to the National Department of Education and I said you know I must just tell you that I am not going to do the oil. I think it's too dangerous.

Jane's narrative also reflects some unresolved safety issues that come with the prescribed experiments. Some of the prescribed experiments are not conducted if it is perceived that they may be dangerous. She is of the opinion that not enough time has been allocated for laboratory work activities in the subject policies. She feels that if she was allowed more time she would be able to do more with her learners and that her laboratory work practice is compromised because of time limitations. Jane expressed the following views on the subject policy on time allocation,

If I had something to say with national education I would ask them that we have more practical work time so that for every single topic that we do the learners should be doing a practical on their own so that they can discover a bit more not just me talking, telling them these are the facts. I think they would understand things and appreciate things they discover a bit more.

Jimmy (former Coloured school) generally sounded disgruntled by his learners' attitudes and behaviour. He is of the opinion that some of the learners that he teaches are not supposed to be in the physical sciences and maths stream at all. He feels that they are wasting their time because eventually they are going to be changed to other streams. He sees no way in which he can assist these learners when they are still in the physical sciences stream because according to him they are not supposed to be there. Jimmy aired the opinions he has on how learners make subject choices:

I am beginning to believe that, some parents they force their children to do physical sciences while a child is not inclined for that subject. We then at a later stage make them switch to mathematical literacy instead of mathematics and physical sciences but unfortunately one can only do physical sciences and mathematics and not mathematical literacy.

For Tendai (former Indian school) engaging learners in laboratory work means that she should make sure they become independent and are able to function as laboratory practitioners themselves. For her it is not just about consolidating the scientific concepts learnt in class but also about developing skills that have to do with the practice of laboratory work as a discipline. She also perceives her laboratory practice to be having a positive effect on the process of teaching and learning. Laboratory work helps her to keep her learners excited and motivated:

The good things that I'm doing I can say are getting the students to be involved, getting them to know their chemicals and all and see them from their raw state to whatever we are doing, motivating them because like now I think they feel like...some of the learners you saw like those who were vocal and very active they are not the best students, they are not the best, but they are excited, so if I maintain that excitement I know they will learn something.

Tendai seems to be aware of a number of ways to conduct laboratory work. She is able to classify the type of laboratory work activities that she interprets the subject policy as specifying that teachers should facilitate for learners. Tendai on interpreting the CAPS syllabus holds the view that the new curriculum stipulates that they are no longer doing

practical work as investigations but that they should perform them as experiments to confirm theory that has already been taught:

Now we are being told we are no longer doing practical investigations we are doing experiments so they are starting with a theory and then just confirm or see what they have said so maybe the only question is, is that true and then we are just going to say 'Yes it's for real'. The aim is already provided and the theory is given. You are just doing an experiment to confirm. It is no longer an investigation.

Tendai feels that if she could make improvements on the subject policy she would increase time allocation for practical activities in science. She is of the opinion that, if the subject policy is placing a lot of emphasis on practical activities and that teachers should regularly incorporate laboratory work in the process of teaching and learning, then more time should also be allowed to ensure teachers are able to implement the policy successfully. Tendai thinks that time allocated for laboratory activities is not adequate:

On improvement, since we are getting this new curriculum which actually needs us to do a lot of these activities I think there's a need for increased time allocation. Again that is another barrier in the school. I have single lesson of 45 minutes so sometimes to execute a practical work activity and explain in one lesson is not possible so you do the practical today and then explain the next day. There is a gap in the consolidation I feel I could do with slightly more time.

Kabelo (African township school) interprets the CAPS syllabus as stipulating that laboratory work activities should be incorporated in the teaching of science regularly. To him the syllabus requires that experiments be incorporated in every lesson. He realises that the prescribed practical activities are not enough for him and his learners to be able to conduct experiments in every lesson. He says as a teacher he should come up with practical activities that he can facilitate for his learners. Here is how Kabelo expressed how he interprets the CAPS syllabus on what it stipulates about laboratory activities:

With this CAPS they say if you are conducting a lesson make it a point that it is accompanied by a practical investigation or an experiment but they are some experiments which are prescribed. You can do as many experiments as you can but there are those which are prescribed and there are those that are recommended so we just follow the work schedule but you are not limited to perform some of the experiments that you feel that you must do even if they are not there in the work schedule.

Kabelo holds the same views as Tendai that, although the CAPS syllabus requires them to conduct laboratory activities more frequently, considerations were not made to make sure teachers have ample time at their disposal in order to make that subject stipulation a reality. He strongly believes that the time allocation is not adequate:

If ever maybe they can then allocate more than two hours because the maximum that they want is two hours for practical work for the learners to be able to do the write-up so if we can have two hours I know we can do whatever we want to do for the experiments, the write-ups and finishing the experiments.

What comes out of Melusi's narrative about his laboratory work practice is that he considers himself to be well prepared for the kind of work that he does of facilitating laboratory activities in several schools. He feels he got the appropriate preparation for him to be able to successfully execute his duties:

The exposure that I got is reasonable enough for me to be able to execute the work. Now it will depend from individual to individual to say do you need to learn more and thinking out of the box, getting out of the norm, getting more skills but basically the training is enough, it is sufficient.

Betty (private school) considers herself to be sufficiently prepared for her to be able to facilitate practical work in school chemistry. She also feels that some of her colleagues, despite the fact that they may have well recognised qualifications, are not competent enough to easily facilitate chemistry practical work for learners. She thinks they are not very eager to try out chemistry experiments with their learners. Betty may be in a position to show other teachers how to conduct some of the chemistry laboratory activities because she considers them to be easy:

We are very privileged because the material is available its easy but let's put it this way it's difficult I think there is always a hurdle for a teacher to get over to realise that actually I can do a practical activity and it's not easy because they see it as something difficult. I think as well in any school somebody has to show the teachers that it is easy to do practical work. There's always a hurdle of getting over a teacher's hesitancy to do practical work.

Farai (private school) concurs with Tendai and Kabelo on the way they interpret the CAPS syllabus as saying it requires teachers and learners to frequently engage in laboratory work. He thinks that it is a good thing that practical work should be a regular feature in the process of teaching and learning. Farai also feels he is sufficiently prepared for the task of meaningfully engaging learners in laboratory work. He also realises that he needs to be

continually developing himself professionally and keep in line with the current trends in laboratory work practice as well as technological advancements:

The current CAPS syllabus is emphasizing more on practical work which is a good thing. The preparation that I have had is sufficient for my work. I don't think that I necessarily need to go through a course but maybe exposure to many different ways of doing the same experiment so that at least we don't get to be more like blinkered towards one way of doing it. Besides with the developments, technology developments lately you know there are better ways of doing it.

Farai expressed his opinions on how to successfully conduct laboratory activities for learners even when learners display negative attitudes towards laboratory work. He feels that if learners are not taking laboratory work seriously there is something that can be done. He feels that teachers should structure the laboratory work activities in a manner that seriously engages the learners so that at the end of the day they see the importance of practical work in their learning process. Previous discussions have revealed that Farai converts verification experiments to be more beneficial by asking the learners to design experiments that should yield the known result:

Unfortunately when you are at school as a student there is this tendency that you don't like doing practical work at first but if it's done properly they realise its importance. At lower levels you find learners usually think the time to do experiments is more like it is time to have fun in class. The practical work needs to be well structured because once it's done like that they tend to focus and then usually you get appreciation from learners from that type of experience.

4.4.3.2 Teacher belief systems shaping IBLW practice

As teachers are facilitating laboratory work for their learners, they are being driven by a number of deeply rooted beliefs. Eight beliefs were salient from the teachers' narratives. First, there was a belief held by some teachers that laboratory work helps learners to improve and consolidate their understanding of scientific concepts which may not happen if they are just taught science theoretically. Jane (former model C school) also believes she can use laboratory work to prepare her learners for examination type questions:

That's why we chose the five activities because it covers the different aspects of it. And also that it is the type of question that I am anticipating in the exam where they are going to test the theory so if they can do the practical and they have done the theory and they can put it together now you know they will get a better understanding.

Betty (private school) believes that chemistry concepts are too abstract for learners to understand them easily. Therefore she believes laboratory work makes chemistry real for learners:

I think it makes it real to them because chemistry is very abstract and I can't visualise atoms and I think chemistry to young people is like a fog. You can't see it you can't feel it so the more we do practical work so that they can see where people get the information from in order to draw up their theories and to try and explain what is happening the more real it becomes to them I think.

Betty (private school) also shared her observations on how learners were able to dispel some misconceptions through the laboratory activity that she was observed facilitating for learners:

Whereas today's practical is for me to get into their heads the actual theory that ionic compounds only conduct electricity when they dissolve so it's to me practical activities serve different purposes all the time and then we just assess what we think is important with that particular topic that we cover.

Tendai (former Indian school) shared her experiences on how her learners improve their understanding of scientific concepts through laboratory work practice:

They enjoy at least I capture their attention and I keep them coming back for more. With practical work I just told myself discovery is the best way of learning so they are able to understand more I think from the practical activities. I also gained experience but I also think that I had a solid base because of the type of curriculum we did.

Kabelo (African township school) believes that practical work assists learners in understanding and remembering scientific concepts:

Using experiments to teach chemistry for me is worthwhile because if these learners like we were doing this experiment on Boyle's Law whereby we were investigating the relationship between volumes and pressure it is worth-while for them because when they are doing that they will remember it for the rest of their lives. It's unlike when you are just memorising the Boyle's Law but if you are hands on you would say after 10 years I did this experiment and I know how it is done.

Melusi (African rural school) believes that incorporating laboratory work in the process of teaching and learning enhances learners' understanding of concepts:

The organisation wants to enhance the understanding of physics and chemistry through experiments, so what we will be doing is like I am not substituting a teacher. Teachers cover the theory and then we sort of reinforce or enhance that

understanding by way of introducing experiments because you know learners have got different learning styles. Some relate their learning to practical skills some they easily relate to the theory.

Second, some of the teachers believe that as they engage learners in laboratory work they are preparing them for tertiary education when they take up science-based courses:

Quite a few of our girls will go to University especially the girls in the science class. Quite a few of them will go into engineering and things like that so we have to do practical activities and develop that skill for them (Jane, former model C).

Melusi shares the same belief with Jane of realising that some of the learners they are currently teaching will enrol in science-based courses at university and may need to continue practising laboratory work:

At the same time we are helping the country to cover the skills shortage in science; engineering and technology related professionals because from this physical sciences now at least they can be able to enrol in tertiary institutions.

Third, another belief was that by engaging learners in laboratory work activities they are preparing them for everyday life activities in the home and outside of their homes. Through laboratory activities teachers try to show learners instances in which they can use knowledge of scientific concepts to make the right decisions in life situations. Jane likes to explore how scientific concepts can be applied in the kitchen when cooking and cleaning utensils:

For me the most important part is to get the kids to understand that science has a place in society that what we do every day is because of some scientific knowledge that we have. If we cook a meal in our school, cooking is a good example just because it's girls. If we have to clean something like a kettle when it is clogged, we then ask them how you clean it. I try to encourage them to understand that this is the relevance of the subject.

Kabelo believes that after experiencing laboratory work in which scientific concepts are made manifest the learners should be able to apply the same scientific knowledge to everyday life activities. He tries to show the relevance of science to learners in real life through laboratory activities:

Even if we apply it to our daily lives when you are driving a motor car and you go to the garage to pump your tyre you will know how to use the gauge and you will know that it is dangerous if you over inflate the tyre so they can apply

that in our daily life situations, and it is going to help them to remember whatever they have done.

Fourth, practical work played a motivational role. By engaging learners in laboratory work they were also kindling the learners' interest towards laboratory work itself and science. They saw it as way of keeping the learners motivated as they are learning physical sciences. Tendai is one of the teachers who observed how learners are motivated to learn science through laboratory work activities:

Now at school let me say I am doing more because I discovered that when I do more practical activities the kids get more interested.

Fifth, Tendai believed that one way of preparing another generation of laboratory practitioners is through meaningfully engaging in laboratory work with learners. Tendai believes she herself received a strong foundation in laboratory work as a learner and when she was in tertiary education. She believes that is the reason why she can successfully facilitate laboratory work for her learners, unlike other teachers in her school who come to her for guidance. Tendai also believes that by engaging her learners in laboratory work she is grooming another generation of laboratory work practitioners which has a solid foundation in knowledge and skills. In the following narrative Tendai aired most of her beliefs on what she can achieve through laboratory work:

I think when they do the practical activities especially themselves they become more interested in learning the theory because they are applying what they have seen to the theory. They can confirm the theory that we are doing. I see continued value in practical work especially with these grade 10s that I have groomed, they are itching, and they don't even want me to demonstrate for them they want to handle things themselves so I feel I am even preparing them even for University.

Sixth, another belief expressed was that as they are facilitating laboratory work for learners they are also developing professionally. They see themselves learning together with their learners because sometimes they get a chance to conduct experiments that they have never conducted before. Tendai (former Indian school) realises that she is now conducting more and trying out new laboratory activities as teacher to add to her school and tertiary experiences that she considers to have been meaningful. This makes the teachers look forward to the experiences that they go through each time they engage in laboratory work with their learners. Jimmy (former Coloured school) is one of the teachers who believe that

he should also learn something from these experiences. Jimmy himself did not experience meaningful laboratory work both in school and in tertiary education; therefore, his experiences in class have been the main source of what he knows about laboratory work:

The support may not be enough but I don't expect her to do everything she only guides us and from there I take it a step further. That is how I will grow. I cannot expect the facilitator to help me in everything. I can't always say 'Madam I can't do this practical activity come and help me'. That way I won't grow.

Seventh, it was also expressed that laboratory work is part of teaching and learning of science as a methodology as well as content and that learning science without engaging in laboratory work is not complete. This notion came out in Tendai's and Farai's narratives. As alluded to earlier in the discussion, Tendai believes in grooming the next generations of laboratory work practitioners. This can only be achieved if laboratory work is treated as content as well and not just as a vehicle to achieve learner understanding of scientific concepts only. Farai (private school) feels very strongly about the issue that science is a two faced subject which consists of theory and practical work. To him both the theory and practical work have equal importance to the extent that learners cannot be made to learn the theory only while neglecting the practical aspects of science. Farai strongly believes that the teaching and learning of science without the incorporation of laboratory work is improper and unethical. He believes that, even if learners can pass their matric examinations without having gone through laboratory work experiences, they would have poorly developed scientific knowledge and skills:

If practical work is done often usually you get good results but if you are just doing it erratically or as per requirements of the syllabus then it's unfortunate. You don't really get good results. You may get good results but deep down in you, you know that it's not really a good thing that you have because the students don't have that proper understanding because they just have the theory but the practical is lacking.

Finally, a belief was aired that it is the teachers' duty and responsibility to make sure that learners go through meaningful laboratory experiences. Betty (private school) believes that laboratory work must not be treated as an afterthought but should be carefully incorporated into the process of teaching and learning through careful planning. Farai (private school) believes that the meaningful engagement of learners in laboratory work can only be achieved through purposeful planning and proper structuring of the activities by the

teacher. He realises that experiments are mostly for theory verification because scientific concepts are taught to learners before they can conduct the experiments. Farai, then, is of the opinion that teachers should demonstrate creativity and innovation by way of structuring the laboratory activities in a way that meaningfully engages learners in inquiry:

With regard to the use of experiments, if you structure your practical activities properly and the moment learners realise that this is to be done and it has to be done the right way and probably you are just verifying a theory or something that has been done already then it helps because you put them in a situation where they know the result that they are supposed to get but they have to get it practically.

4.4.3.3 Teacher beliefs that fail to have an impact on IBLW practice

There are four teacher beliefs salient from the teacher narratives which fail to have an impact on laboratory work practice. These are beliefs that teachers hold on how to effectively practice laboratory work but they fail to incorporate these beliefs as they facilitate laboratory work for learners. Teachers may find themselves doing things that are not in line with what they believe in because they fail to overcome certain challenges that stand in their way. The beliefs that fail to make an impact on laboratory work practice are not common to all teachers. Some teachers are able to find ways of overcoming certain challenges that stand as hindrances to their laboratory work practice while other teachers fail to find ways of overcoming the challenges. The first belief that teachers expressed is that they know that for laboratory work to be meaningful and effective it should be conducted frequently.

Jane (former model C school) believes learners should engage in laboratory work regularly and learn science concepts through inquiry but she acknowledges that this is not what she manages to achieve with her learners. For her lack of time stands in the way of letting her learners to be exposed more to laboratory work:

I think the confidence, the fact that they don't make contact with the chemicals and the equipment often that is a problem and time because we have to push them to finish in a double period. Some could discover other things but we say no just do what we have to and finish in time. Everything is just about time, time and time.

Kabelo (African township school) believes that learners should be allowed enough time in the laboratory in order for them to engage meaningfully in inquiry activities although it is not always possible for him and his learners to have sufficient laboratory time:

You know that experiments are not like teaching. The learners must assemble this and that. They must do trial and error and time is running out. By the time the period is over which means that time is not sufficient for us to do all the experiments to such an extent that we are not able to do some of the experiments and so we just do them theoretically because of time.

Farai (private school) is of the opinion that he should have at least three laboratory activities with his learners but he is not able to meet that standard because of inhibiting circumstances in the school,

The frequency with which we do experiments is not good enough because under normal circumstances there wouldn't be any harm if we have three experiments in a week not necessarily writing a full report but getting information, getting results, analysing those results rather than just teaching it theoretically but then that comes again against certain setbacks of the timetabling.

It is important to note at this point that although Betty (private school) and Tendai (former Indian school) also feel that time is a constraint for them to practice laboratory work effectively, they manage to engage their learners in practical work every week. This is in contrast to the rest of the teachers who may be able to engage the learners in practical work once to three times a term.

The second belief that is not reflected in teachers' laboratory practice is reflected in Tendai's (former Indian school) narrative. Tendai believes that learners should be allowed to record what they observe during experiments and write their own experiment reports with limited guidance from her. However, because she does not want the process to take longer than scheduled, she finds herself rushing the learners by giving them extra guidance. As observed during the laboratory activity that she facilitated for her learners, Tendai provided extra guidance through questioning techniques that she applied with her learners so that they could provide information under the headings she put on the chalkboard:

I am not really satisfied because sometimes I am forced to rush them because they are relaxed. I had to conclude the section and it's a Friday and they were a bit relaxed so some of the write-up that I was doing on the board was too

guided I could have put sentences or questions and they complete them but I have done that for other sections so now I just wanted to wrap it up and I was time constrained.

The third belief that may not be reflected in teachers' laboratory practice emerged from Tendai's narrative. Tendai's belief that learners should discover scientific concepts through laboratory work activities is in conflict with her interpretation of the subject policy which she understands as stipulating that laboratory activities are now about verifying theory. She realises on the one hand that as a teacher one of her duties is to implement the policy. On the other hand she has long standing beliefs on how to engage learners meaningfully in inquiry during practical work. For her learners should discover scientific concepts as they conduct experiments and not know the concepts beforehand:

The aim is already provided and the theory given then you just doing an experiment to confirm. It is no longer an investigation. Actually at the beginning I let them discover but now today unfortunately you found us towards the end. We did discover precipitates and what have you. Now we were summarising everything in a table, we were just confirming, we were at the confirmation stages because we had already done the preliminary experiments to discover aspects.

The fourth belief that may not be reflected in teachers' laboratory practice is that learners should be allowed to pose investigative questions for experiments that they conduct. This comes from Betty's narrative. Although Betty believes that learners should be given a chance to pose investigative questions, she gives them to the learners because she cites time constraints:

I think pupils must be able to pose the question to say this is the question I want to ask but I think also may be time is limited. We often give them the question because to let them go and pose a question it takes too long and again different practical activities serve different purposes. Today I gave them the question and they were predicting and looking at the results.

4.4.3.4 Teacher commitment

This section focuses on what teachers do to overcome challenges in the school settings that might inhibit the successful practice of laboratory work. There is one common challenge that emerged from the teachers' narratives that stands in the way of effective laboratory work practice that teachers make efforts to overcome. The challenge is on how time constraints inhibit effective laboratory work practice. Teachers use the means at their

disposal to create more time for meaningful laboratory work. From the teachers' narratives it seems there are four things that teachers do to make sure they have significant time to conduct practical work with their learners. First, teachers arrange to stay behind with their learners after school so that they may conduct the laboratory work activities. Not all teachers are able to do this because conditions in the school may not permit this or because they opt to use other methods. The option of using the afternoons is not easy because of two reasons that came out of the narratives. Learners are generally tired during that time and also they may have to find alternative transport to go home after missing their buses. For instance, although Tendai (former Indian school) is prepared to remain with the learners after school, this is not possible because learners use organised modes of transport to ferry them to their homes.

Farai (private school), however, has been able to solicit the learners, parents and guardians' support so that they come to pick up their children on the days that he asks them to remain behind. Farai explained how he makes use of afternoons to make sure he engages learners in meaningful laboratory activities:

The curriculum is so wide you can hardly have time to really do it as you would wish to. That is a problem and I do know what we can do about it because everyone wants a piece of the learners' time and given the time that they have, it's hectic and really challenging. That is why we end up utilising the afternoons of which it is unfair. It just has to come from you to say I'm getting out of my way to do this but you find that you are also putting the learners under pressure as well.

Although Jimmy does not mention it, his learners revealed how he is prepared to go an extra mile by sacrificing his afternoons in order to conduct laboratory work with them. The learners said, "He just says today we are going to do an experiment and we must do it now or after school."

Second, the other measure that teachers can take so that learners are able to have enough time to finish their experiments each time they conduct them is described in Jane's narrative. She said that she makes sure the laboratory activity task has clear instructions that are easy for learners to follow so that they won't waste time trying to figure out what they should do. Jane explained what she does as preparation so that learners are able to at least manage to collect the necessary data for analysis during experiments:

We try to give the girls the instructions to be very clear and precise so that they don't have to spend half an hour trying to figure out what they should do. We try to also give them very specific indications. We also give the indications to them a week before so that they can read it in advance and prepare for it. If we work with chemicals like we do now they must read a little bit about each of them, what is the safety precaution for each of them.

Third, another measure that teachers may employ to make sure they are able to meaningfully facilitate laboratory work practice in limited time arose from Betty's (private) school. Betty uses careful planning at the beginning of each year whereby a year book of experiments that should be conducted in each grade is developed. By developing this schedule of laboratory work activities she is purposefully integrating practical work in the teaching and learning of science. Betty is of the opinion that time should not be an excuse for teachers to fail to engage their learners in laboratory activities. Betty described how she uses purposeful planning to minimise challenges caused by time constraints:

The time issue it really is a challenge but when we plan our year we plan in such a way that you can fit in the most number of practical activities. If you plan I don't know if we plan well we can get enough practical activities in. If you do your teaching and then you just do practical work as something extra there won't be time. You need to plan from the beginning that it's part of the whole learning experience then there is time you know there really is.

Fourth, another measure that is taken by teachers to make sure learners are able to complete the tasks of the experiments they conduct in the scheduled time is by making use of careful preparation before the learners are made to conduct the experiments. Most schools do not have laboratory assistants who are responsible for any preparations that have to be made. Out of the seven schools used in this study only Betty's school has laboratory assistants. They have two of them in the school. Tendai, on realising that the laboratory does not have an assistant to help in preparing for laboratory activities, makes use of her learners to help in the preparations. She involves them to assist in the setting up of equipment and preparation of other materials prior to the day they intend to conduct the experiments:

And we also don't have a lab assistant to prepare the equipment and chemicals in advance for us so a lot of time is spent on preparation but I am also now in some instances involving them in preparing some of the reagents so that they get used to the names and looking for the names and handling the equipment.

Tendai also explains how else she uses preparation as a way to overcome the time constraints challenge. Learners are put in groups prior to the day they are supposed to conduct laboratory activities and asked to use their textbooks to assist them in designing the procedure of the experiments so that when they come they already know what to do and what materials to assemble. The learners also come to the laboratory having written up part of the experiment report to the part of ‘procedure’, except for the results which they will get during the activity:

I could do with slightly more time. Under normal circumstances I tell them maybe because the textbooks that they are using they are curriculum orientated so I tell them that we are going to be doing this. Normally I should prepare the chemicals in advance and then put them in the groups and sometimes demonstrate, but now with some of the sections I was involving them in the preparation of the solutions.

Farai (private school), Betty (private school) and Jane (former model C school) also use preparation by way of making learners read about the activities before they come to conduct them.

4.4.3.5 Teacher motivation

This part captures teachers’ narratives on their sources of motivation as well as demotivation as they endeavour to facilitate laboratory work for learners. There are a number of motivational factors that drive teachers when they are engaging learners in laboratory work activities. It is also important to note that teachers experience motivation to practice laboratory work with their learners in unique ways because the motivational factors seem to stem from their own previous and present personal experiences of laboratory work. Some teachers like Jane (former model C school), Kabelo (African township school), Tendai (former Indian school) and Farai (private school) as they narrated their stories animatedly painted pictures of how they have come to love laboratory work and develop a keen interest in it although it is for different reasons. As they engage their learners in laboratory work they hope for their learners to develop the same kind of love and interest for the practice.

Jane showed a lot of enthusiasm when she talked about how she practices laboratory work. She hopes that learners realise that laboratory work demonstrates how science can be used to solve real life problems:

I really enjoy doing practical work. For me every time I have done a practical activity it kind of gives me that extra spark to say you know what, they understand, that there is a need for the subject and this subject can broaden horizons which is what my whole aim is, for them to discover the subject as I experience it. I love it and I am hoping for them to love it too. So every time we do a practical activity it really is a motivational factor for them. I enjoy that.

Farai has a long standing and firm interest in laboratory work. He developed an interest and inclination towards laboratory work that can be traced back to the time he was in school:

When I was a learner, the reason why I did science is because I just wanted to be in the lab. I wanted to be with the apparatus. I wanted to have my hands on anything that is inside there, so already I was somebody who had decided that whatever it takes I had to do it.

One of the things that Jane considers to be important and wishes to achieve with her laboratory work practice is for learners to observe phenomena in the laboratory so that they can also be enthused by science like her by seeing how science can be applied in real life situations. She gave an example of some of the activities that they do in the laboratory:

For me the most important part is to get the kids to understand that science has a place in society that what we do every day is because of some scientific knowledge that we have. If we have to a clogged kettle we ask them, ‘how do you clean it?’ All of that science is in our homes, in our world and to me doing certain practical activities and we do a lot with food a lot with kettles and things like that. I try to encourage them to understand that this is the relevance of the subject.

Jane finds it easier to find real life applications of chemistry concepts than when it comes to physics concepts. Her motivation lies in demonstrating to learners how science is useful and makes life easier. She further elaborated on how she shows her learners how science can be applied in real life:

In my class different from other classes I love cooking and I like science. So for me the one thing that I would not stop is that I try once a month or twice a month to bring some food aspect into my class because most of the girls, someday must prepare meals for their families so I’d like to bring things like GI. For example if you bake a cake if you put a lot of sugar in it it’s a little bit like home economics.

Jane also wishes she could always be able to conduct experiments with her learners in which they are able to see new things and observe the wonders of scientific phenomena. She enjoys it when her learners show excitement each time they experience the

manifestation of scientific phenomena in the form of chemical and physical processes first hand. Jane further emphasised her intentions to make sure she impresses her learners through laboratory work activities,

I think if I could have had better knowledge of different processes we could have done things that could have been even more impressive. That could be beneficial to the subject. Now at this stage I now have to do everything and I am quite happy I think I am at par, but I must say every now and then I do have a wish that I could have more experience that I could do something different and encourage the kids more.

Jimmy's narrative reflected how he is struggling to work with learners who are rowdy, playful and chaotic. He showed signs of demotivation because there seems to be nothing that he can do about the learners' behaviour but to continue trying to teach them physical sciences and facilitate laboratory work under those conditions. Jimmy is demotivated by the learner's disruptive behaviour, negative attitudes and disciplinary issues:

For me, for them to get that culture of learning, to create that culture of learning I battle really with these learners so that they can get that culture of learning so much that we have educators that are quite despondent here, those who are hardworking especially those who are dedicated. When they come to school they expect learners to be focused in class and stop playing with cell phones and stuff like that.

Jimmy's frustrations with the learners also serve as a motivation for him to continue working with them until their performance improves. He realises that, despite the learners' attitudes and behaviour that act as inhibiting factors towards meaningful teaching and learning, he must not give up but try to think of ways of improving the situation. He also realises that he should reach a stage with his learners where they are able to benefit significantly from laboratory work activities:

I wish I could do more but then if somehow the children can be made aware that what I'm doing there in front during a demonstration is linked to what is written in the textbook but now I really don't know I fail to make them understand that there is a link between what I'm doing and what they see in the textbook and also for them to take down notes, observations and so on. Maybe it's a learning process. It affects me sometimes.

Tendai is motivated by seeing changes in her learners as they go through laboratory work experiences as well as seeing all her learners getting actively engaged in the activities. As alluded to earlier on in the discussion, Tendai hopes to groom her learners into another

generation of effective laboratory work practitioners. Therefore, when she observes her learners being transformed and gaining experience as they learn how to practice laboratory work, she gets excited:

Some of the learners you saw like those who were vocal and very active they are not the best students, they are not the best, but they are excited, so if I maintain that excitement I know they will learn something. They are my weakest so my practical activities have enabled me to involve my weakest learners and for them to love science instead of shying away because at that point I have placed them forward and they are the ones conducting so they are enjoying.

Tendai summarised what drives her as she practices laboratory work in the following way:

They enjoy, at least I capture their attention and I keep them coming back for more. With practical activities I just told myself discovery is the best way of them learning so they are able to understand more I think from the practical work.

Kabelo derives his motivation from trying to make sure his learners do not go through what he experienced as a learner. He was never engaged in laboratory work activities as a learner. He realises that his learners will be disadvantaged if they learn science without engaging in practical work. He also hopes that his learners will appreciate the role of laboratory work in learning and enjoy the practical activities as much as he did when they were first introduced to him:

I was enjoying each and every time when we're in the laboratory all the apparatus were there everything was there. It was hands-on every time. I've never come across a lesson where they would say there are no apparatus each and every time the apparatus will be there. That is why I say now when I come to school that let me do the same thing that I was doing at tertiary, because during my school years in my high school I never had experiments.

Kabelo also gets his motivation from the belief that learners will remember scientific concepts that they learn through laboratory work activities for much longer than when the concepts are taught to them theoretically. He also thinks laboratory work helps learners in applying scientific concepts in real life:

Using experiments to teach chemistry for me is worthwhile for them because when they are doing that they will remember it for the rest of their lives. It's unlike when you are just memorising the Boyle's Law but if you are hands on you would say after 10 years even I did this experiment and I know how it is done and can apply it to our daily lives.

Melusi's work is basically to reach out to disadvantaged schools where there is little or no laboratory work. With his work he aims to expose the learners from those schools to laboratory work activities. He hopes that his intervention will contribute to the attainment of better results in physical sciences because he believes learners will improve their understanding of science through the experiences that he makes them to go through. Melusi feels that laboratory activities should be conducted to consolidate learners' understanding of scientific concepts. If he realises that he is about to conduct experiments on topics that the learners have not covered, he does not proceed but redirects the focus of the lesson to teaching so that next time he comes around he will be able to conduct the experiments with the learners. Therefore, he is driven by the need to consolidate learners' understanding:

At times you have setup all the equipment you are going through the experiment starting from section A of the theory and then you discover that even if they say that these learners have done the theory in class but it's not what they have and then ultimately there is no reason why one should rush through the practical activity before they know the basic concepts.

Like Melusi, Betty (private school) conducts experiments with learners in order to consolidate learners' understanding of the scientific concepts that she teaches them. She feels that theoretical explanations of scientific phenomena are not sufficient to make learners understand everything. Betty's motivation also stems from the belief that laboratory activities improve learners' understanding of scientific concepts. Betty uses the laboratory activity that she was observed facilitating for learners to share her experiences on how practical work assists learners to improve their understanding:

I think it makes it real to them because chemistry is very abstract and I can't visualise atoms and I think it's like chemistry to young people is like a fog. You can't see it. So what they measure and what they see is quite different from the pictures that they had in their heads so it's a way of getting rid of any misconceptions allowing them to understand what's really happening so it's very invaluable.

Betty's laboratory practice might be influenced by that learners sit for both practical and theoretical examinations. It is important to note that since learners are going to sit practical examinations Betty makes sure she uses her laboratory work practice to prepare them. The practical examinations may act as a driving force in the manner in which laboratory work is practiced. She said:

They do their practical exam. The Form 3s do it twice a year, the Form 4s and 5s do it three times a year.

Farai's motivation stems from his belief that science is both a practical and theoretical subject. He places equal importance on the two components. He feels that teachers should work to achieve learner understanding of scientific concepts as well as develop learners' knowledge and skills in laboratory work practice. This is evidenced by the approach he takes to allow learners time to design experiments before they conduct them after he presents a problem to them while he provides minimal guidance. He also puts measures in place to make sure he is able to check whether the learners did the task properly by, for example, testing gases that they collect in chemical reactions that are part of the experiments,

The moment you do it in a practical way there has to be more understanding but unfortunately there is this issue whereby at times somebody will just do it as way of demonstrating to the learners but it doesn't really get to the learners as they go on fine they will understand the theory but for them to have that hands on experience which we prefer, for them to have it, they don't really get it.

Six teachers' motivational factors towards laboratory work practice have been identified: first is the need to improve and consolidate learners' understanding of scientific concepts; second is the hope to motivate and kindle the learners' interest towards laboratory work practice; third are efforts by teachers to show learners the relevance of science in everyday life activities; fourth is the need to prepare learners for practical examinations; fifth are hopes by some teachers to groom and prepare a generation of laboratory work practitioners who are going to pursue related studies for their tertiary education; and last is the urge to put into practice the notion that science is both a practical and theoretical subject; therefore, the teaching and learning of science is compromised if it lacks the practical component.

4.5 Contextual settings and learner populations interface with teacher IBLW practice

This theme captures issues in the contextual settings of the schools as well as the nature of the learner populations that interface with IBLW teacher professional identity. The theme

is organised into the following subthemes: (i) contextual settings and (ii) learner populations.

Figure 4.3: The influence of contextual settings and learner populations on IBLW practice

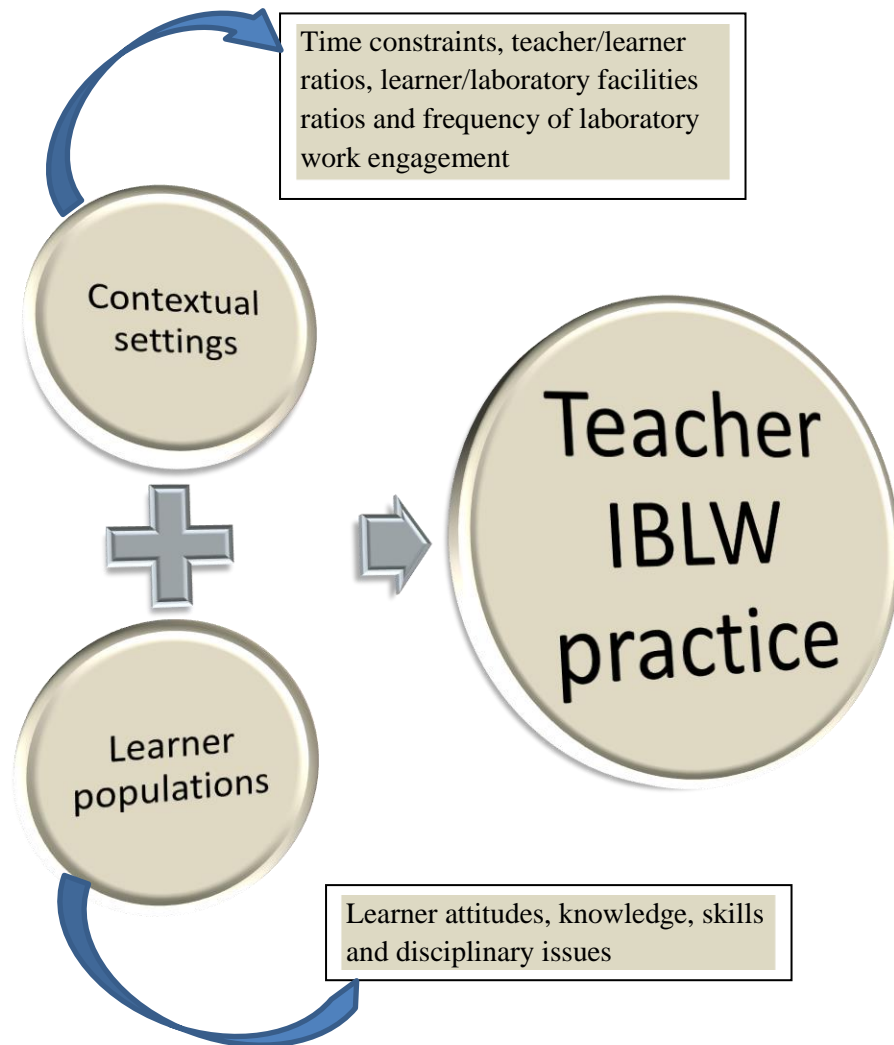


Table 4.3 Inclusion and exclusion data indicators for Theme 2

Theme 2: How contextual settings and learner populations shape teacher professional identity

I am very strict about my learning area which is physical sciences. I tell the children if you are doing physical sciences you need to be focused all the time. You need to be busy all the time. They sometimes ask me ‘Sir, can’t we make jokes?’ I say we can make jokes but we should limit. (Jimmy, former Coloured school)

Subtheme 2.1: Contextual settings

This subtheme focuses on the interface of school contextual settings and the practice of IBLW

Subthemes and categories	Inclusion indicators	Exclusion indicators
<p>Category 1: Time constraints</p>	<p>This category includes data on discussions that teachers make on how time constraints stand in the way of effective practice of IBLW</p> <p>This data includes what teachers do to create time for IBLW practice outside of the normal allocated time</p>	<p>This category excludes data on discussions made on other constraints that stand in the way of effective practice of IBLW</p>
<p>Category 2: Learner/teacher ratios</p>	<p>This category includes data on the discussions made by teachers and learners on how learner/teacher ratios get in the way of IBLW practice</p> <p>This data also includes how learner/teacher ratios work in favour of IBLW practice</p>	<p>This category excludes data on discussions on how other school settings get in the way or promote IBLW practice</p>
<p>Category 3: Learner/laboratory facilities ratios</p>	<p>This category includes data related to how learner/laboratory ratios get in the way of effective practice of IBLW</p> <p>This also includes data related to how learner/laboratory ratios promote effective practice of IBLW practice</p>	<p>This category excludes data on how other contextual settings get in the way or promote IBLW practice</p>

Category 4: Frequency of laboratory work engagement	<p>This category includes data on how the frequency of laboratory work engagement gets in the way of effective IBLW practice</p> <p>This includes data on how the frequency of laboratory work engagement promotes effective IBLW practice</p>	This category excludes data on how other contextual settings get in the way or promote IBLW practice
Category 5: Other contextual setting issues	<p>This category includes other contextual setting issues that directly interface with teacher professional identity.</p> <p>The issues may be promoting or inhibiting the practice of IBLW</p>	The data excludes contextual setting issues that do not fall into the 'other' category
Subtheme 2.2 : Learner populations		This subtheme focuses on how learner populations' attitude and behaviour interface with IBLW teacher identity positions
Category 1: Learner attitude towards IBLW	<p>This category includes data on the discussions made by teachers and learners on how learners attitudes get in the way of effective practice of IBLW</p> <p>This data also includes instances where learner attitude promote effective IBLW practice</p>	This category excludes data on how other contextual settings get in the way or promote IBLW practice
Category 2: Learner knowledge and skills in IBLW	This category includes data on discussions made by teachers and learners on how learner knowledge and skills get in the way of effective IBLW practice	This category excludes data on how other contextual settings get in the way or promote IBLW practice
Category 3: Learner disciplinary issues	This category includes data on discussions made by teachers and learners on how learners' disciplinary issues get in the way of effective IBLW practice	This category excludes data on how other contextual settings get in the way or promote IBLW practice

4.5.1 Contextual settings

This sub-theme captures issues of (i) time constraints; (ii) learner/teacher ratios; (iii) laboratory/laboratory facilities ratios; (iv) frequency of laboratory work engagement and (v) other contextual setting issues.

4.5.1.1 Time constraints

For Jane in the former model C School, the school timetable for lesson delivery lasts from 07:00 hours to 14:00 hours. Any teaching and learning activities should be done within that time period. If the timetable is offset by other unforeseen circumstances like a prolonged morning school assembly then the time for lessons thereafter is reduced accordingly. Jane explained how time constraints get in the way of meaningful laboratory work practice:

Sometimes if assembly runs over the periods are shortened by 5 to 10 minutes which means the classes that come they won't finish. Throughout the day, there are also some interruptions that can happen so that puts a lot of pressure on the practical because some of the activities once you do the theory you must do the practical before you can move to the next sections so that is how the running of the school can influence it.

Jimmy in a former Coloured school does not mention anything about time being a constraint but there is evidence that time constraints also stand in the way of effective laboratory practice. In the laboratory activity in which Jimmy was observed facilitating for his learners, learners were not able to repeat the experiment as specified by the task. Time had run out. The experiment report was also to be written as homework since there was no time for learners to be able to analyse and interpret results during the laboratory session. However, Jimmy did not mention time constraints to be one of the challenges that he faces. This might be because, as revealed by learners, he is prepared to sacrifice some of his time after school to facilitate laboratory activities for his learners; therefore, he does not see time constraints as a challenge anymore. Although Jimmy does not say anything about time being a constraint for him, it was, however, reflected in the following conversation between Jimmy's learners and me,

Researcher: Sometimes you do? That's what I am asking to say how often.
How often do you do it yourselves?

Learner 1: When we have a lot of time, when we are not behind.

Learner 2: In a double period

Tendai also finds herself struggling to conduct all the laboratory activities in the scheduled time. She is even not able to have afternoon lessons with the learners. The learners are immediately ferried home by an organised transport. Therefore she cannot explore the option of utilising the afternoons because learners leave immediately after school:

Given the context of the school I think I could do more if I had more time. The constraint is the time because to do more you'll have to do them in the afternoons but the problem in the school is that most learners are commuting using organised transport so home time is home time for them. It is difficult to have them after hours, and we also don't have a lab assistant to prepare the equipment and chemicals in advance. For us so a lot of time is spent on preparation.

Tendai shared her experiences on how time constraints act as a hindrance to effective laboratory work practice. Most of the teachers participating in this study would prefer to facilitate a practical activity that they can complete in one lesson. However this is not always the case. Some activities of the laboratory activity have to be done as homework or spill over into the following lessons. This puts a strain on teachers' efforts to keep up with the work schedule,

I think there's a need for increased time allocation again that is another barrier in the school to say I have single lesson of 45 minutes so sometimes to execute a practical and explain in one lesson it's not possible so you do the practical today and then explain the next day. There is a gap in the consolidation I feel I could do with slightly more time (Tendai).

Betty from a private school also reflects on how they never manage to complete all the activities in a laboratory session although they frequently engage in laboratory work,

With the conclusion that is an important part because a teacher has to at the end sum it up like today and we never finish a practical work very seldom do we finish a practical activity in a lesson.

Kabelo from an African township school also feels the strain as he tries to engage in laboratory work during science periods as determined by the school time table. He finds the time scheduled for lessons not sufficient to meaningfully facilitate laboratory work for his learners. He says;

If it is 40 or 30 minutes of what you have as a lesson you must teach and at the same time do experiments and you know that experiments are not like teaching the learners must assemble this and that. They must do trial and error and time is running out. By that time the period is over which means that time is not sufficient for you to do all the experiments to such an extent that we are not

able to do some of the experiments and so you just do them theoretically because of time.

Farai in a private school also finds time scheduled for science lessons to be insufficient for him to be able to engage learners in a laboratory work session and finish conducting all the activities in the same way it is being experienced by other teachers in this study,

If you have a single period that's thirty five minutes you can't really do much in it. If you have double period fine that's about seventy minutes but how many do you have per week like in this case I only have one double period per week and at times it misses out like in this case this Friday is a holiday it falls away so it becomes a bit complicated, but well we try here and there to utilise the afternoons but you know you'll be putting these learners under a lot of pressure.

Melusi from an African rural school described how in his unique job of moving around schools and facilitating laboratory work for learners time constraints hamper the progress of his work. His situation, unlike that of other teachers, is compounded by the fact that he is a visiting teacher and that he has to book the visits. If he fails to complete a laboratory activity with the learners, he won't have an opportunity to follow it up in the next lesson. It makes his situation more inhibitive. He shares his experiences on how he is affected by time constraints in the following way,

You find in schools things like time. Time is one of the challenges. These experiments truly speaking they are long and detailed. We prefer doing the theory and everything in section B and C of the experiments but in most cases at times you may not be able to do everything because you find that maybe they've got two periods. Usually I look at the timetables of the schools and target the days when the science classes have got more double periods.

4.5.1.2 Learner/teacher ratios

In this study most of the classes for physical sciences were observed to be not very large classes. The number of learners in a class was less than 20 in most cases. Kabelo (African township school) and Farai (private school) are the only teachers in the study who had to deal with large classes when they are facilitating laboratory work activities for learners. Kabelo is the only one who complains about large classes. For him the large classes are another inhibitive circumstance in the contextual setting of his school. Kabelo struggles to effectively supervise learners as he attempts to provide them with direct individual attention because the learners have to form very large groups:

The numbers are too high. The learners are more than 35 or more in a class. They are too many for you to be able to check what they are doing.

For Farai the classes are normally not large because there are 18 learners in each of his two classes. However, when the laboratory activities have to be conducted in the afternoons, he combines the two classes. Farai supervised a class of 36 learners during the laboratory activity that he was observed facilitating for learners because it was conducted after school. Some of the groups had to wait for their turn to use the space and materials in the laboratory.

4.5.1.3 Learner/laboratory facilities ratios

Jane's school formerly fell under the model C categorisation and is over 110 years old. This is coupled with the history of its background that it was formerly a school for Whites only during the apartheid era and it enjoyed privileges in terms of infrastructure availability and development (Selod & Zenou, 2003). For example, the school has four science laboratories which are well equipped. The laboratories do not have assistants to man them now and all the preparations for laboratory activities and general care of the laboratories rests on the shoulders of the teachers and learners. Presently the school also receives external support in the form of laboratory materials and professional development for teachers through workshops. Jane confirmed that the school has sufficient materials and equipment to engage learners in laboratory activities in a meaningful way:

That black box that we've got there with all the chemicals is part of the Dinaledi support they have given us. The projector that's on my wall that we use for teaching is also from Dinaledi. We receive a lot of support from national and from our district office. On this Saturday again they have teacher training for the boxes to make sure you know how to use them because some people are very scared. We do have a lot of support.

Jimmy's school was formerly reserved for Coloured learners only. Historically the school was under privileged in terms of resource allocation and support under the racist and segregating laws of the apartheid regime (Selod & Zenou, 2003). Presently the learner population is from multi-cultural backgrounds although Coloured learners constitute the majority. There are two science laboratories in the school which may also be used as classrooms. Jimmy believes they have enough materials in the school for them to be able to conduct laboratory activities with learners:

In the school where I am right now we are average stocked in as far as the equipment is concerned. Some of the equipment is not being used but we are also short of the other equipment. We will place an order very soon I think also to accommodate for the grade 12 CAPS Which we should be in implementing

next year we don't have a major crisis here what we have in sufficient for the time being but we can do with a little bit more.

He correctly points out that they are short of some equipment. This was evident during the laboratory activity that he was observed facilitating for the learners. Each group of learners had to wait for its turn to use the one apparatus that was mounted by the teacher for them to be able to conduct the experiment. However, what they have is sufficient for laboratory work activities to take place.

Tendai's school was formerly reserved for Indian learners only. Historically the school did not enjoy the privileges that schools for White learners had in terms of resource allocation and support under the racist and segregating laws of the apartheid regime, (Selod & Zenou, 2003). However the support that former Indian schools received then was more than the support availed to former Coloured schools and African schools (Selod & Zenou, 2003). Presently the learner population is from multi-cultural backgrounds and learners from Indian and African cultural backgrounds constitute the majority. There are four science laboratories in the school which may also be used as classrooms because learners come to the laboratories when they are having science lessons. The laboratories have materials to enable teachers and learners to engage in laboratory work.

Tendai's laboratory has recently been replenished with new kits of laboratory materials and equipment that enable her to facilitate laboratory activities even in classrooms which are furnished with just chairs and tables:

There are kits that are there the new kits and I have gone for training on how to use the micro kits and what have you and you discover that they can actually work even if you don't have Bunsen burners. They actually work as a miniature laboratory. The arrangement here is that every teacher has her/is own base, the learners come to you so it gives you more time to prepare and once you have things in order you are not moved from there.

Although Tendai and her learners have enough materials and equipment to enable them to conduct laboratory activities, she wishes she can get equipment that will enable her to incorporate computer technology in laboratory work:

I think is that the technology is lacking because fine they have to see but there are some things that I might not want to do because they are dangerous and what have you which can be shown visually on projectors and so on. I need a projector because I could show them, or I could motivate them with the videos

from u-tube. For now because I have a laptop I can get things from the Internet but I don't have the projector. I am still working on getting a projector.

Kabelo teaches in an African township school. This is an example of schools that were set aside for African learners from the townships. The learner population of the school is still solely constituted of boys and girls of African cultural backgrounds. Historically the schools like this one enjoyed the least privilege in terms of resource allocation and support under the racist and segregating laws of the apartheid regime (Selod & Zenou, 2003). There is one science laboratory in the school and learners and teachers take turns to come and use the laboratory facilities for experiments that they have to conduct. This implies that it may take some time before a teacher and his/her learners may have an opportunity to engage in laboratory work activities that they have planned in the school.

The school laboratory, the equipment and the materials were donated by two organisations from the corporate world. The donors went further to have computer technology equipment installed in the laboratory. The laboratory sometimes runs short of materials because the school depends solely on donations. In the laboratory activity that Kabelo was observed facilitating for his learners he had to improvise by replacing pumps with syringes so that learners could set up an apparatus to investigate the relationship between volume and pressure in Boyle's law. There was only one proper instrument to alter the volume of air and the teacher used it for the demonstration that he conducted. Learners had been asked to bring bicycle pumps but no learner managed to bring any pump to use in the experiment.

Kabelo described how before the donation of materials and equipment that the school received from donors in the corporate world the laboratory was in a bad condition:

The equipment that we received in the laboratory that we are working with was a donation. Without them it was very, very bad but now we have these tables with all the equipment inside through the support of (the donors). We used to tell the Department of Education that we want this and that but until now we have not received anything. We received some chemistry kits and some first aid kits that they donated. These are the people who have supported us.

Kabelo wishes the laboratory was fully equipped with things like fume cupboards, running water and fire extinguishers, among other things. He said since the laboratory does not have fume cupboards they often get discouraged from conducting some chemistry

experiments. Kabelo wishes the science laboratory could be upgraded so that it could be a safe place to work in:

If ever my laboratory can be well-equipped with projectors, bounded screens and fume cupboards to extract gases and running water because up to so far we don't have running water. We bring water in containers and then if ever there is an emergency like a fire then there will be a problem. We need fire extinguishers. Those are the things that we need now.

Melusi's school is situated in an African rural setting. There are five classrooms and a two-roomed administration structure of corrugated iron. It may be concluded that the school is disadvantaged in terms of infrastructural development. The learner population in the school is constituted of boys and girls of African cultural backgrounds. There is no laboratory in the school; therefore, Melusi brings laboratory micro kits and other equipment and materials to a classroom whenever he is to conduct a laboratory activity with the learners. Learners described the situation at the school in the following conversation they had with me:

Researcher: Can you think of something that can be done to improve the way you conduct laboratory work? There is always room for improvement...in the way you do practical work. What can you say?

Learner: Yes frequency, the frequency and perhaps the availability of apparatus. For now we do experiments in groups of more or less seven or more. It will be kind of cool if we do it in pairs. We would be more upfront, up close and personal with these things and we would comprehend more and participate more.

Betty works in a private school for learners who come from high income backgrounds. It is a boys' high school. There is an average of about 18 learners in a class. The learner population in the school is from multi-cultural backgrounds although White learners visibly constitute the majority. There are four science laboratories in the school and they have the privilege of having two laboratory assistants in the school. Betty said the school has all that they need in terms of materials and equipment to enable them to conduct all laboratory activities that they plan to engage in with learners:

We are very lucky in the school because we have nice apparatus. We have laboratory assistants so it's very, very easy to do practical work. We are a very privileged because the material is available it's easy.

However she also feels she would welcome more equipment and materials that would enable her and the learners to find new ways of conducting the experiments:

I'm happy with it you can always improve but really we have very nice apparatus and we can make it work for us. I would like more apparatus. I think the fact that we always try out new experiments and that to me is nice that we don't just have six experiments that we repeat every year I would get bored with that. There are certain experiments that we know we have to do but we always try to improve them.

Farai works in a private school for learners who come from middle income backgrounds. The learner population in the school, which consists of both boys and girls, is from multi-cultural backgrounds although African learners visibly constitute the majority. There are four science laboratories in the school but there are no laboratory assistants. The teachers are responsible for the maintenance of the laboratories that they use as base classrooms. Learners take turns to come to the laboratory during their science periods. Unlike the private school in which Betty works, learners in Farai's school are not examined by an independent examinations board but write examinations under the supervision of the Department of Education. Farai participates in school clusters that include state public schools.

Farai revealed that although the laboratory has materials and equipment to enable them to engage in laboratory work sometimes these materials are not sufficient for them to conduct certain experiments. The laboratory has equipment which enables him to incorporate computer technology in laboratory work practice:

In some cases if an experiment is one that has got enough materials they would do it in pairs in some cases in groups but if we realise there is not enough apparatus I can just do demonstration in class and then we use the projectors to collect the information and then they analyse the results but what's important to me is that they have to know how they are collecting the information and then they decide on their own how they analyse and interpret that information.

4.5.1.4 Frequency of laboratory work engagement

For Jane (former model C school) laboratory work in which learners handle materials and manipulate equipment is not frequent. However, Jane makes sure she performs demonstrations most of the time so that learners may be able to observe the scientific

phenomena under study. Jane acknowledged that she does not engage her learners in laboratory work frequently:

Because we don't do practical work that often they don't do it that often but we do a lot with them quite often in the form of demonstrations so when they do it they are really unsure of themselves that's a challenge so if we could once week or once a month have a time that they can do a practical activity they could develop more confidence.

Learners' impressions on how often they conduct laboratory activities concur with the impressions expressed by Jane. It seems as if they take time to be hands-on because they normally engage in laboratory work for school-based assessment purposes:

If it's like a practical then it's once a term. It's unlike when the teacher like when she is showing us how something works it's once every two weeks quite often actually she just does some small experiments in class to show us examples from the text book (Sarah, Grade 11 learner).

For Jimmy (former Coloured school) laboratory work activities in which learners are hands-on are not frequent. Insights from the focus group interview with learners reveal that laboratory activities are only conducted when there is time and, therefore, they are not a priority. This was reflected in the conversation I had with the learners:

Researcher: How often do you conduct experiments in the lab?
Learner: We do it most times. Every time we are doing something in the lab the teacher starts to demonstrate it.
Researcher: Oh he demonstrates the experiment.
Learner: Yes.
Researcher: Do you get chance to do it yourselves?
Learner: Yes we do.
Learner: Sometimes we do.
Researcher: Sometimes you do? That's what I am asking to say how often? How often do you do it yourselves?
Learner: When we have a lot of time, when we are not behind.
Learner: In a double period.

Jimmy's narrative revealed that the instances that he conducts the laboratory activities as demonstrations are more than the times learners conduct laboratory activities:

They don't see the chemistry behind what you are doing but I do most of the demonstrations especially when it comes to chemistry. I wish I could do more but then if somehow the children can be made aware that what I'm doing there in front during a demonstration is linked to what is written in the textbook.

For Tendai (former Indian school) laboratory work is one of the strategies that she frequently uses in the teaching and learning of science. Her practice is characterised by frequent engagement in laboratory work. As alluded to earlier on in the discussion, she works to groom her learners as laboratory work practitioners. She engages her learners in preparation of equipment and materials and, as a result, learners prefer to conduct the experiments themselves as opposed to watch their teacher demonstrate. Therefore practical work activities in which learners are hands-on are more frequent than teacher demonstrations. Tendai's narrative reflected that she frequently incorporates laboratory work in the process of teaching and learning:

Where it is possible I do a lot of practical work I can say 75%. Given the context of the school I think I could do more if the time was sufficient. The constraint is the time because to do more you'll have to do them in the after in the afternoons but the problem in the school is that most learners are commuting using organised transport so home time is home time for them it is difficult to have them after hours.

Tendai's quest is to groom her learners so that they develop knowledge, skills and beliefs aligned with the use of laboratory work in the learning and teaching of science:

I see continued value in practical work especially with these grade 10s that I have groomed, they are itching, and they don't even want me to demonstrate for them they want to handle things themselves.

Tendai's learners confirm that they engage in laboratory work regularly. This was reflected in the conversation that the learners had with me:

Researcher: How often do you conduct chemistry experiments in the lab or let's just say physical sciences experiments in the lab?
Learner: I would say at least twice in a week.

For Kabelo (African township school) learners do not engage regularly in laboratory activities in which they get to handle materials and manipulate equipment. This is against the background that there is only one laboratory in the school that is shared by all science teachers and learners. Through the learners I established that Kabelo's learners do not engage in laboratory activities in which they conduct the experiments themselves regularly. They only remember a few activities that they have engaged in. This is reflected in the conversation I had with the learners:

Researcher: Do you remember any experiments that you have done?

Learner: I remember when we were investigating the boiling point and the melting point we did it last year. We were investigating the boiling points of liquids for example water. We had ice and we had to crush it and then boil it so we had to liquefy it because it was a solid. The topic was about kinetic molecular forces... I remember the experiment because it was the first experiment that we did when we arrived in grade 10.

Learner: Another experiment that we did was proving the Newton's laws. We were investigating the relationship between acceleration, force and mass. Last year we also did an experiment on circuit boards on electricity.

Researcher: And then this year?

Learner: That was the first experiment of Newton's law so it was last term.

For Melusi (African rural school) learners do not frequently engage hands-on in practical activities. Melusi is not the learners' fulltime teacher. He comes to the school only once in a while according to his schedule to expose learners to laboratory work experiences. Melusi's schedule is filled up because he visits seven schools in total and works with learners in Grades 10-12. It may take some time before he can complete all the visits in his schedule so that he may start the next round of visits. Melusi's learners reveal that they conduct laboratory work activities once in a while when he is able to slot them in his very busy schedule. This is reflected in the conversation that they had with me:

Researcher: How often can you say you are doing practical work?

Learner 1: Once in a while.

Learner 2: Every term.

Learner 3: We did it once in three months, something like that.

Learner 2: But sometimes twice.

Learner 1: I don't recall at all. I can't to recall a certain pace to say it's once every three months or once every six months.

Researcher: It's not regular?

Learner 1: No.

Learner 3: It's once every term.

Melusi explained why he cannot meet with learners frequently to conduct laboratory activities:

I've got seven schools. We take grade 10 to 12. There is a system of electronic booking system that we do in advance for a month so each school already knows that this month maybe they will have 2, 3 to 4 visits and then personally what I do is I don't follow the standard that maybe we try to make equal visits to schools. I do the visits as per need of the school. By need I am not saying that some schools will not be visited altogether but you look at the needs of the school.

Melusi further shared his experiences on how he schedules his school visits:

In other rural schools like right now this is just an ordinary classroom you can't say it is a lab so such schools need more visits and even when you do those visits you also prioritise the grades at times because you must cater for 10, 11, 12 so in some of the cases you might find that you do two visits in a week catering for the same grade like maybe grade 12 trying to push them to be in line with the work schedule you see.

For Betty (private school) hands-on laboratory work activities are a frequent experience for learners. This is against the background that Betty uses a pre-developed workbook of experiments that should be facilitated for learners in a year. Also learners should develop practical work skills for them to be able to go through practical examinations twice or thrice a year. Betty and her learners engage in laboratory work on a regular basis. The learners revealed that they frequently engage in laboratory work activities in the following conversation with me:

Researcher: How often do you conduct physical science experiments?

Learner: I think for every unit that we will be covering like electrochemical reactions there should be about three practical observations and then a practical examination every week or so.

Learner: Every week we have practical examination.

Reflections in Betty's narrative corroborate what the learners reveal. She says; I'd say we do practical once a week maybe with some sections once in every two weeks but it's a lot. We haven't got time for more you can always think of more nice things to do but it's enough for them to learn from here.

For Farai (private school) laboratory work in which learners are hands-on is not a frequent experience. He conducts a lot of teacher demonstrations most of the time. This is made easy by the incorporation of computer technology where he can easily use a projector to show learners what he is doing at his table. Learners may be able to collect results and analyse them although they are not involved in the manipulation and handling of materials. Farai's learners engage in laboratory work activities in which they conduct the experiments themselves once or twice per term. They revealed this in the following conversation that they had with me:

Researcher: How often do you conduct experiments in the lab like this?

Learner: Once or twice a term.

Learner: Once or twice a term?

Learner: But not all of them count like for marks

Farai acknowledged that he does not frequently engage learners in laboratory work. He is not happy about the frequency with which he is able to engage learners in laboratory activities:

The frequency with which we do experiments is not good enough because under normal circumstances there wouldn't be any harm if we have three experiments in a week not necessarily writing a full report but getting information, getting results, analysing those results rather than teaching just teaching it theoretically but then that comes again against certain setback of the timetabling.

4.5.1.5 Other contextual setting issues

This category captures other contextual setting issues which interface with the practice of IBLW but which do not fall under the above mentioned categories because they may be unique to school settings.

Although Tendai appreciates the fact she is based in her laboratory and does not have to share with other teachers in the school, she still said that she is struggling to find her way around the laboratory. This is because she has been in the school for only one year and no one was there to assist her to settle down. She wishes she had a laboratory assistant to help her maintain the laboratory and prepare for experiments. She realises, however, that she is able to prepare for experiments without disturbances and disruptions because she is not sharing the laboratory with another teacher:

The challenges I have in the school my challenge is one I am new in the school and the laboratory that seem to be not to have been used as they should have been so even the arrangement the house-keeping of the laboratory is not proper so you search and search before you get your apparatus so you spend more time I have no one to assist me to locate some of the things so when I want to do sometimes I have to source from outside.

Melusi's (rural school) experiences as a teacher who facilitates laboratory work for learners are unique. He is solely employed by the organisation that he works for particularly to function as a laboratory work facilitator for learners. His work takes him to seven different schools. He has to develop identity dispositions that enable him to work in different school environments. He sees himself as a staff member of seven different schools. Melusi described how he has to learn to adapt to different school contexts as he works to engage learners in laboratory work activities in seven schools:

I can say I am a member of staff of seven schools such that if I come to this school today I should be able to relate to the situation and if tomorrow I am at school X I should also be able to relate because here I would meet a certain group of individuals which would be different from the next. There is the challenge of being able to adapt to all those different situations and fit. The whole aim is being able to adapt in the situation and be able to do my job and that's the goal.

4.5.2 Learner populations

This section captures findings made on learner attitudes, skills and knowledge as well as disciplinary issues that interface with how teachers facilitate laboratory work.

4.5.2.1 Learner attitudes towards IBLW

Jane's learners find it difficult to work in groups during laboratory activities. They feel they could work better if they worked in pairs with other learners. On being asked what they found to be most challenging when they were conducting laboratory activities, learners cited working in groups as an obstacle when they were conducting experiments. They saw cooperation and working together as a waste of time, because they have to be engaged in long debates before agreeing on anything. A learner said, "Group work. Sometimes people are not very close." She further explained saying:

We all have different opinions. Everybody has different opinions on how fast it should be done or how accurately you have done it and some people will think that she didn't do it well enough now I must redo it and then the other person says oh but you are wasting time (Jamila, Grade 11).

Another learner expressed:

Experiments themselves are not really difficult. You just have to follow process and then it's okay but I think group work is the hardest thing (Candice, Grade 11).

Learners find the part of following the steps of the procedure of the experiment to be the easiest of the tasks when they are engaged in laboratory activities. This is against the background that Jane gives her learners clear instructions on how to conduct the experiments so that they don't take a lot of time trying to figure that out.

One outstanding contextual setting in Jimmy's former Coloured school is the nature of learner behaviour. Jimmy considers the learners' behaviour to be unruly and chaotic.

Teachers are continually battling to maintain order in the school. Jimmy conceded that getting learners to calm down so that they can focus on their school work is an uphill task,

They are exposed to wrong things outside the school premises and those wrong things, elements they enter the school premises. And it spills over to some of our learners.

He observed that during the time that I was with him and his class the learners were well behaved and quiet. This could have been as a result of him talking to them after the same class was found to be unruly and chaotic the previous week by a team that came to conduct a whole school evaluation:

Normally when they come in they are chaotic I have to shout to keep them quiet it was strange to me today that they were quiet and I am sure it was because you were sitting there with us (Jimmy, former Coloured school).

This is also reflected by the field notes in the research journal where there is a caption which said:

Teacher shows me a storeroom that he uses to store laboratory equipment and materials. He says he is afraid to leave the materials and equipment in the laboratory because learners have a tendency to vandalise or steal them. He showed me some of the equipment that had been broken by the learners.

Besides the fact that learners are chaotic and rowdy, Jimmy also revealed how his learners are playful and not serious about their school work. This was revealed when he shared some of his experiences with them:

I am very strict about my learning area which is physical sciences. I tell the children if you are doing physical sciences you need to be focused all the time. You need to be busy all the time. They sometimes ask me ‘Sir, can’t we make jokes?’ I say we can make jokes but we should limit.

Tendai has a few elements amongst her learners who don't prepare for laboratory activities as she expects them to. Generally she finds the learners to be very cooperative most of the time. These are the learners whom she has been able to groom into a culture of regular laboratory work practice:

The learners can support me by being more involved I think and doing their work in time, of which I think at the moment I don't have a lot of complaints. I think they are wilfully involved. Some groups that a bit slow, those who don't read and prepare in advance so if they read and prepare in advance so that they are ready for whatever practical activity we want to do that would assist me in saving time and enable us to do more.

Some of Tendai's learners are not too happy about the way they are made to practice laboratory work because she expects them to complete some tasks without her giving them clear step by step instructions. The learners do not like the idea of having to figure out some things for themselves:

The teacher should just help us along the way because sometimes we get confused. We don't know exactly how it should look or what should be happening so she can at least just guide us in the beginning like this is going to happen or this is not supposed to happen or this is what might possibly happen, this is the precaution you must take and stuff like that...and also she must not blame us too much you see. Sometimes we do mistakes we must learn from our mistakes (Shriya, Grade 11).

For Melusi in the African township school learners may be seeing the equipment that they will use to conduct experiments for the first time that particular day because the school has neither a laboratory nor laboratory equipment and materials. He brings with him only the materials that are necessary for the practical activities that he would be facilitating for learners. The equipment that he uses for his experiments is in a way more technologically advanced than the conventional equipment found in most laboratories. For example, instead of ammeters and voltmeters they use current probes and voltage probes whereby the taking of the readings is computer assisted. Some of Melusi's learners are not comfortable with the incorporation of computer technology during laboratory activities. This was reflected in the conversation that the learners had with me:

Learner: The one thing that gives me fear? For me it's this thing it's the computer for me.

Researcher: The computer?

Learner: Yes. We don't have computers in our school and I don't even understand how to operate it and sometimes when I am looking I am saying these are tricks what are they doing. I don't understand I am just like okay this how it's done. I am just quiet but I do not really understand and I am looking at how it's done.

For Farai (private school) learners portray a negative attitude towards laboratory work activities. He is still working to make the learners get used to the idea that laboratory work is part of science teaching and learning. Some of the learners believe that they can learn science without engaging in laboratory work; therefore, they always try to resist it by coming up with all kinds of excuses so that they do not remain to conduct the experiments

after school. Farai explained how his learners do not take laboratory work activities seriously:

When they come to grade 10 they only think, 'We can just do this without practical work.' Now when you want to introduce probably you are with them they tend to resist a bit by trying to tell you, 'No we can't do this. We have arrangements for transport' and things like that but if you keep on insisting and insisting and put pressure well it usually works out. With the school settings it's the issue of time.

Learners corroborated Farai's observation that they are not too keen to engage in laboratory work during a conversation that I had with them:

Learner: Normally if they tell us we are going to be doing an experiment for us to be serious he is going to tell us it's for marks.

Researcher: So for you to be serious he must tell you it's for marks?

Learner: So for us to be serious we do it with the assumption that it's going to be for marks.

Farai further explained how his learners display negative attitudes towards laboratory work activities and how after they have been exposed to laboratory work a number of times they may start to warm up to practical activities:

Unfortunately when you are at school as a student there is this tendency that you don't like doing practical work at first but if they are done in a properly they see the importance. The practical activity needs to be well structured because once it's done like that they tend to focus and then usually you get appreciation from learners from that type of experience.

The learners gave insights into why they may be displaying a negative attitude towards laboratory work. They feel the teacher is not giving them enough support when he leaves them to figure out some of the things on their own during experiments. This was reflected in the conversation the learners had with me:

Researcher: Anything else that you would like to tell me about how you do experiments?

Learner: Specifically about the experiment or the teacher? (laughs)

Researcher: The experiments and how the teacher teaches experiments.

Learner: Can I share something knowing that it won't get to him?

Researcher: Yes.

Learner: I think I'd enjoy physics I like physics.

Researcher: Physics and chemistry you mean?

Learner: I think I would enjoy it if maybe the teacher helped out us a bit more. If he gave us a bit more guidance, I would enjoy it a lot better.

Some of Farai's learners do not make themselves available if the experiments are to be conducted in the afternoons:

The support that I want from my learners for the successful use of lab work with this type of learners is availability. Or they can tell you "I can't be available my parents are coming to take me" and things like that.

4.5.2.2 Learner knowledge and skills in IBLW

For Jane (private school) learners believe that they could improve the way they conduct experiments in the laboratory if they received more guidance and insights on what results to expect. They are not sure whether they have collected the expected results each time they conduct experiments and they can only tell after the experiment reports have been marked. Learners are anxious about the conclusions that they draw from the experiments and they wish they could receive more guidance so that they are able to give a correct solution to problem of the experiment. Therefore, each time learners are conducting these experiments for assessment they get very anxious:

If they can give us like a general guideline of what should happen in this experiment and then what they are looking for in the conclusion just like a general guideline. They don't have to tell us we want to see this, this and this just a general guideline to put us in the right path because sometimes people just accidentally go everywhere and we get guidelines but we wouldn't actually know where we are supposed to be going with the project (Carla, Grade 11).

Jane's learners said that they struggle with giving a good conclusion of the experiments. The conclusion of the experiment contains the solution of the experiment. This was reflected in the conversation that the learners had with me:

Learner: Usually everyone's write-up is quite good until the conclusion part.

Researcher: Why is it like that?

Learner: Because sometimes you just misinterpret stuff. You don't give them exactly what they are looking for because sometimes they mark according to the memo and we don't know what exactly they're looking for and they can't give us a guide of what they are looking for because we have to figure it out. Like the specific terminology we might not use that same terminology in our conclusions, and they could possibly misinterpret our answers because we didn't use the word that we were supposed to.

Researcher: But is it possible for you to get the question right and then the conclusion wrong at the end?

Learner: I think sometimes maybe our interpretation starts getting wrong and somewhere along the line something goes wrong and then the conclusion is wrong.

Jimmy (former Coloured school) observed that the learners are still struggling with understanding the scientific concepts. This is against the background that learners are presenting disciplinary issues. He explained how the learners are responding to the use of laboratory activities to consolidate the scientific concepts they learn in class and from books:

They don't see the chemistry behind what you are doing but I do most of the demonstrations especially when it comes to chemistry. I wish I could do more but then if somehow the children can be made aware that what I'm doing there in front during a demonstration is linked to what is written in the textbook but now I really don't know I fail to make them understand that there is a link between what I'm doing and what they see.

Jimmy realised that some of the learners that he teaches end up abandoning physical sciences altogether for other subjects because they fail to cope:

I am beginning to believe that, some parents they force their children to do physical sciences while the child is not inclined for that subject. I don't have the facts but there could be one or two isolated cases where we cannot progress in the subject especially physical sciences and mathematics. We then at a later stage make them switch to mathematical literacy instead of mathematics and physical sciences.

Tendai (former Indian school) is worried about the learners' skills and knowledge of laboratory work because she intends to groom learners who can use laboratory work methods to learn science. This makes her not to focus only on the learners' mastery of theoretical aspects of science but also the practical issues. Tendai thinks that she still has to work on her learners' knowledge and skills on chemicals and equipment as well as laboratory safety rules:

Most of them don't have the basic knowledge about the chemicals especially the laboratory safety rules. Although I am supposed to consolidate it but it is easy when they already know it from an earlier experience, so the basics that they should have from maybe from grades 8 and 9 of giving the names of the chemicals and whatever they don't seem to have it. So that's one challenge I have.

For Kabelo (African township school), his reflections about his learners' knowledge and skills as they practice laboratory work demonstrate that he allows them to formulate the investigative questions of the experiments and give the solutions. Kabelo shared his

experiences of how he is still working to make sure the learners are able to formulate the investigative questions and draw the conclusions of the experiments:

They'll just write stories in the conclusion because the conclusion now you must check what you have at the top but in most cases they just write stories there in the conclusion instead of just concluding in a simple way they come up with stories but when a check every information is there but then the conclusion is too big if you can ask them precisely they can answer you.

Melusi reveals that his learners are able to conduct the experiments if he gives them proper orientation. However the learners are worried that they are not familiar with proper laboratory settings, materials and equipment. They wish they could be afforded an opportunity to work in proper laboratory environments. They even harbour fears that they find themselves at a disadvantage if ever they are to be exposed to proper laboratory settings as they endeavour to pursue tertiary education. This was reflected in the conversation generated during a focus group interview with me:

Learner: Some apparatus are not found in the textbook like some of the apparatus that we saw in this experiment we have never seen them in our textbook.

Learner: If have never seen them before and Mr Melusi says pick a certain equipment how would I know.

Learner: How would you know if you have never been taught before? You see?

Learner: Your teacher should to teach you before.

Learner: How would we know?

Learner: It wouldn't be simple.

Learner: Maybe there's a lesson where you go to the lab and study everything in the lab and learn the names of materials.

Farai (private school) observed that his learners lack familiarity with laboratory materials and equipment. He feels that they do not know their way around the laboratory well enough. In the following narrative Farai confirmed what has been alluded to earlier on that learners are not frequently engaging in laboratory work. According to his observation, the result is that learners are lacking the basic knowledge and skills necessary for effective laboratory work practice:

The learners lack exposure from early stages to the laboratory setup and to that type of learning where they have to be involved with experiments. This is one thing that hinders or that acts as a setback and sometimes you find even up to matric learners don't know some of the laboratory equipment by name or what they are for. It all goes back to the early stages like grade 8 grade 9.

The learners revealed that they find the designing of experiments challenging as well as writing good experiment reports. What they said was in line with what has been alluded to earlier in the discussion that Farai structures the laboratory activities in such a manner that learners design the procedure of the experiments. Learners find the process of designing the procedures challenging. This was reflected in the conversation that the learners had with me:

Learner: I think personally I can't properly design and write down a proper investigative report.

Learner: That's where we lose marks.

Researcher: The write-up?

Learner: You can do the whole experiment correctly and just writing the report you lose marks.

Researcher: So it means the results that you get are not correct?

Learner: Not necessarily the results that we get but the format of the report how you work your answers like little details count with our teacher. He gets hectic there.

Learner: The order of the report, how you worded how... Everything just counts, spaces between lines (laughs).

4.5.2.3 Learner disciplinary issues

Jane (former model C school) wishes learners could always take laboratory work seriously and be conscious of laboratory safety precautions all the time. She realises that when she is engaging learners in laboratory activities she has got to be extra alert to look out for learners who might put themselves and others in danger by being naughty:

If you can get kids that are focused on the task at hand it makes your job as a teacher a lot easier. If you have one or two people that try to fool around, that are trying to be funny but that can cause harm to someone else so if you can just get them to realise how serious that got to be that being silly now can cause someone else bodily harm so I must say if anything just focus at the job at hand, let's move on. That's all you expect from your learners.

Jimmy (former Coloured school) complains about the unruly, chaotic and rowdiness of the learners' behaviour. Most of the time during the interview Jimmy's narrative focused on the learners' behaviour. He shared what he observes about other factors that compound the unruly behaviour of learners:

The rate of absenteeism in the school is such that you'll find that there are four or five educators who are absent per day. As you can see today fortunately there only two who are absent today so we do get children who are not supervised. You find that those children are playing outside coming to your

class from outside still with that spirit that they had outside. They are still wild and stuff like that.

Jimmy admitted that the learners' behaviour disturbs him. His face became sullen as he described how he is deeply affected by the uncontrollable behaviour of the learners:

It affects me sometimes. We had a team last week for the whole school evaluation team in this very class. When they came in they were chaotic I had to shout to keep them quiet. It was strange to me today that they were quiet and I am sure it was because you were sitting there with us.

He tried to explain why learners behave in such a manner. He pointed out that the learners problems have got their source in the communities that the learners come from and some of the learners bring those issues with them to school:

We've got these few elements here amongst the learners. They are exposed to wrong things outside the school premises and those wrong things enter the school premises and it spills over to some of our learners.

Kabelo complained that his learners have a tendency to vandalise equipment and even steal things from the laboratory. This is against the background that the school has only one laboratory that relies on donations for equipment and materials. Therefore, any damage that is done to equipment or any theft that the school suffers in the laboratory is a serious set-back:

The other challenge is that learners can damage the equipment and the teacher may not be able to see it. You can't control them as a teacher because the numbers are too high more than 35 or more. They are too many for you to be able to check what they are doing when you move from one table the others are doing something that they are not instructed to do like you saw some of them they just push the syringe without taking it off they are damaging the spring inside.

Melusi revealed that the learners sometimes try some mischief on him. He said he normally encounters learners who become mischievous when he is newly introduced to them as they try to find out what kind of teacher he is. However, he seemed to know how to handle them:

You know it's just like the normal challenges that a new teacher would face when introduced to a certain class. The kids always try this and that with you. They want to see if they do this how you react. Some they even test how knowledgeable you are. I am not saying those are problems. Those are initial challenges when you are trying to settle within the school system.

Betty (private school) acknowledged that she makes efforts to work on the learners' behaviour from when they are in lower grades so that they realise that the laboratory is not a place to try naughty things. She explained how she has to work on her learners so that they behave appropriately when they are in the science laboratory:

I think it takes quite a while to teach them how to behave in a laboratory because they are learning manners and they are boys they want to empty everything together. They want to see if they're going to be explosions and that sort of thing so I think from the learner point of view yes you have to teach them how to behave in a laboratory that they can't run around and that they have to pack up afterwards and that sort of thing.

Generally learners present undesired behavioural issues during the time they are conducting laboratory work activities that the teachers have got to be aware of and have ways of dealing with if the practical activities are to be safe and effective.

4.6 Teacher professional identity positions in IBLW practice

This theme captures the four teacher professional identity positions in IBLW that are salient from the findings of this study. The four teacher professional identities are: (i) learners are provided with the question and procedure of the experiment and the learners figure out the solution; (ii) learners are provided with the procedure of the experiment and they figure out the question and the solution in the experiment; (iii) learners are given the question and solution of the experiment and they figure out the procedure and (iv) learners are given the solution of the experiment and they figure out the question and the procedure.

Figure 4.4 Teacher identity positions in IBLW practice

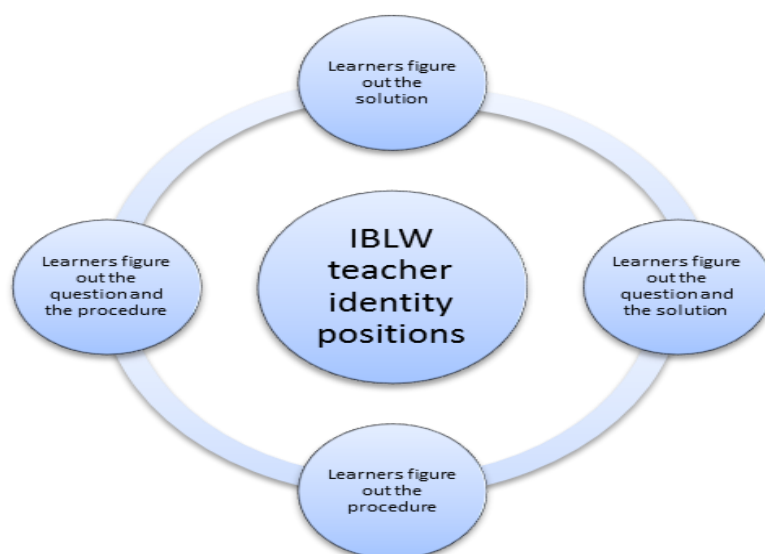


Table 4.4 Inclusion and exclusion data indicators for Theme 3

Theme 3: Teachers positioning themselves in terms of IBLW teacher professional identity		
<i>I think pupils must be able to pose the question to say this is the question I want to ask but I think also may be time is limited we often give them the question because to let them go and pose a question it takes too long. Betty (Private school)</i>		
Subthemes and categories	Inclusion indicators	Exclusion indicators
Subtheme 1	Learners are given the investigative question and procedure and they figure out the solution	
Category 1: Jane from a former model C school	<p>This category includes data on the discussions made by Jane and her learners revealing the IBLW teacher identity position</p> <p>This also includes data collected through observations revealing the IBLW teacher identity position</p>	This category excludes data from other school contexts.
Category 2: Jimmy from a former Coloured school	<p>This category includes data on the discussions made by Jimmy and his learners revealing the IBLW teacher identity position</p> <p>This also includes data collected through observations revealing the IBLW teacher identity position</p>	This category excludes data from other school contexts
Category 3: Melusi from an African rural school	<p>This category includes data on the discussions made by Melusi and his learners revealing the IBLW teacher identity position</p> <p>This also includes data collected through observations revealing the IBLW teacher identity position</p>	This category excludes data from other school contexts
Category 4 : Betty from Private school (I)	<p>This category includes data on the discussions made by Betty and her learners revealing the IBLW teacher identity position</p> <p>This also includes data collected through observations revealing the IBLW teacher identity position</p>	This category excludes data from other school contexts
Subtheme 2	Learners are provided with the procedure and they figure out the investigative question and solution	
Category 1: Kabelo from an African township school	<p>This category includes data on the discussions made by Kabelo and her learners revealing the IBLW teacher identity position</p> <p>This also includes data collected through observations revealing the IBLW teacher identity position</p>	This category excludes data from other school contexts

Subtheme 3	Learners are provided with the investigative question and solution and they figure out the procedure	
Category 1: Tendai from a former Indian school	<p>This category includes data on the discussions made by Tendai and her learners revealing the IBLW teacher identity position</p> <p>This also includes data collected through observations revealing the IBLW teacher identity position</p>	This category excludes data from other school contexts
Subtheme 4	Learners are provided with the solution and they figure out the investigative question and the procedure	
Category 1: Farai from Private school (II)	<p>This category includes data on the discussions made by Farai and his learners revealing the IBLW teacher identity position</p> <p>This also includes data collected through observations revealing the IBLW teacher identity position</p>	This category excludes data from other school contexts

4.6.1 Learners figure out the solution

Learners are provided with the investigative question and the procedure of the experiment and they figure out the solution. This sub-theme captures the teacher professional identity positions of four teachers in the study. These are (i) Jane from a former model C school; (ii) Jimmy from a former Coloured school; (iii) Melusi from a rural school and (iv) Betty from a private school.

4.6.1.1 Jane from a former model C school

Grade 11 learners were observed conducting experiments to investigate intermolecular forces and their effects on evaporation, surface tension, solubility, boiling points and capillarity. According to the worksheet of the experiment, learners were required to write an experiment report using the format of the scientific method with the following headings:- Investigative question, Hypothesis, Variables, Aim, Apparatus, Method, Observations, Results, Interpretations, Conclusion and Evaluation. The worksheet already contains the aim, list of materials to be used, diagram of the apparatus setup and instructions of the method. Jane provided the learners with the investigative question:

I give them the problem like this practical (activity) I said we are going to test intermolecular forces and after all the five experiments I want to know which

substance has the strongest intermolecular forces and why do you say that. That was the discovery. That's why we chose the five experiments because it covers the different aspects of it.

Learners have to formulate the hypothesis, conduct the experiment, record the observations and results, and write the interpretations, conclusion and the evaluation. Learners also receive the worksheet about a week before they come to conduct the experiment so that they can prepare for it:

We try to give the girls the instructions to be very clear and precise so that they don't have to spend half an hour trying to figure out what they should do. We try to also give them very specific indications. We also give the indications to them a week before so that they can read it in advance and prepare for it. If we work with chemicals like we do now they must read a little bit about each of them.

The learners confirmed that they are provided with the procedure of the experiment:

The experiments aren't really hard. They are quite basic especially because they give us the steps. And I think like taking out the results is pretty simple because you just need to read off like the thermometer or whatever you are testing or write down what you see (Maxine, Grade 11).

There is evidence that learners use the results from experiments to draw conclusions. They use their results from experiments to draw conclusions of the experiments although they may not be always correct. On this the learners said:

Usually everyone's write-up of the experiment is quite good until the conclusion part because sometimes you just misinterpret stuff. You don't give them exactly what they are looking for because they mark according to the memo and we don't know what exactly they are looking for and they can't give us a guide of what they are looking for because we have to figure it out (Carla, Grade 11).

Discussion of Jane's IBLW practice

Jane is an experienced teacher who has been exposed to laboratory activities from the time she was in school through to teachers' college:

The school that I attended the teachers allowed us to do a lot and that is where I think the whole interest started to see how things happen. I was trained in Pretoria. We were a very small class so we did everything that we could as a practical. I studied for a diploma in education and I am currently busy with my BEd honours in teaching and learning.

The exposure to laboratory activities is continuing throughout her current practice as a teacher and through professional development exercises both as a participant and as a facilitator. Jane knows her way around the science laboratory to an extent that she can conduct professional development exercises for other teachers in the use of IBLW as a teaching and learning strategy.

The extensive experience that Jane has in the practice of IBLW has made her develop firm beliefs about this teaching and learning strategy. She feels that the incorporation of IBLW in teaching and learning is important for purposes of motivating learners, linking science with everyday life activities, preparing learners who intend to pursue further studies in science- related fields and preparing learners for examinations.

Even though Jane commands this extensive experience with laboratory work and that the laboratories in the school are fairly equipped and resourced and provide a good environment for the practice of IBLW, she still faces a challenge that acts as a hindrance to the frequent and effective practice of IBLW with her learners. She claimed that the time allocation does not permit her to do some of the things that she knows she could do with her learners for IBLW:

I would like to do more but the syllabus is extremely full so we just have to do some of our things as a demonstration because there is no time, but whenever we have a lesson somewhere we try to put a practical in even if it's boiling water or to give the measurements.

Therefore, most of the laboratory activities end up being performed as demonstrations for learners to observe.

The school enjoys favourable contextual settings for the practice of IBLW. The settings include the presence of an experienced teacher in the practice of IBLW, a well-equipped and well-resourced laboratory, professional development support for teachers and learners who wish they could get more laboratory time and not only for assessment purposes. However, these favourable conditions are offset by what Jane highlighted as lack of time to allow learners to engage in IBLW more frequently than what they can afford to do at the moment. She finds herself managing to just make learners engage in the prescribed experiments meant for assessment. Most of what constitutes laboratory work for Jane and

her learners are teacher demonstration of experiments. With those demonstrations Jane still manages to achieve what she hopes to develop in learners through laboratory work activities which are consolidation of their understanding of scientific concepts; demonstration of the relevance of science in everyday life and learner motivation. However the development of learner skills and in inquiry through laboratory work is compromised.

The experiments are normally done according to the specifications of the scientific method which requires that, among other things, learners should formulate an investigative question, design a procedure for the experiment and find a solution to the investigative question. Jane gives learners the investigative question of the experiment:

I give them the problem like this practical (activity) I said we are going to test intermolecular forces and after all the five experiments I want to know which substance has the strongest intermolecular forces and why do you say that. That was the discovery. That's why we chose the five experiments because it covers the different aspects of it.

She also designs the procedure of the experiment for learners by way of giving them steps to follow in setting up the apparatus of the experiment. The teacher also assists learners during the setting up of the experiment apparatus and makes sure learners are following the procedure although they are left to record whatever they observe and write down whatever results they get.

A number of reasons may be put forward at this point on why the teacher makes sure that learners are provided with the procedure of the experiment and are monitored throughout to make sure they execute the steps as they are given. First, learners' exposure to laboratory activities is limited and for that reason they may not really know what to do when they are left to conduct the experiments on their own. Second, the teacher is also concerned about safety issues in the laboratory. It is important that she keeps her learners safe and one way of ensuring that is not to allow them to try any other apparatus besides that designed for them to use. Third, the teacher must make sure the learners conduct the laboratory activities since they are meant for assessment; therefore, providing the procedures of the experiments ensures that all learners are able to collect results that they can analyse, interpret and draw conclusions from. Fourth, the teacher explained how time

constraints force them to structure the laboratory activities in such a way that they can be completed in the allocated time:

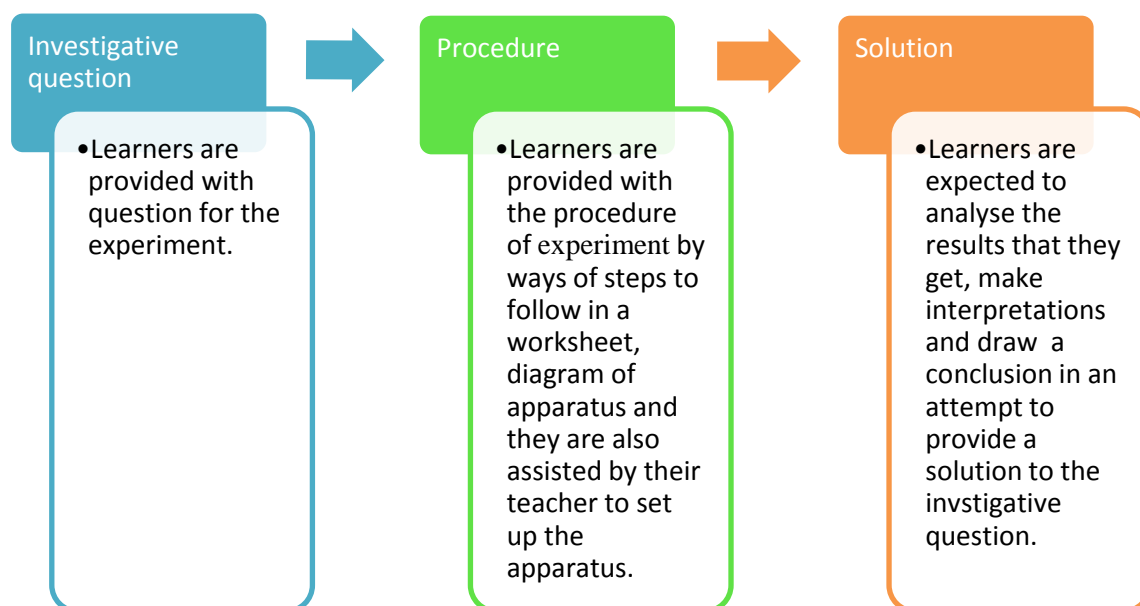
We have to push them to finish in a double period. Some could discover other things but we say ‘No just do what we have to and finish in time’. Everything is just about time (Jane, former model C school).

One of the things that Jane considers to be important and wishes to achieve with her laboratory work practice is for learners to observe phenomena in the laboratory so that they can also be enthused by science like she is by seeing how science can be applied in real life situations. She gave an example of some activities that they do in the laboratory:

For me the most important part is to get the kids to understand that science has a place in society that what we do every day is because of some scientific knowledge that we have. If we cook a meal in our school, cooking is a good example just because it’s girls. If we have to clean a clogged kettle and all that science is in our homes.

For that, learners do not need to be able to design procedures of experiments or discover anything beyond what she plans for them to discover since she can just show them.

Figure 4.5 The level of inquiry of Jane’s laboratory practice



4.6.1.2 Jimmy from a former Coloured school

The investigative question of the experiment that the learners were observed was articulated by the teacher in this way: “Is there any relationship between how fast the trolley is moving and the steepness of the slope of the track?” Jimmy proceeded to perform a demonstration of how the learners should execute the steps of the procedure of the experiment. The learners’ response in the focus group interview corroborated this finding when they said, “We get it from the teacher or sometimes he gives us an example so that we work it out.”

The inspection of the worksheet also revealed that the method of the experiment was included in the investigation task by way of an instruction structured in the following way: Roll a ball down an inclined plane and using measurements of time and position to obtain a velocity versus time graph and hence determine the acceleration of the ball. Vary the angle of inclination and determine how the inclination impacts on the acceleration of the ball. There is also included the diagram of the apparatus setup with an example of how the experiment can be conducted using ticker tape, ticker timer, trolley, track and some bricks. Learners are left to use the results from the experiments to draw conclusions that they include in the reports of the experiments. However, the teacher would have taken the opportunity to guide them on how to interpret the results as he performs the demonstration. In the demonstration he shows learners how the experiment should be conducted.

Jimmy confirmed the journal entry on how the investigative question, procedure and conclusion of an experiment are developed:

With grade 10s what I do now I will tell them what the practical investigation is about and I’ll tell them normally we have variables here the dependent variable the independent variable we usually start with the investigative question. At times they might be a deviation from what is written in the textbook but I make them aware of the fact that this is your practical so you write what you have observed. Don’t write what is in the text book.

Learners were aware that they should draw the conclusions themselves because they said, “No we get it from the experiment....what we have observed.” They said this on being asked whether the teacher provides them with the conclusion of the experiment as well.

Discussion on Jimmy's IBLW practice

Jimmy is an experienced teacher who has not been exposed to meaningful laboratory activities during his school years. His exposure to laboratory work at university was also limited:

We were not very much exposed to practical work. It was more theory than anything else. The emphasis was on theory than practical. We would only go there just to get the mark on practical.

The only meaningful experience with laboratory activities that Jimmy has been exposed to has been through his current practice as a teacher. He also relies on the professional support that he gets from colleagues and his subject advisor. He has not, however, been able to attend some professional development workshops since he has been engaged in programmes that provide extra lessons for learners.

Jimmy has developed a methodology that he employs when he is facilitating laboratory for his learners. He realises that they are not ready to perform some of the tasks that the experiments require of them for reasons that may range from lack of knowledge and skills to attitude and disciplinary issues. In his approach he guides the learners throughout the whole practical activity even up to the point of performing some of the actions that constitute the execution of the experiment if he feels they may not be able to do it. He, however lets his learners use the results they collect to do their own analysis and interpretation. This is even after he showed them how they can do the analysis of the results using the data collected through the demonstration of the experiment that he performs.

Jimmy believes that he should always be present to guide learners every step of the way. There are a number of reasons that can be put forward to explain why he feels he should guide learners most of the time. First, the learners may not know what to do if they are left to mount the apparatus and execute the steps of the procedure of the experiment. Learners confirmed that the support that they need for them to be able to successfully conduct the experiments is for their teacher to explain everything every step of the way. The learners have had limited exposure to laboratory activities in which they handle materials and

equipment because most of the time they observe experiments that are being performed by the teacher.

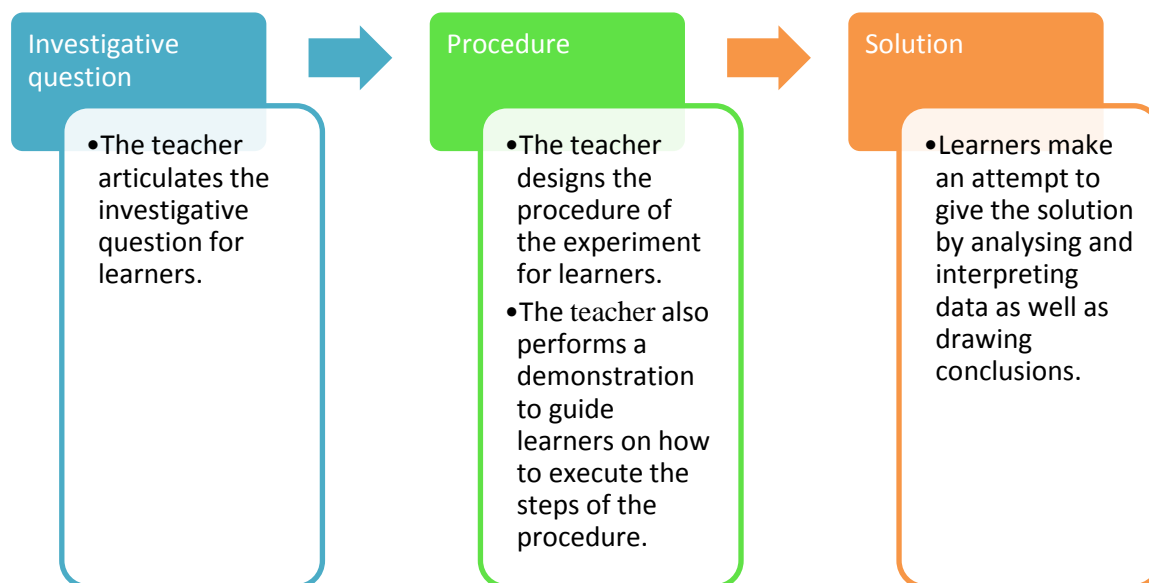
Second, Jimmy is aware of the learners' behaviour which he believes to be chaotic, unruly and rowdy. He says that if the learners are left unattended with laboratory equipment just lying around they have a tendency to vandalise and even steal things. This may explain why he mounted only one apparatus for the experiment so that the groups took turns to come and conduct the experiment under his close supervision.

Third, since the laboratory activity that Jimmy was observed facilitating for his learners was for assessment, he wanted to make sure that learners were able to conduct the experiment and collect the necessary data for analysis and interpretation by guiding them all the way through. This averts a situation where he may have learners who failed to perform the task thereby ending up with no marks for that task.

Fourth, there is evidence that time constraints also stand in the way of effective laboratory practice. In the laboratory activity in which Jimmy was observed facilitating for his learners, learners were not able to repeat the experiments as specified by the task. Time had run out. The experiment report was also to be written as homework since there was no time for learners to be able to analyse and interpret results during the laboratory session. However, Jimmy did not mention time constraints to be one of the challenges that he faces. This might be because, as revealed by learners, he is prepared to sacrifice some of his time after school to facilitate laboratory activities for his learners; therefore, he does not see time constraints as a challenge anymore.

Learner behaviour emerged as the most prominent challenge that Jimmy faces when he attempts to incorporate IBLW as a teaching and learning strategy. The learners' unruly and rowdy behaviour that results in chaotic situations is a very inhibiting condition for Jimmy in the school. His IBLW practice with Grade 10 learners in this study was characterised by the teacher providing an investigative question and the procedure of the experiment for learners. Learners made attempts to come up with the solution to the investigative question.

Figure 4.6 The level of inquiry of Jimmy’s laboratory practice



4.6.1.3 Melusi from an African rural school

Melusi made use of worksheets for laboratory tasks that had been prepared by the organisation that sponsors him to engage learners in laboratory work activities. On analysing the worksheets it was observed that they contained the investigative question and the procedure of the experiment to be conducted but not its solution. The worksheets even provided teachers with methodological suggestions of how to facilitate the laboratory work activities for learners:

Section A has got theory so maybe method wise if you want to follow their worksheet as it is then it will be theory followed by experimental setup and then executing the experiment and then doing the write-up and conclusion.

The procedure of the experiment is set out in the worksheet. The teacher explains the steps of the procedure of experiment by way of conducting a demonstration. The diagram of the apparatus set up of the experiment is also made available in the worksheet. Melusi even set up the apparatus for the learners and assisted them as they conducted their own experiment in groups. This assistance was necessary because the learners needed it. They said, “Yes as long as our teacher is assisting us we are fine.” Melusi confirmed this:

Then like what I have observed they need guidance all the way through of course with the exception of a few outstanding learners when you show them the first and the second steps they can easily relate to the rest and complete it,

and then on the part of the procedure, the procedure usually is set out in steps and those steps, like they are in groups as you saw I will move from group to group.

On whether learners are able to formulate investigative questions for experiments that they conduct, they revealed that they are aware of the purpose of the experiment before they conduct it but they could not conclusively show that they were aware of an investigative question:

For instance in today's experiment we understood that we are basically trying to find out or the aim of our experiment is to prove the theory of Ohms law, to see if it's actually a fact, to see if it's factual or not. I think that was our aim today (Lerato, Grade 11).

The learners gave the solution to the investigative question of the experiment when they wrote up the conclusion of the experiment. They revealed that they usually write the conclusion of the experiments themselves. A learner said, "We do it ourselves. Usually we do. We do it ourselves usually. After finishing the experiment then we write the conclusion."

An entry made in the research journal also revealed that learners are expected to derive the solution of the experiment from the results of the experiments they conduct. The learners make attempts to provide a solution to the problem of the experiment by way of drawing conclusions of the experiment. Section C of the worksheet also contains questions that learners need to respond to and these questions guide learners so that they can see the solution to the experiment problem. The experiment task requires that the learners each write an experiment report and submit it so that they can be marked by the teacher. When the learners receive their experiment reports after they have been marked, they also get copies of the marking memorandum that the teacher was using so that the learners may get to compare what they did and what was expected of them.

Discussion on Melusi's laboratory practice

Melusi has been exposed to laboratory work experiences from the time he was in school. He also had laboratory work experiences in university where he was training to be a teacher. Melusi further received professional development training on how to facilitate laboratory work for learners by way of being exposed to laboratory activities that the

learners may conduct in schools, the use of equipment and different apparatus setups and the incorporation of technology in the science laboratory. He believes he sufficiently prepared for his work as a science teacher who only specialises in facilitating laboratory work activities in different schools. Melusi's current practice involves the use of technologically advanced equipment in the laboratory as compared to the conventional apparatus setups that have always been used for laboratory activities:

We use soft wares so it's like we are moving away from the traditional conventional apparatus like these you see the voltage probes and the like instead of ammeters and voltmeters. For these ones I think they are okay because they go in line with the changing technology.

Equipped with the knowledge and skills to incorporate technology into laboratory work activities and the use of laboratory micro-kits, Melusi is able to use ordinary classrooms to engage learners in laboratory work activities. However, he still faces some challenges as he works to bring laboratory work experiences to learners in any circumstances.

The first challenge that can be highlighted is that of time constraints. He said that the laboratory activities that they conduct need more time than a double lesson that is usually set aside for these activities. He said, "You find in schools things like time. Time is one of the challenges. These experiments truly speaking they are long, detailed, for them and for me." Therefore, sometimes it is not possible for them to finish activities in time.

The second challenge is that Melusi works with learners from seven schools. Some of the learners that he finds in the schools have never had any exposure to laboratory work activities because the schools do not have science laboratories and materials to use in science experiments. During the short time that he is with learners he should be able to assess their needs so that he can engage them meaningfully. Sometimes after assessing their needs he may be forced to engage them in other learning activities before he can consider them ready to conduct the experiments that he has planned for them:

Unlike if I would come straight with an experiment and say okay according to the work schedule you must have done Ohms law now state the Ohms law what is an ohmic conductor and things like that you find that their level of understanding might still be very low such that they might still need a bit of nurturing.

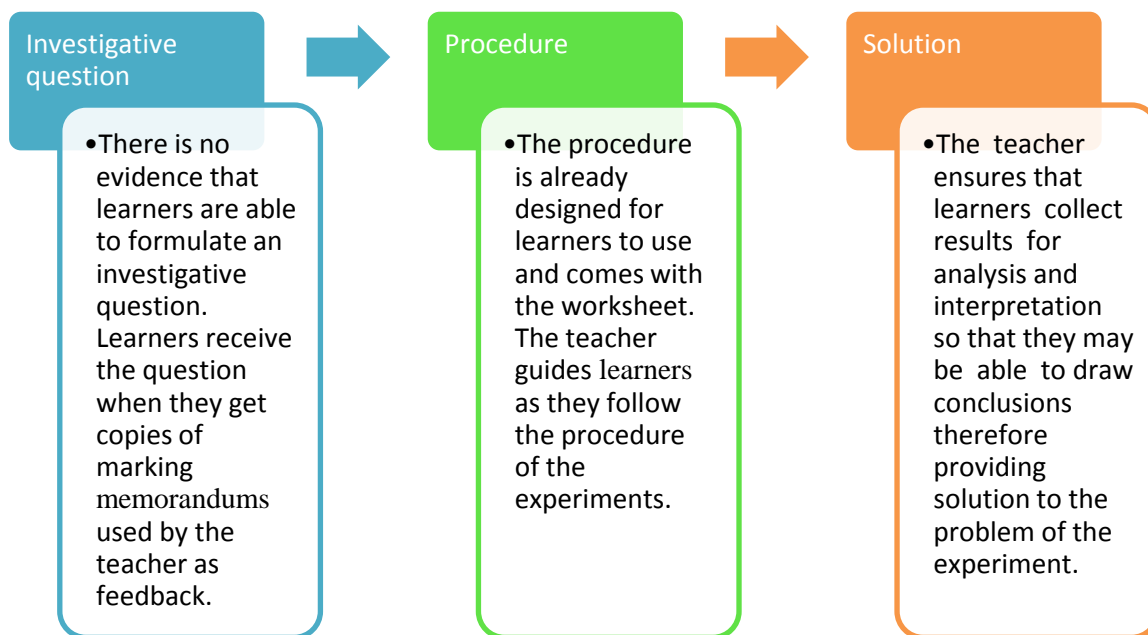
Melusi provides constant guidance for learners throughout the laboratory activity starting by making sure they have the conceptual background knowledge necessary for them to be ready to conduct the experiments:

Now what I've realised is when you take that approach where you give them a bit of background and not assuming that they have already done it in class but give them two or three pointers around that topic before conducting the experiment. Most of them would easily relate to the practical activity that they are doing with the theory. Then like what I have observed they need guidance all the way through.

Based on the activity observed and focus group interview with learners, the learners showed that they are not yet familiar with formulating investigative questions for the experiments that they conduct. A reason can be put forward to explain why they are unable to formulate an investigative question. Learners have very limited exposure to laboratory work activities. The only exposure that they have with laboratory work is when Melusi visits them; therefore, the learners have not had enough time to learn and familiarise themselves with the different components of the scientific method where learners have to formulate investigative questions and hypothesise, among other things.

The learners are provided with the procedure of the experiment in the worksheet. The teacher still needs to guide them as they execute the steps of the procedure. Learners are not able to design experiments and apparatus setups because they are not familiar with the laboratory equipment and materials. However, the teacher ensures that learners collect results that they will analyse and interpret so that they may be given an opportunity to draw conclusions from the experiments and thereby give solution to the experiment problem.

Figure 4.7 The level of inquiry of Melusi’s laboratory practice



4.6.1.4 Betty from a private school

Betty believes that the learners should be able to pose the investigative question of the experiment although she may not always give them the opportunity to do that. To get going Betty provided her learners with the investigative question among other things before they were able to conduct the experiments on their own:

I think pupils must be able to pose the question to say this is the question I want to ask but I think also may be time is limited we often give them the question because to let them go and pose a question it takes too long and so and again different practical work serve different purposes.

Learners are provided with the procedure of the experiment. The instructions on how to conduct the experiments are in the workbook of laboratory activities. Each learner has his own workbook with all the activities for the year. Learners refer to the instructions of the experiment in the workbook as they conduct the experiments. Betty also made sure the materials and equipment to be used for the experiments were laid out on a table where they would be able to go and collect what they needed. She also explained to the learners how they should set up the apparatus. Learners collected the materials that they needed and worked in groups to set up the apparatus of the experiment. Betty moved from group to group giving the learners the guidance and the assistance that they needed.

Although the learners were provided with the investigative question and the procedure of the experiment, they were required to draw conclusions of the experiments:

They get cross with me sometimes because I always say to them write a justified conclusion and they never, they'll say, 'This is the conclusion these substances conduct electricity' then I say to them you have to write about your data like this one which has ions in it did conduct electricity and it's a process you just have to go over it many times to teach them that that's just how you do it properly as a scientist.

The learners also believe they should provide the solution to the investigative question. They confirmed that they are given an opportunity to draw their own conclusions. When asked whether they are able to draw conclusions of experiments one learner said:

Pretty much through the experiment you can actually see your conclusion. They may help you throughout the experiment and in what you want to prove but as soon as you do the experiment you can actually conclude it yourself (Ryan, Grade 10).

This is also reflected in the entry made in the journal. In the reflections learners completed the experiment and they put away the materials from their working posts. Learners sat down and began to compare their observations during the experiments on conductivity and the predictions that they had made. They started writing up the experiment report including in it the circuit diagram of the circuit used in the experiment, the interpretations made from the observations and the conclusion of the experiment

Discussion on Betty's IBLW practice

Betty is an experienced science teacher who never had exposure to laboratory work activities when she was in school. However, she had meaningful experiences in laboratory work when she was going through university education. These experiences were further enhanced during the years that she was working in a laboratory environment before she started her teaching career. Her teaching practice has also ensured that she is continuously exposed to laboratory work experiences as she works with her learners. Betty believes she has been prepared sufficiently in laboratory work practice and she considers herself to be unlike other teachers who have fears when it comes to conducting experiments with learners. This can be extrapolated from the following extract of her narrative:

There is always a hurdle for a teacher to get over to realise that actually I can do a practical and it's easy because they see as something difficult. My

colleagues are all well-trained teachers but for them to do chemistry practical work they don't like it because chemistry practical activities don't always work. They really don't so there's always a hurdle of getting over a teacher's hesitancy to do practical work.

Betty also works in an environment where laboratory practical work is taken seriously as a teaching and learning strategy. Evidence shows that Betty and her learners engage in laboratory work activities frequently. The development of a year workbook for experiments ensures that laboratory work becomes part of teaching and learning. Betty also has to prepare her learners for the laboratory practical examinations that form part of their assessment. Learners have to possess the basic knowledge and skills in laboratory work activities if they are expected to sit for practical examination. It means there are times when learners have to independently set up apparatus, follow through the instructions of experiment procedures and collect results without any guidance from the teacher.

The school does not lack in terms of laboratory materials and equipment for learners to engage in meaningful laboratory work experiences. The small classes also ensure that learners work in small groups of three to four learners and it makes all of them to be actively involved in the experiment tasks.

The findings in Betty's IBLW practice show that learners are provided with the investigative question. She explained why she has to formulate the question for learners although she also believes they should be able to formulate questions. She cited time constraints as one of the challenges that stand in the way of her laboratory practice with learners. Therefore, to ensure learners manage to execute and complete the steps of the procedure in the allocated time, she provides them with the investigative question as a measure to manage time. For her it is important to successfully engage learners in a laboratory activity because it is strictly and specifically part of the activities that constitute science curriculum implementation. They develop an experiment work schedule for every year in an effort to prepare learners for science practical examinations. For learners to conduct and complete the experiments, Betty has devised a way in which learners do only certain tasks that can be accommodated in the science lesson. These tasks exclude formulation of the investigative question:

I think pupils must be able to pose the question to say this is the question I want to ask but I think also may be time is limited we often give them the question because to let them go and pose a question it takes too long.

Learners are provided with the procedure of the experiment. All they have to do is to follow the instructions in the practical activity workbook as well as seek the guidance of their teacher to set up apparatus and execute the steps of the procedure. After every laboratory activity learners should at least have collected results even though Betty says they seldom finish all the tasks of an experiment as determined by the scientific method. However, if learners manage to collect results they will be able to continue with the tasks of analysing, interpreting and drawing conclusions in their own time.

There is no doubt from the findings that learners are expected to draw their own conclusions from the experiments conducted. Both Betty and the learners believe that learners should use the results obtained from the experiments conducted to draw conclusions. Interestingly one learner expressed himself in the following way emphasising why it is important for learners to be allowed to draw conclusion for the experiments they conduct:

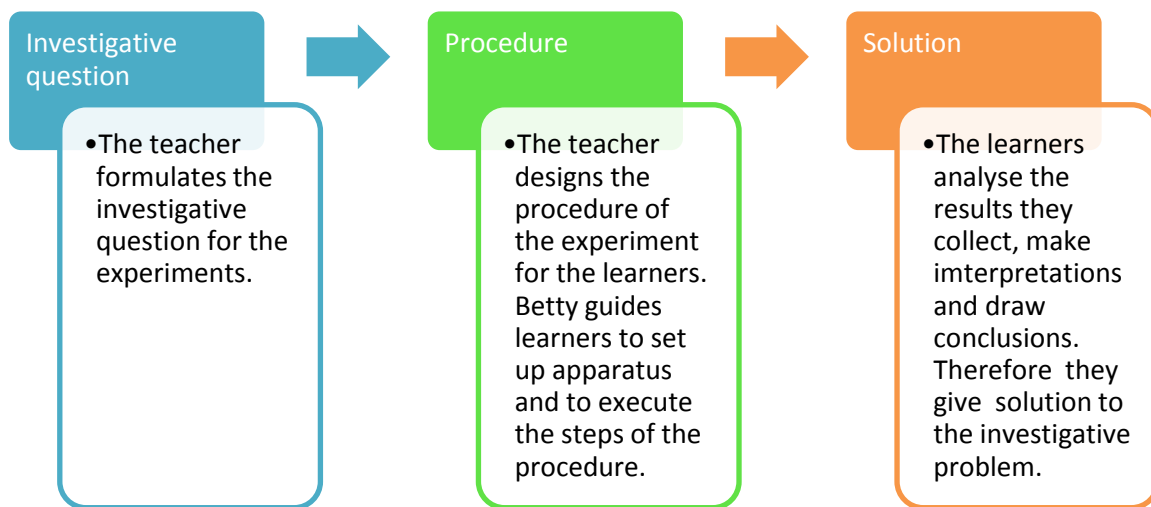
I think in terms of educational psychology you learn the most when the conclusion is reached on your own (Cliff, Grade 10).

Betty also expressed strong beliefs that the drawing of conclusions is a very important part of an experiment. This could be one of the reasons why she emphasised that learners should learn to do it on their own. She went to great length to share her experiences on how she encourages her learners to draw conclusions and thereby providing a solution to the investigative question that she has provided for them:

They get cross with me sometimes because I always say to them write a justified conclusion and they never they'll say this is the conclusion these substances conduct electricity then I say to them you have to write about your data like this one which has ions in it did conduct electricity and it's a process you just have to go over it many times to teach them that that's just how you do it properly as a scientist.

In Betty's IBLW practice learners are provided with the investigative question and procedure of the experiment. The learners are guided as they conduct the experiment. They analyse the results that they collect and make efforts to interpret and draw conclusions. It is in these conclusions that the solutions to the investigative questions should be expressed.

Figure 4.8 The level of inquiry of Betty’s laboratory practice



4.6.2 Learners figure out the investigative question and solution

In this section the IBLW identity position is such that learners are provided with the procedure of the experiment while they figure out the investigative question and articulate its solution.

4.6.2.1 Kabelo from an African township school

Kabelo ensures that he provides the learners with the procedure of the experiment. This is reflected in an entry made in the research journal in which the teacher was observed performing a demonstration of the experiment with one of the apparatus. The proceedings were projected on a screen which acted as video camera so that both the demonstration and the learners were displayed simultaneously. The teacher invited learners to assist in the conducting of the demonstration.

Another entry in the research journal affirmed that Kabelo provided learners with the procedure of the experiment and encouraged them to formulate the question and come up with the solution. The evident emphasis on the use of the scientific method ensured that every time an experiment was conducted learners and teacher had an opportunity to reflect on the investigative question and the procedure of the experiment as well as the solution to

the investigative question as they drew conclusions, amongst other tasks that constitute the scientific method. What was evident is that Kabelo encourages learners to formulate an investigative question and provide the solution when they draw conclusion but he designs the procedure of the experiment for them. He even conducts a demonstration to show learners the steps of the procedure as well as setting up the apparatus for them.

Kabelo reflected on how the learners constructed the investigative question and drew up the conclusions of the experiment as he went through the learners' experiment reports. The learners seemed to be doing well when it came to formulating the investigative questions but they still struggled to draw conclusions to the experiments that they conducted:

They'll just write stories in the conclusion because the conclusion now you must check what you have at the top but in most cases they just write stories there in the conclusion instead of just concluding in a simple way. They just come up with stories but when I check all the information is there but then the conclusion is too big. If you can ask them precisely they can answer you.

Learners also reflected on how they come up with investigative question for experiments. One learner used the example of the experiment that they were observed conducting to explain how she comes up with the question when I asked them if they were able to formulate investigative questions:

Yes we are because let's take for an example we are doing Boyle's law. We want to know how Boyle came to the conclusion of having the law. So we are posing the question we want to know the relationship between the dependent and the independent variables and the constant variables so then before we can do that we have a question we have the hypothesis (Bongi, Grade 11).

Learners have different ways in which they come up with an investigative question of an experiment. One learner thought it was easier to formulate the investigative question once she had drawn the conclusion of the experiment after analysing the results she had collected. Another learner explained how easy it was for them to formulate an investigative question:

I think it's also easy to come up with the investigative question when you have the law maybe, the conclusion already. Then you know that maybe with Boyle's law you know that volume is inversely proportional to pressure it is easy to come up with the question when you try to put yourself in Boyle's shoes maybe. Then that way you are able to answer yourself (Zinzile, Grade 11).

A third learner also used the experiment that they were observed conducting to try and explain how they come with an investigative question as well as the hypothesis of the experiment:

Maybe he was wondering why when we increase the pressure this happens...right an experiment is one in which you don't know the outcome of that experiment so if you are doing an experiment and you have different outputs then you wonder why this is happening, why is that happening so then before he came to the conclusion he looked at the relationship between pressure and volume (Sphiwe, Grade 11).

All these different approaches confirmed Kabelo's observations about the way the learners draw their conclusions that, although they do not draw conclusions in a precise way, the ideas are always present in whatever they write. This is confirmation that learners are given an opportunity to pose the investigative question.

Discussion on Kabelo's IBLW practice

Kabelo is an experienced teacher who was never exposed to laboratory work experiences when he was in school. His laboratory work experiences only started when he was in teachers' college. He believes that, since he was unfortunate not to have experienced laboratory work when he was in school, he should not let that happen to his learners. He has first-hand experience of how science learners who have not had an opportunity to engage in practical laboratory activities are adversely affected as they pursue tertiary education in science related fields that involve laboratory work:

I started experiencing that in tertiary but now we were having a problem in handling those apparatus because we never had chance to touch them at school so we were afraid to touch them because we didn't even know how to handle some of them because we never had chance to touch them in high school. So we were afraid to touch some of them because we didn't know how to handle them it is in a teacher education at least I enjoyed that because it was hands-on experience.

Kabelo feels he should expose his learners to laboratory work experiences. The approach that he uses in the laboratory is that he closely guides the learners every step of the way. Although he starts by performing a demonstration of the experiment before the learners can be instructed to conduct their own experiments, he still makes sure he sets up the apparatus of the experiments for all the groups before he lets any learner touch anything. The learners only start to conduct the experiment after the setup of the apparatus is ready

for use. He still continues to give step by step instructions to learners supervising every action that they perform checking on how they handle the equipment.

Two reasons can be considered as to why he limits the handling of materials by learners. First, he expressed his concerns about learners' tendency to vandalise equipment in the laboratory:

The other challenge is that these learners when they are exposed to these equipment some learners can damage the equipment without you the teacher noticing that they are damaging them you can't control them as a teacher because the numbers are too high more than 35 or more.

For this reason he feels there is a need for him to make sure learners do not break anything by allowing them minimum contact with the equipment. The materials in the laboratory are already in short supply and most of them are acquired through donations from non-governmental organisations. Therefore, it is reasonable to hold on to the materials for longer before there is a need replace them. This is compounded by the fact that there is only one science laboratory in the school and teachers take turns to use the laboratory with their learners.

Second, it can be considered that learners have limited exposure to laboratory activities in which they handle materials and equipment and, therefore, may not have the knowledge and skills to successfully set up apparatus for experiments for the following reasons. First, Kabelo cited time constraints as inhibiting effective laboratory work practice:

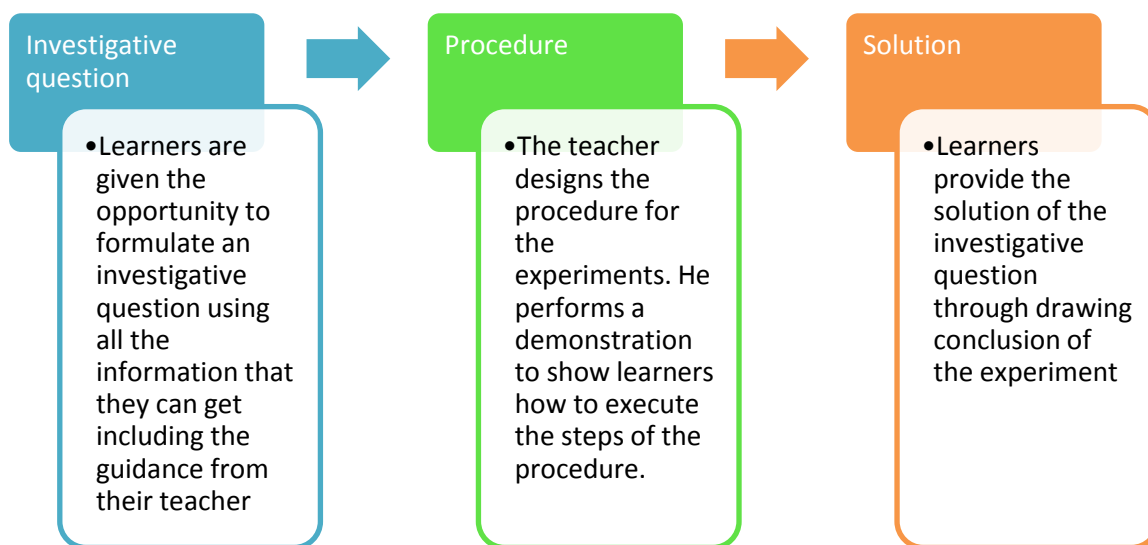
If it is 40 or 30 minutes of what you have as a lesson you must teach and at the same time do experiments and you know that experiments are not like teaching the learners must assemble this and that must do trial and error so time is running out by the time the period is over which means that time is not conducive for you to do all the experiments to such an extent that we are not able to do some of the experiments and so you just do them theoretically because of time.

Third, the classes are usually large resulting in learners working in groups of 8-10 learners. In such circumstances not all learners are able to be in contact with materials. The materials are also in short supply and this has been alleviated by the incorporation of computer technology which enables learners to observe simulations of experiments and experiments that conducted using one apparatus, record results that they can analyse and

interpret. However, the net result is that learners have limited contact with materials and equipment.

There is evidence that emphasis on the use of the scientific method ensures that every time an experiment is conducted learners and teacher have an opportunity to reflect on the investigative question and the procedure of experiment as well as solution of the investigative question as they draw conclusions amongst other tasks that constitute the scientific method. What has been evident is that Kabelo may encourage learners to formulate an investigative question and provide the solution when they draw conclusions but he designs the procedure of the experiment for them. He even conducts a demonstration to show learners the steps of the procedure as well as setting up the apparatus for them.

Figure 4.9 The level of inquiry of Kabelo’s laboratory practice



4.6.3 Learners figure out the procedure

In this section learners were provided with the investigative question and its solution. They were asked to design the procedure of the experiment.

4.6.3.1 Tendai from a former Indian school

Grade 11 learners were observed conducting experiments to prepare copper (II) carbonate in the laboratory. There was no worksheet for the experiment but learners could refer to textbooks to get any information that could assist them. The teacher presented a problem to learners on how they could produce copper (II) carbonate in the laboratory. She used questioning techniques for the learners to identify the soluble salts that they could use as reactants in a chemical reaction to produce copper (II) carbonate. The teacher wrote the formulae for the salts on the chalkboard as they were given by learners.

As Tendai used questioning techniques for learners to identify the soluble salts they should use for the experiment, she articulated the investigative question. The learners were able to identify the soluble salts because the solution to the experiment was known. Learners knew that they should prepare copper (II) carbonate.

With the investigative question and the solution of the experiment known, learners were supposed to design the procedure using all materials like textbooks, except for the teacher's help. A learner said:

We first do like for an example we will write. We will discuss like what we will do in the equations and what will happen the previous day. And on the same day we take out the chemicals for tomorrow's experiment so when we come to class tomorrow we can be organised (Rashid, Grade 11).

The learners found the process of figuring out the procedure of the experiment challenging hence they wished they could get more help from their teacher. They had to identify the materials and equipment as well as the steps of the procedure of the experiment. Learners might find themselves not sure and experience moments of uncertainty as they tried to figure out how they should conduct the experiment. As they go about devising the method of the experiment they were filled with anxiety:

The teacher should just help us along the way because sometimes we get confused. We don't know exactly how it should look or what should be happening so she can at least just guide us in the beginning like this is going to happen or this is not supposed to happen or this is what might possibly happen, this is the precaution you must take and stuff like that, and also she must not blame us too much you see. Sometimes we do mistakes we must learn from our mistakes (Omar, Grade 11).

Discussion on Tendai's IBLW practice

Tendai is an experienced teacher who has had exposure to laboratory work from school through to teachers' college. Tendai believes she acquired a 'solid foundation' in the practice of laboratory work. She believes that her learners should also be exposed to laboratory work activities the way she experienced them when she was in secondary school. About her laboratory work experience she said, "I don't know how to put it. At school if we did practical work it was twice a week." This sentiment was also echoed by her learners when they were asked about the frequency with which they do laboratory activities. One learner said, "I would say at least twice a week." Tendai makes attempts to mirror her school experiences into her current practice in laboratory work.

Tendai was proud to say that she had groomed some learners that she managed to teach from Grade 10 and that these learners prefer to do the experiments themselves instead of her conducting some demonstrations. She even said that if it was not for the time constraints she would be able to conduct more experiments with her learners. It is important to mention at this point that the laboratory activity that Tendai was observed facilitating for her learners was not an assessment task but just one of the lessons that she uses to implement the curriculum. Also it may be important to mention that Tendai's teacher professional identity that defines her to be well grounded in the practice of IBLW is recognised by her colleagues who approach her for advice and mentoring.

A number of reasons can be put forward as to why Tendai ensures that her learners frequently engage in laboratory activities. First, she generally believes science is taught and learnt through practical work. She said, "With practical work I just told myself discovery is the best way of them learning so that they understand more I think."

Second, she interprets the current curriculum as stipulating that teachers should facilitate more laboratory activities for their learners than in the previous curriculum. This can be seen when she said, "Since we are getting this new curriculum which actually needs us to do a lot of these activities I think there's a need for increased time allocation."

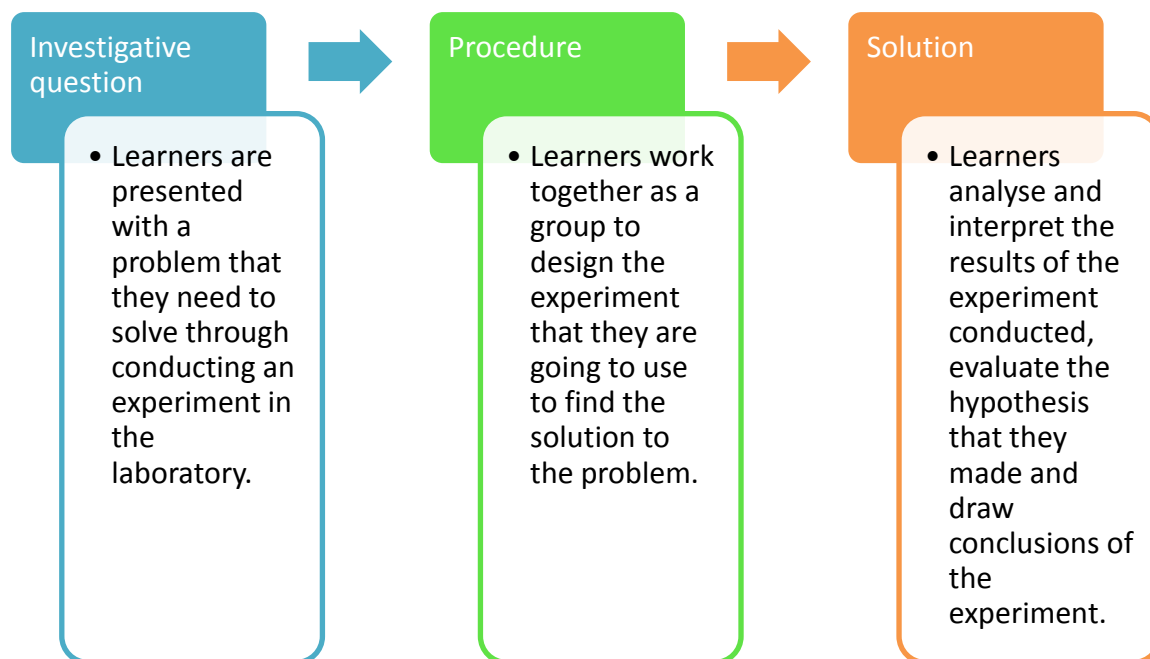
Third, she believes that for her learners to do well in university if they pursue science-related study programmes, they should have a solid foundation in the practice of laboratory work and that they should acquire this in school. Fourth, Tendai uses laboratory activities to engage all learners in learning science actively because she observes that all learners are able to use their hands to handle materials and equipment in the science laboratory irrespective of their general performance in the subject.

Although Tendai cites time constraints as one of the challenges that act as a hindrance to effective laboratory work practice, she still manages to regularly conduct experiments with her learners without even engaging in extra lessons after school. Tendai would even be prepared to incorporate computer technology in her laboratory practice if the facilities were available.

It is also important to point out the favourable conditions from the contextual setting of the school that promotes Tendai's IBLW practice with her learners. First, her learners are very cooperative according to her observations. She even said that she does not have any complains about the learners' behaviour. Second, the laboratory has sufficient materials and equipment for her to conduct laboratory activities with the learners. Third, she is able to receive professional development support through workshops to train her in the new trends in the practice of IBLW.

Tendai's IBLW practice has her giving the learners a problem that learners should solve by way of conducting an experiment. Therefore, if she presents the learners with a problem, she expects them to design the procedure of the experiment in order to get to a known solution to the problem.

Figure 4.10 The level of inquiry of Tendai’s laboratory practice



4.6.4 Learners figure out the investigative question and the procedure

The IBLW identity position in this section is such that learners are exposed to the solution of the experiment and they are expected to formulate the investigative question and design the procedure of the experiment.

4.6.4.1 Farai from a private school

Learners were observed conducting a laboratory activity in which they were tasked to design an experiment to investigate the effect of surface area on the rate of reaction. Learners would then conduct the experiment that they designed and write an experiment report using the format of the scientific method with the following headings: Investigative question, Hypothesis, Variables, Aim, Apparatus, Method, Observation/Results, Interpretations and Conclusion/Evaluation. Learners do not have a worksheet since they have to design their own experiment.

Farai explained how he puts his learners in situations where they have to design the procedure of the experiment. He shared his experiences on the rationale behind the method that he uses when engaging learners in laboratory work. His method provides opportunities

for learners to make the most of verification experiments by creating avenues for learners to engage in meaningful inquiry:

Then given such a situation it forces them to do the right thing. It forces them to do it the right way and they can't cheat because they know what they are supposed to get and they know you know what they are supposed to get. If you realised earlier on I would tell them that fine you have done the experiment you have collected the gas but as long as the gas doesn't produce a positive test then something somewhere is wrong and you have to re-do it.

Farai is aware that most the experiments that he facilitates for learners are verification experiments. However, he engages them in inquiry by asking the learners to design an experiment to produce the expected results. Therefore, learners are expected to formulate the investigative question of the known solution and then design the experiment to get the particular solution. Farai used the laboratory activity that he was observed facilitating for his learners to explain his methodology:

What I did was that since this one was more of a verification experiment, the question came from them even the whole experimental report. They need to know all the topics and sub-topics of that experimental report that they have to produce. The learners came up with the procedure. On the solution from what I was checking when they were doing (the practical activity) they could easily tell by using the theory.

Learners confirmed that they already had the solution of the experiment:

The thing is he taught us about rate of reaction before so when we do the experiment we know what we are expecting from a certain experiment. Like you already know what the outcomes are supposed to be like. In this case we know how the graph is supposed to be like in the rate of reaction.....so when we record our results we expect it to be more or less or at least more or less like the graph (Thabiso).

Learners also shared how they prepare themselves so that they might be able to construct the investigative question and design the experiments. Learners said before they conduct an experiment they read about the topic:

We research the topic before we go to see how the experiment can be conducted and what we are going to need. We research about it beforehand so when we get there we are not completely blind. We know what we want and how to get there (Jill, private school).

Discussion on Farai's IBLW practice

Farai is an experienced science teacher whose school laboratory experiences have had an impact on his beliefs on laboratory practice. He developed an interest in laboratory activities when he was still in school. Although his teachers' college experiences with laboratory work were not as intensive as the school experiences, they worked to consolidate his skills and knowledge. Farai is also actively involved in making sure that laboratory work is meaningfully incorporated in the teaching and learning of science not only in his school. He facilitates workshops for teachers to help them to facilitate laboratory work for learners. He is also currently involved in the development of an experiment workbook that will enable teachers who are working in under resourced schools to meaningfully engage learners in practical work in science.

Farai creatively uses verification experiments to engage learners in meaningful inquiry activities. One way in which he does it is through giving learners a problem for which the expected results may be known by the learners. In the problem he will ask the learners to design an experiment that they can use to solve the problem. In the laboratory activity that he was observed facilitating for learners he asked them to design an experiment to investigate the effect of surface area on the rate of reaction. Learners may already have a solution to the problem but they must design an experiment that will give the expected solution. One learner corroborated this when he said:

How to do an experiment I have learnt from getting it wrong all the time. I did it like this is the first time I can't do it like this is probably how it's done so that's how we learnt. He has never really shown us how to...taught us how to do a proper scientific experiment (Thapelo).

Another learner confirmed this when she said:

The thing is he taught us about rate of reaction before so when we do the experiment we know what we are expecting from the certain.. like experiment. Like you already know what the outcomes are supposed to be like in this case we know how the graph is supposed to be like in the rate of reaction. So when we record our results we expect it to be more or less at least more or less like the graph (Kagiso).

An explanation can be put forward on why Farai encourages learners to design experiments. An examination of his beliefs reveals that he feels that science is a two pronged discipline consisting of the theory and the practical work. These two components

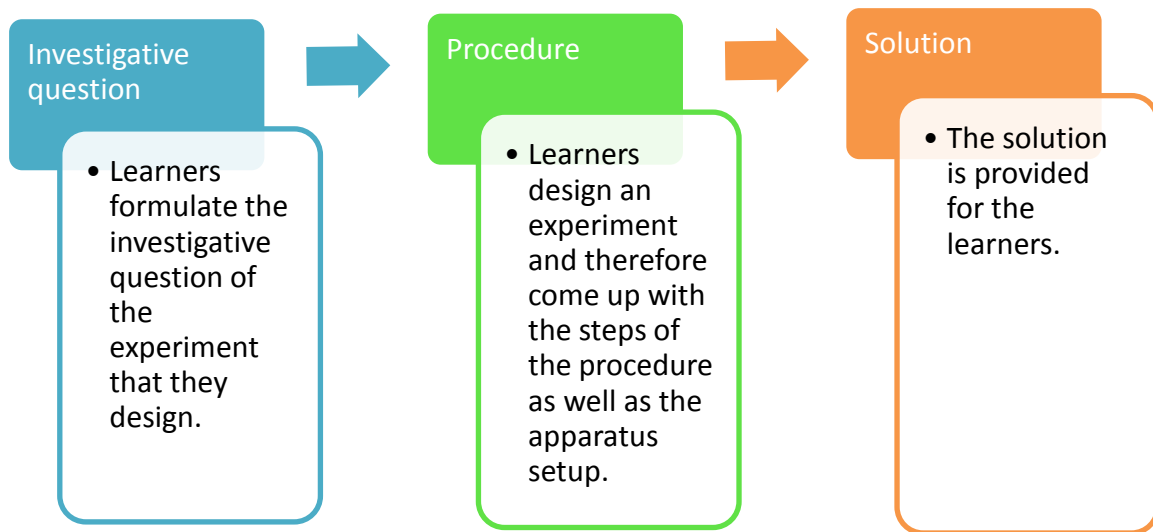
should be made manifest in the teaching and learning of science. He believes that the exclusion of practical work results in learners obtaining an incomplete development of scientific knowledge and skills. He went to great length to passionately explain why science should not exclude practical work:

If you are just doing it erratically or as per requirements of the syllabus then it's unfortunate that you don't really get good results. Fine you may get good results but deep down in you, you know that it's not really a good thing that you have because the students don't have that proper understanding because they just have the theory but the practical is lacking.

Although he firmly believes that laboratory work has to be incorporated in the teaching and learning of science, he realises that most of the time theory is taught first. Working against this background he has to come up with a method of engaging learners in inquiry while verifying theory. Therefore, one way that he uses is for learners to design experiments. In these experiments learners get an opportunity to formulate an investigative question and develop the procedure of the experiment. These kinds of laboratory activities need sufficient time of about two hours or more because the learners do the planning of the experiment during the laboratory session. This is why he conducts this kind of laboratory work with learners after school.

For experiments demonstrations that he conducts in class he incorporates technology so that the learners are able to observe the experiments on projectors and collect results that they analyse, interpret and draw conclusions from on their own. By incorporating technology in laboratory work and by having laboratory sessions after school Farai has managed to find ways of overcoming the challenge of time constraints.

Figure 4.11 The level of inquiry of Farai’s laboratory experience



4.7 Chapter summary

This chapter has presented the findings made from the data collected for this study under the themes personal identity expression, contextual settings and teacher professional identity positions in IBLW practice. Although the process of analysing the findings may have begun as they were being presented, the following chapter will solely present a comprehensive analysis and discussion of these findings. This will be Chapter 5 of the study which deals with the analysis and discussion of findings.

CHAPTER 5

ANALYSIS AND DISCUSSION OF FINDINGS

5.1 Introduction

This chapter presents the analysis and discussion of study findings. The presentation of the discussion has been organised under the following topics. First, the presentation is on how the findings of the study reflect the findings made in the reviewed literature under the heading “Echoing the literature”. Second, a discussion on some subtle differences that may be noticeable between literature findings and findings of the study is presented. Third, the presentation turns to point out aspects of the findings in the reviewed literature that did not come as findings in this study under the heading “Areas of silence in the study”. Fourth, the discussion focuses on how the study findings engage the theoretical framework of this study. Fifth, the presentation focuses on study findings that contribute to the body of knowledge because they are considered to be falling under areas of silence in the reviewed literature under the heading “Generation of new knowledge”. The analysis and discussion aims at unravelling the intellectual puzzle of: *How does teacher professional identity interface with the practice of IBLW in school chemistry?*

5.2 Echoing the literature

There are similarities between findings in literature and the findings of this study. The following aspects of teacher identity shapers were of significance in this study: teacher professional training and development; contextual settings and learner populations; sense of agency and personal identity features in the form of teacher perceptions and beliefs, motivation, commitment, narratives, prior school experiences. Teacher professional identity positions in IBLW in this study are compared with positions in the literature reviewed in Bretz and Fay (2008) and Fay et al. (2007).

5.2.1 Teacher training and teacher professional development

Internationally it was found that teacher training and teacher professional development play a very crucial role in shaping teacher IBLW professional identities as was the case with this study. One of the general aims of teacher training programmes is to develop particular teacher identities (Edwards & Blake, 2007; Malderez et al., 2007; Monereo, 2010). It provides teachers with the necessary knowledge and skills to enable them to facilitate IBLW for learners (Beauchamp & Thomas, 2009; Settlage et al., 2009; Battery and Fanke, 2008; Coenders, 2010; Sterling & Frazer, 2010, Stolk et al., 2010). Locally authorities agree that teachers need to be exposed to continuous professional development, especially with the constant changes made to the curriculum (Bantwini, 2010; Stoffels, 2006; Jita & Vandeyar, 2006; Vanger et al, 2007). Most teachers in this study considered themselves to be sufficiently prepared as professional teachers who can effectively engage their learners in meaningful laboratory work. Five of the seven teachers in this study have a science teaching qualification from a university and two have diplomas in science education. It can be concluded that they are all qualified physical sciences teachers.

Hick (2008) points out that, teachers who practice reform have student-centred beliefs that they acquired during their teacher training programmes. Some outcomes of purposeful professional identity development of teachers by teacher training programmes were observed in some participants in this study. Jane (former model C school) and Kabelo (African township school) show tendencies of incorporating the Science-Technology-Society-Education (STSE) philosophy as they facilitate laboratory work for their learners. The approach aims at making science relevant to societal needs such as ordinary life activities (Solomon and Aikenhead, 1994; Aikenhead, 2003). Predetti et al. (2008) are advocates for the implementation of programmes that purposefully shape pre-service teacher identities to align with STSE reform drives. Jane uses laboratory work as a way of revealing the relevance of science to everyday life by applying scientific knowledge to solve real life problems. Kabelo always makes sure he alludes to situations in life in which the learners can apply the science knowledge to help them make sound and good decisions during laboratory work activities.

Literature in South Africa highlights the constant educational reforms (Jansen, 2007; Msila, 2007; Parker, 2006; Bantwini, 2010) and authorities like Stoffels (2006) bemoan little professional development for teachers in line with the reforms to address what Jita and Vandeyar (2006) observe as a gap between policy and teacher identity. IBLW as one of the strategies under inquiry teaching and learning is a relatively new policy drive in the South African education system which came with the massive education reforms (Bantwini, 2010; Vanger et al. 2007). Teachers would need to go through professional development exercises. Although Stoffels (2006) complains of little professional training being availed for teachers, in this study participants were found to be actively involved in professional development exercises in one form or the other.

From the findings of the study there is a drive to introduce laboratory micro kits in the school districts in which this research was conducted in line with the CAPS syllabus. Teachers like Jane (former model C), Tendai (former Indian school) and Kabelo (African township school) had recently undergone professional development on the use of the materials. Some of the teachers like Farai, Betty, Tendai and Jane even assume facilitator roles during the teacher development exercises and mentoring roles in and around their schools in laboratory work. Betty's experiences with professional development takes a different shape because she is in a private school that does not rely on the Department of Education for professional support. The teachers in the science department get together to develop workbooks for all the practical activities that learners should engage in for each school year. This serves as professional development for the teachers. Melusi's work as teacher is a bit more specialised because he mainly focuses on facilitating laboratory work for learners. He received specialised training for that.

The findings in the study seem to indicate that for teachers to successfully implement laboratory work they need to receive professional training and continuous professional development. Professional training and development is an indispensable tool in the shaping of teacher identities and it sometimes determines the orientations of the identity positions. Teachers usually develop beliefs and perceptions about IBLW during teacher professional

training and development in line with science educational goals (Predetti et al., 2008; Hofstein & Lunetta, 2003). This is consistent with findings by Kang and Wallace (2005) who propound that teachers' epistemological beliefs explain their teaching practices.

Continual teacher professional development has been observed to be critical in empowering teachers with skills and knowledge in laboratory work. Professional development in this study resulted from continued classroom practice, attending workshops aimed at addressing issues in laboratory practice, facilitator and mentoring roles assumed by teachers in laboratory work in and around their schools and through the development of materials such as workbooks for experiments as in the cases of Farai and Betty, both in private schools.

Teachers also acknowledge the role played by their college and university experiences with laboratory work in contributing to the development of the knowledge and skills that they have. This is very significant for Melusi (African rural school) who received specialised training to handle and manipulate the technologically advanced equipment and materials that he uses for laboratory work with his learners. The equipment may not be used by any teacher who did not receive the training. This is corroborated by Hofstein and Lunetta (2003) saying that a science laboratory is a unique environment and teachers should go through experiences by way of professional training or development for them to be able to facilitate practical work that is meaningful and effective for learners.

Jimmy (former Coloured school) had no school experiences with laboratory work activities and very limited university experiences with laboratory work. When he went for teacher practice during the fourth year of university, he did not have the confidence in his knowledge and skills to engage learners in laboratory work. For this reason he had to find a mentor who would help him with professional support every time he planned to engage the learners. This demonstrates the important role played by professional training and development in IBLW practice.

This support and training has potential to transform teacher identity positions in the wake of contextual challenges. The introduction of laboratory kits in schools and training for teachers empowers both teachers and learners to conduct practical activities not only in laboratory setups but also in other places like ordinary classrooms. This kind of intervention would be very helpful in the African and former Coloured schools in this study where resource availability is scant as compared to schools from other contexts. Kabelo (African township school) finds these professional development exercises useful because he said they give him an opportunity to discuss the ‘difficult’ experiments with colleagues and facilitators of the workshops. Therefore, professional development affords him an opportunity to keep transforming his laboratory work. Even in schools that enjoy favourable conditions for laboratory work practice by way of availability of laboratory facilities, this training is like a shot in the arm because it opens up more avenues for teachers and learners on how to practice laboratory work.

5.2.2 Contextual settings and learner populations

Internationally and locally studies allude to the significance of contextual settings to the successful implementation of IBLW both in a direct way and indirectly (Vanger et al., 2007; Hattingh et al., 2007; Stoffel, 2005; Coenders, 2010). Contextual settings is a very broad theme since schools vary in nature and form because they have their origins in the political, social and economic systems in place (Lasky, 2005). It is not feasible to attempt to discuss all the aspects of school contextual settings here. For this reason contextual settings are discussed broadly according to the categorisation of schools in African, private, former Coloured, former model C and former Indian schools. However, time constraints and learner populations as contextual setting issues receive particular attention in the discussion because of their significance as themes that emerged prominently.

Internationally and locally when authorities say that factors like school environment, nature of learner population, the impact of colleagues and school administrators play a part in the shaping of teacher identity (Beauchamp & Thomas, 2009; Roehrig et al., 2007; Bantwini and King-McKenzie, 2011) they agree that contextual settings form part of teacher professional

identities. Findings of this study highlight how time constraints, learner populations and availability or lack of laboratory equipment influenced how teachers structured learner inquiry actions during laboratory work.

This study was taken to different contextual settings and also to schools with different learner populations. The contextual settings have historical significance because they have developed from the school settings that existed before the dawn of independence which saw the abolishment of categorisation of education along racial lines. This saw the end of an education system divided into Black education, White education, Indian education and Coloured education schools (Ogunniyi, 2013; Selod & Zenou, 2003; Lewin, 1995). However, new categorisations emerged such as former model C, former Indian, former Coloured, African township and African rural among others (Selod & Zenou, 2003). Before independence the categorisation of education into classes was significant because this had implications on the distribution of resources whereby it was not equitable. White schools got the lion's share of the resources followed by Indian schools then Coloured schools and finally Black schools (Ogunniyi, 2013).

Although an education system which functions along racial lines has been put to an end in South Africa, some schools still enjoy better infrastructural settings than others. The findings of the study revealed that the formerly disadvantaged schools are still relatively disadvantaged. The reasons for the schools to continue being disadvantaged may have their sociocultural roots traced to the period of apartheid in the country. Lasky (2005) propounds that political, social and economic conditions determine the nature of school reforms which, in turn, have the potential to shape teacher identity.

Findings of the study revealed that there is a disparity in availability of laboratory facilities in terms of infrastructure, equipment and materials when comparing schools from different contexts with similar learner enrolment of about 1500 learners. The African township school had one science laboratory. The African rural school had no science laboratory. Equipment and materials are carried and set up in classrooms. The former Coloured school had two

science laboratories. This is quite different from the situation in the former model C, former Indian and private schools which each have four science laboratories.

This scarcity of materials in the less fortunate schools impacted negatively on the frequency with which learners are engaged in laboratory work which, in turn, negatively impacts on the development of skills and knowledge in laboratory work and inquiry activities. The poor development of knowledge and skills in laboratory work seemed to inform the decisions made by teachers on how to structure practical activities in terms of the inquiry actions that learners engaged in. Kang and Wallace (2005) point out that teacher practices respond to learner needs. This is corroborated by Flores and Day (2006) and Milne et al. (2006) when they point out that contexts influence teacher practice because they can either be challenging or supportive. Flores and Day (2006) propound that contexts are capable of reshaping teacher identities.

The participating teacher in the African township school was observed to consider how best he could protect the equipment and materials from damage during laboratory activities so that they lasted longer since the school was not in a position to replace them easily. This made Kabelo to restrict learner independence as they handled materials and equipment by setting up the apparatus for them so that they could later go through the paces of the experiment while he watched them closely. If Kabelo has a need to set up apparatus for his learners, it follows he has to design the steps of the experiment procedure and not leave it to be done by the learners. Kabelo's actions can be contrasted to the actions of teachers in the private, former Indian and former model C schools where shortages of laboratory equipment and materials were not reported. In these schools learners were allowed to handle and manipulate equipment and materials freely.

The sufficient supply of materials may lead teachers to let learners set up apparatus for the experiments but this may not necessarily lead the teachers to let learners design the steps of the experiment procedures. Study findings reveal that from the four well-resourced schools in this study, learners were allowed to design steps of experiment procedures in two of the schools while teachers designed experiment procedures in the other two schools. This suggests

that the decision to let learners design the steps of experiment procedures does not solely depend on the availability of laboratory materials although it may be part of a whole set of complex issues around teacher identity position. The former Coloured school with learner enrolments of over 1500 has two laboratories in the school which are also used as classrooms to teach other subjects because of the dire shortage of space to accommodate learners. This has negative implications on the laboratory time that the learners can be exposed to and on the materials available for meaningful laboratory work practice.

The infrastructural conditions prevailing in the two African schools and the Coloured school are in sharp contrast to what was observed in the two private schools, the former model C and the former Indian schools. The former model C, private and former Indian schools with the same learner enrolments like the African township and former Coloured schools of over 1500 have four laboratories each. A teacher is based in each of the laboratories. Science teachers do not share laboratories. Learners take turns to come to laboratories when it is time for science. It makes it possible for science to be taught in the laboratory every time. These settings make it possible for learners to constantly enjoy laboratory work time.

The situation improves when it comes to Betty's private school. With lower learner enrolments the school has four science laboratories. Besides having each of the four science teachers working in his/her laboratory, the school also has two laboratory assistants to help the teachers in the maintenance of the laboratories and preparation of materials. Learners can have more laboratory time because they even come to prepare for their experiments during their free periods and the learners who are in the science club have access to the laboratories for their activities.

The above study findings help to show how sociocultural issues play a crucial role in the shaping of school contextual settings because Lasky (2005) says they have their origin in the prevailing political, social and economic systems. The African schools in this study are still to a large extent relatively disadvantaged when compared to schools from other contexts.

The trends in the availability of laboratory materials and equipment per school context do not seem to point to any particular IBLW teacher identity position in this study. It cannot be said from the findings of the study that in schools where there are shortages of materials teachers tend to assume particular IBLW teacher identity positions. Some teachers from well-resourced schools were observed to assume the same identity position as teachers in schools that are under-resourced. Betty (private school), Jane (former model C), Jimmy (former Coloured) and Melusi (African rural) were observed to take up the same IBLW teacher identity positions when facilitating laboratory work for learners. They provided learners with the investigative questions and the procedure of the experiments and learners were expected to figure out the solutions. It also follows that some teachers who frequently engage learners in laboratory work activities resulting in learners having developed equipment manipulative skills were observed to assume the same identity positions as teachers who engage learners in laboratory work once in a while. Learners who do not engage frequently in laboratory work struggle when it comes to equipment manipulation and material handling in the laboratory.

The categorisation of the schools in terms of them being private, former model C, African, former Indian and former Coloured seems to have implications on the availability of laboratory facilities in schools. African schools seem to be the hardest hit by the shortage of materials and equipment for use in practical work. However, what is interesting is that the study findings do not link any contextual setting to any teacher IBLW professional identity position. The most common teacher IBLW position in the study is practiced by four of the teachers. These are Jane (former model C school), Jimmy (former Coloured school), Melusi (African rural school) and Betty (private school). Since contextual settings in terms of private, former model C, former Indian, former Coloured and African school could not explain teachers' IBLW professional identity positions, it implies that lack of resources or availability thereof may not directly explain why teachers practice laboratory work in the manner that they do.

The observations made in the above discussion on school socio-cultural contexts allow for this study to conclude that conditions of laboratory facilities, materials and equipment may not

directly determine the IBLW identity position assumed by teachers. This conclusion is based on the observation that teachers working in laboratory conditions with similar provisions of laboratory materials and equipment assume different identity positions. Just as teachers working in laboratory settings that lack in materials and equipment may assume the same IBLW identity positions displayed by teachers in laboratory environments that are sufficiently supplied with materials.

Time constraints

Internationally and locally literature mentions time constraints as one of the challenges that stand in the way of effective practice of IBLW (Chueng, 2007; Stoffels, 2005; Stoffels, 2006). In the South African context Stoffels (2005) describes time constraints as intensification of workloads in which teachers have so much to do in a limited time. Chueng (2007), mentions that time is one of the factors that stand in the way of effective laboratory work practice. Study findings identified certain factors in the school settings that play a significant role in the shaping of teacher IBLW professional identities. One of them is time constraints. Teachers from all the school contexts complained of time constraints as inhibiting them as they work to facilitate laboratory work for learners. In some instances teachers directly considered time constraints in determining the teacher actions and the learner actions in the formulation of investigative questions for experiments. Betty (private school) realises that if she allows her learners to formulate the question it may take them some time and, therefore, they may fail to complete other tasks of the laboratory activity. She is compelled to provide the investigative question for the learners. She said “We often give them the question because to let them go and pose a question takes too long.”

Jane (former model C school) after emphasising how time is always a constraint in the school revealed that she also provides her learners with the investigative question. Although she does not directly link time constraints to why she provides her learners with the investigative question in her narrative, it can be concluded that just like Betty (private school) letting the learners try and figure out the investigative question will require more time that she doesn't have. Study findings also point to the notion that time constraints inform teachers on how they

determine teacher actions and learners' action when it comes to the designing of experiment procedures.

Five out of the seven teachers in the study provide their learners with experiment procedures. These are Jane (former model C school), Jimmy (former Coloured school), Kabelo (African township school), Melusi (African rural school) and Betty (private school). Time constraints seem to be the reason teachers do not let learners design the procedures of the experiments. This is quite evident from Jane's narrative. She realises that her learners need some time to be able to come up with the procedure. She said, "We try to give the girls the instructions that are very clear and precise so that they don't have to spend half an hour trying to figure out what they should do."

An analysis of worksheets for Jimmy (former Coloured school), Melusi (African rural school) and Betty (private school) revealed that experiment procedures are already written out for the learners. This can be seen as concerted efforts by teachers to make sure they are able to conduct and complete practical work activities in the time that is allocated for science lessons. All the teachers confirmed that they rarely finish all the tasks of an experiment in one lesson. Teachers seemed to feel that if they can provide the learners with the investigative question and lay out the procedure of the experiment for learners there will be enough time for learners to conduct the experiment and collect results. Once they collect the results they can continue with the analysis and drawing up of conclusions in their own time.

Time constraints is one of the contextual setting issues that seemed to contribute in informing teachers to structure laboratory work activities in which experiment questions and procedures are part of the content availed to learners. This is done as a measure to ensure practical activities are completed within allocated lesson times.

Learner populations

Learner populations internationally have been observed to be one of the issues in contextual settings that interface with teacher professional identity (Beauchamp & Thomas, 2009) and

that may direct teacher practices (Kang & Wallace, 2005). In this study learner populations were observed to play a role in informing teachers on how they decide on learner actions and teacher actions in the process of posing an investigative question, designing experiment procedures and giving a solution to the investigative question. In this study learner populations manifested in three ways in which they interface with teacher professional identity positions. These are learner attitudes, learner knowledge and skills and learner disciplinary issues as indicated by emerging themes.

Learner attitudes, knowledge and skills in laboratory work and disciplinary issues were some of the aspects that teachers in this study would take into account when determining learner inquiry actions. These aspects were observed to either inhibit or promote teacher actions to structure practical activities in a manner that allows learners to gain more autonomy over formulation of questions, design of procedures and articulation of solutions. With learner attitudes there were cases in which learners showed a marked interest in laboratory work which resulted in them showing a willingness to complete certain tasks successfully. This is contrasted with cases where the teacher knows beforehand that learners may not be able to successfully engage in certain inquiry tasks because of their negative attitudes.

Tendai's experiences (former Indian school) show how learner attitudes towards laboratory work enable her to let learners design procedures of experiments after she gives them a problem that seeks a desired and known outcome. In the activity that she was observed facilitating for learners, she requested learners to prepare copper (II) carbonate in the laboratory. Learners managed to work in their groups to determine what they needed for the experiment and how they would conduct it. The picture below shows learners who could be left to work by themselves to figure out the steps of experiment procedures in a set time and be able to finish the task.



Picture 5.1 Learners cooperating in designing the procedure of experiment

Tendai's Grade 11 learners managed to figure out the procedure of the experiment during one laboratory session and conduct the experiment. This is possible for her because, as she revealed, the learners are very cooperative and enthusiastic about practical work. If she asks them to design procedures of experiments they are ready to do it. They are the kind of learners who would rather conduct most of the experiments themselves than let her demonstrate for them. Tendai says the following about her Grade 10 learners, "They want to handle things themselves."

When Tendai talked about grooming her learners she was referring to her efforts in making sure that the learners develop knowledge and skills in laboratory work practice. She is very conscious of what she wants to achieve with laboratory work which is not just consolidation of scientific concepts but also making sure that they become a capable generation of laboratory work practitioners in future. She showed signs of impatience at her learners because they had not yet developed sufficient knowledge and skills in laboratory work.

Tendai's narrative does not allude to any disciplinary issues on the part of learners. She complained of only a few learners who do not take time to read ahead on the practical activities they should be conducting. She said they usually take longer than anticipated to complete their tasks on the day of the experiment. The case of Tendai shows how learners' attitudes, knowledge and skills and disciplinary issues can inform teachers on how to plan learner and teacher actions during practical activities.

In contrast to Tendai's learners, Jane's learners (former model C girls' high) may find the task of working together as a group to come up with an experiment procedure to be very challenging and they may not complete it successfully or finish in the allocated time because they hate working in groups. They revealed that working in groups is very difficult for them. They like working in pairs as friends but Jane seemed to have observed this because she makes sure she arranges them in groups when they come for the practical activity. She said she does this to ensure that they all prepare for the activity because they won't know who they will be working with. The learners feel strongly about working in groups because they feel it is difficult to agree on anything when they are not close friends. One learner gave the reason by saying, "We all have different opinions."

For Jimmy (former Coloured school) the situation is quite different. Jimmy's learners are not very eager to take part in the handling and manipulation of materials during practical activities. He said they just watch indifferently most of the time without showing signs of an interest in the practical activities. These are the learners whom, according to Jimmy, display unruly, rowdy and chaotic behaviour most of the time. The learners, according to Jimmy, have a tendency to vandalise laboratory equipment at every opportunity. He said teachers in the school are always working hard to keep them under control so that they may settle down to let the process of teaching and learning take place.

Some of Farai's learners (private school) are also not too keen to engage in practical work. He manages; however, to engage them actively each time he facilitates laboratory work for them. Farai observed that some of the learners do not see the importance of laboratory work and take

it as an opportunity to play and not take their work seriously. Therefore, he structures the laboratory activities in such a manner that compels learners to actively participate in the activities. This is in agreement with the notion by Hofstein and Lunetta (2003) that students' behaviour in the laboratory is to a great extent directed by what teachers expect of them. Farai realises that most experiments that they conduct are mainly for verification; therefore, he tasks the learners to design experiments to achieve desired results to ensure that learners engage in some form of inquiry. He makes sure they do not cheat by testing the gases that are produced from the experiments. If the gases test negative, he makes them repeat the experiments. This is in contrast to providing learners with procedures which they can just follow like a recipe. Some of the learners are not happy to be going to all this trouble. They are not too keen to do all the work involved in the process of designing an experiment and conducting it because they are not really sure whether they are doing the correct thing. The teacher does not give any input except to test the gases at the end. Learners find this challenging as one learner complained, "I have learnt how to do an experiment from getting it wrong all the time."

When teachers realise that learner skills and knowledge are not well developed for the learners to attempt the inquiry tasks at hand, they provide them with guidance and assistance which may mean that the teacher will formulate the investigative questions and design experiment procedures and then leave learners to use the collected results to articulate solutions. Poor development of skills and knowledge may be as a result of infrequent learner engagement in laboratory work activities because of material and equipment scarcity. Here are examples from the study from the former Coloured school and the African rural school of how poor development of knowledge and skills manifested themselves.

A number of observations were made when Jimmy (former Coloured school) was facilitating laboratory work for his learners. First, Jimmy provides guidance to his Grade 10 learners almost in everything that they do during the experiments. He is ready to take over the handling of material and manipulation of equipment when he sees that they are not doing it correctly or when he feels that they are making little progress. This is after he would have provided the investigative question to learners and conducted a demonstration to show learners how they

should follow the procedure of the experiment. Although the provision of an investigative question and the procedure of the experiment may be a way of cutting down on time wasted so that activities may be completed in a lesson, Jimmy may also be aware that his learners may not be able to successfully come up with an investigative question or procedure of an experiment. Learners' skills and knowledge for those inquiry processes might still be under developed.

The same applies to Melusi's learners (African rural school). Learners are not frequently engaged in laboratory work activities because the school does not have a laboratory and they rely on the services provided by Melusi each time he manages to put them on his schedule. It follows that learners' skills in laboratory work are under developed. Melusi has to provide the investigative question, experiment procedure and guidance throughout the activity so that the learners may be able to conduct the experiments.

Disciplinary issues were observed to have a significant impact on teacher decisions on whether learners may be left to perform particular inquiry actions by themselves. In the African township and former Coloured schools learners portrayed certain behaviours bordering on indiscipline. The indiscipline manifested itself as playfulness, naughtiness, and tendencies to vandalise and remove equipment and materials from the laboratory without being seen. This scenario seemed to force teachers to put measures in place as they facilitate laboratory work for learners and some of the measures had a direct bearing on what inquiry actions would be performed by the learners. Teachers may not allow learners free manipulation of equipment and materials to perform trial and improvement of experiment procedures because they want to prevent damages and theft of materials and even to prevent learners from hurting themselves.

It was observed that Jimmy mounted one apparatus on which learners would investigate the relationship between acceleration of a moving object and the slope of the plane on which the object is moving. Groups of learners took turns to come and perform the experiment under his close supervision. By maintaining close supervision Jimmy makes sure the learners focus on

the task at hand and they also do not take the opportunity to fiddle with the delicate equipment in the way that they should not. Jimmy keeps most of the equipment and materials locked in a storeroom as a way of keeping them safe.

The same way of closely supervising learners was observed with Kabelo (African township school) as he was facilitating laboratory work for his learners. Kabelo complained that his learners have a tendency to vandalise equipment and steal things from the laboratory. This is against a background where the school has one laboratory only which relies on donations for materials and equipment. Kabelo has to make sure the materials and equipment are well taken care of if there is going to be any laboratory work to talk of in the school. He sets up the apparatus for learners and he instructs them not to touch anything until he gives them the go ahead. During the laboratory activity in which Kabelo was observed facilitating for his learners, there was an incident whereby he was visibly not pleased when he realised some learners had already fiddled with the apparatus set ups that he had prepared for use for the experiment.

According to the study findings, issues of vandalism of laboratory equipment and materials were only evident in the African township and the former Coloured schools. Teachers in these schools strictly control and supervise how learners interact with laboratory materials and equipment. This is not the case in the other five contexts in which this study was taken.

In the African rural school Melusi demonstrated how his learners should set up the apparatus for experiments and gave them a chance to practice it without worrying about issues of vandalism which he never complained about in his narratives. Teachers in the two private schools, the former Indian school and the former model C schools did not allude to any problems of vandalism and theft of materials. They also did not show any anxiety when learners are interacting with materials and equipment.

Third, the study findings point to the notion that sometimes teachers must ensure all learners are able to conduct the laboratory activities meant for assessment by providing them with the

procedures of the experiments so that they all manage to collect results that they can analyse, interpret and draw conclusions from, write reports and submit them for marking. This way every learner is assured of a mark for continuous assessment.

Contextual settings and IBLW teacher identities

To conclude the section on contextual settings and learner populations it is important to point out what was observed about IBLW teacher identity positions in relation to contextual settings. Study findings revealed that the school settings in South Africa which are former model C, former Coloured, former Indian, African and private schools do not directly determine the teacher IBLW professional identity positions assumed by teachers. This is after study findings showed that the most common IBLW teacher identity position was observed in a former model C, former Coloured, African rural and private school. This identity position is when teachers provide learners with investigative questions and the procedure of experiments expecting learners to figure out the solutions in the experiments.

This is set against a background in which studies may allude to the existence of different cultures of education in South African education as determined by context (Naidoo & Green, 2010; Ogunniyi, 2013; Selod & Zenou, 2003; Lewin, 1995). Naidoo and Green propound that the different school contexts have dominant pedagogic practices. The findings of this study did not seem to support this notion because particular IBLW teacher identity positions could not be linked to particular school contexts.

The current different school contexts still portray some features that they had during the apartheid era. A case in point is that, although other contexts now have learners from multi-cultural backgrounds, some African schools' learner populations still consist of learners from African cultural backgrounds only as was the case during apartheid. This is corroborated by Naidoo and Green (2010) who observe that conditions such as class size, availability of resources and social class context of schools still remain the same even after the dawn of independence in South Africa.

This observation is based on the two African schools in this study. It is worth mentioning that these two African schools were the worst hit in terms of shortages of laboratory materials and equipment. One of the two schools (African township) also has crowded science classes which results from crowding the one and only laboratory in the school. Other schools from other contexts (former model C and former Indian) with similar learner enrolments of around 1500 learners have four science laboratories each. The other African school in this study (rural) does not even have a laboratory and relies on science kits and movable laboratory equipment for practical activities.

5.2.3 Sense of agency

Internationally literature views a teacher's capacity to act in a given school context as his/her sense of agency (Milne et al., 2006; Beauchamp & Thomas, 2009; Lasky, 2005). In the same vein local literature like Stoffels (2006) points out that some teachers are able to rise above the challenges besetting contextual settings to successfully implement laboratory work in the teaching and learning process. For this study a sense of agency is discussed as a teacher's capacity to be able to facilitate laboratory work for learners in the different school contexts where the research was undertaken. In this section an attempt is made to paint a picture that gives an overview of teachers' capacity to act on implementing laboratory practice.

Two trends in laboratory work practice have been observed. First, there is a group of teachers who have their laboratory work dominated by teacher demonstrations as compared to the times that learners are able to handle materials and manipulate equipment. Their capacity to act on implementing laboratory work practice is largely inhibited by contextual settings resulting in the teacher performing demonstrations most of the time. Jane (former model C school) admitted that she does not prioritise laboratory work in which learners conduct the experiments as much as other strategies that she employs in the process of teaching and learning. She said, "I would like to do more but the syllabus is extremely full." Her learners also confirmed this scenario because they wish they could have more time to engage in laboratory work. The learners also allude to how anxious they become when they know they are to conduct a laboratory work activity because usually the activities will be for assessment.

Learners observe that those times are hectic and chaotic because learners are tense and worried about their performance.

Jimmy (former Coloured school) also finds himself doing teacher demonstrations most of the time. He observed that his learners do not show an eagerness to engage in some tasks that constitute inquiry during a laboratory work session. He admitted that he performs mostly demonstrations. For Kabelo (African township school) and Farai (private school) the incorporation of technology in laboratory work results in alienating learners from handling and manipulating of materials and equipment because they are made to observe scientific phenomena from screens from wherever they are sitting in the laboratory.

The learners do not need to come close to the teacher's table. Learners observe more teacher demonstrations than the times they conduct the experiments themselves. The incorporation of technology in this manner is positive in the African township school because of shortages of materials and equipment. At least the learners are afforded an opportunity to record results that they observe, analyse, interpret and draw conclusion. However the development of learners' manipulation and handling skills is limited.

Melusi's laboratory practice is also characterised by the incorporation of technology. The equipment that he uses is technologically advanced in such a manner that his practice is moving away from the use of conventional equipment such as ammeters and voltmeters to current probes and voltage probes. The manner in which Melusi incorporates computer technology in laboratory work differs from that of Kabelo and Farai because the technology equipment is enough for each group to include in the setup of the experiment apparatus. Learners do not have to be observing proceedings from a central point. This approach enables learners to still maintain a hands-on approach to inquiry during practical work. Melusi makes his school visits with the intention of engaging learners in a hands-on experience in laboratory work. The engagement, however, is not frequent because he works with Grade 10-12 in seven schools.

The second trend that was observed is that of teachers whose capacity to act on the implementation of laboratory work results in the frequent engagement in hands-on practical activities by learners. In the case of Tendai (former Indian school) and Betty (private school) learners revealed that they conduct experiments about twice a week. This is quite different from the frequency with which other teachers in the study are able to facilitate laboratory work for learners. Considering that other teachers are only able to engage their learners in laboratory work two or three times a term, Tendai and Betty seem to be more committed to the use of practical work as a teaching and learning strategy.

For Betty (private school) the frequent engagement of learners in practical work may be attributed to how they plan for practical work in the school. Each year they develop workbooks of practical activities that form part of the work schedule. However, Tendai without previously developed yearly workbooks for experiments is able to engage learners in laboratory work twice a week. Farai (private school) can only facilitate laboratory work two to three times a term. The similarities of the contexts are in terms of availability of laboratory facilities, materials and equipment. This cannot be said about the African schools and the former Coloured school which are characterised by shortages of laboratory materials.

The frequency of laboratory engagement may not directly translate to a particular teacher IBLW professional identity position. Although Tendai and Betty both engage learners frequently in laboratory work, they display IBLW identity positions that are different. Betty frequently engages her learners in laboratory work but displays an IBLW identity position that is similar to that of Jane, Jimmy and Melusi whose learners engage in laboratory work two to three times a term. Farai is one of the teachers who engages learners in laboratory work two to three times a term but has an IBLW identity position that is different from other teachers who also engage learners in laboratory work two to three times a term. This is evidence that teachers' capacity to act plays an important role in shaping their IBLW professional identity positions. Teachers are responsible for taking initiatives to act on implementing IBLW through a particular professional identity position that they assume (Lasky, 2005).

5.2.4 Teacher personal identities

A considerable number of studies have been dedicated to how teacher personal identities have the power to shape their professional identities (Lasky, 2005; Prosser, 2006; Zembylas, 2003; Brigido et al., 2010; Kelchtermans, 2005; Keys, 2010). The personal identity aspects that are discussed under this section are teacher perceptions and beliefs; teacher commitment; teacher motivation; teacher narratives and teacher prior school experiences.

Most of the teachers' perceptions reflected how they interpret and view the CAPS syllabus as well as laboratory practice in general. Perceptions were observed to inform teachers as they made crucial decisions on how they would implement IBLW. Teachers were also observed to have developed beliefs about laboratory work which they either acted upon as they engaged learners in laboratory work or failed to act upon. Study findings also established that teacher commitment and motivation, prior school experiences with laboratory work and teacher narratives play a significant role in shaping IBLW teacher identity positions.

Teacher perceptions

Teacher perceptions mainly emanated from how they interpret the subject policies. Teachers were observed to express what they think the subject policy is stipulating and the stipulations may not be part of the teachers' beliefs. In this study they differ from teacher beliefs which are more deeply rooted values, views and conceptions that hardly change (Mapolelo, 2003). Teachers used these interpretations to negotiate IBLW identity positions in the wake of contextual factors and their long held beliefs on laboratory practice. It was observed that if what is perceived by teachers to be how to implement learning programmes does not align with strongly held teacher beliefs they either modify or find alternative ways for implementation (Morgan, 2004).

First, teachers perceived the CAPS syllabus as stipulating that teachers should engage learners more frequently in laboratory work activities. On realising that the subject policy requires them to engage their learners in practical work more frequently, the teachers were quick to point out that the policy did little to address the time constraints issue. They feel that the time

allocated for practical work is not enough and, therefore, it may not be possible for them to implement the stipulation of the policy. Only two teachers out of seven were able to engage learners in hands-on laboratory work activities twice a week while others were able to engage their learners only two or three times a term. They compromised, however, by engaging in teacher demonstrations most of the time for learners to at least observe scientific phenomena.

Second, it was observed that teachers' perceptions on the laboratory practice policies may inhibit teachers' action. Jane (former model C) thinks that some of the prescribed experiments are not suitable because of safety issues and she decided that she would not facilitate them for her learners.

Third, Tendai (former Indian) and Farai (private school) perceive that the manner in which the CAPS syllabus instructs how practical work should be implemented is in the form of verification experiments. Learners are first taught the scientific concepts in class and then they are made to engage in practical work to verify what they have been taught. Tendai said, "The aim is already provided and the theory is given. You are just doing an experiment to confirm. It is no longer an investigation."

This scenario goes against the grain of how both Tendai and Farai believe is the way to facilitate laboratory work for learners. They believe learners should be able to discover scientific theories through practical work. Therefore, as they implement the syllabus policy they still hold on to what they believe. While all the other teachers in this study design the procedure of the experiments for their learners Tendai and Farai structure the laboratory tasks in such a manner that learners design the procedures of the experiment. Since they feel very strongly about learners not being afforded an opportunity to discover theories anymore, making learners design experiments could be a way in which they consider laboratory work to continue being meaningful.

After giving learners the problem for which they have to design the experiments Tendai and Farai leave the learners to work in groups with minimal guidance as they figure out the steps of the experiments. Farai said he is able to check whether the learners actually conducted the

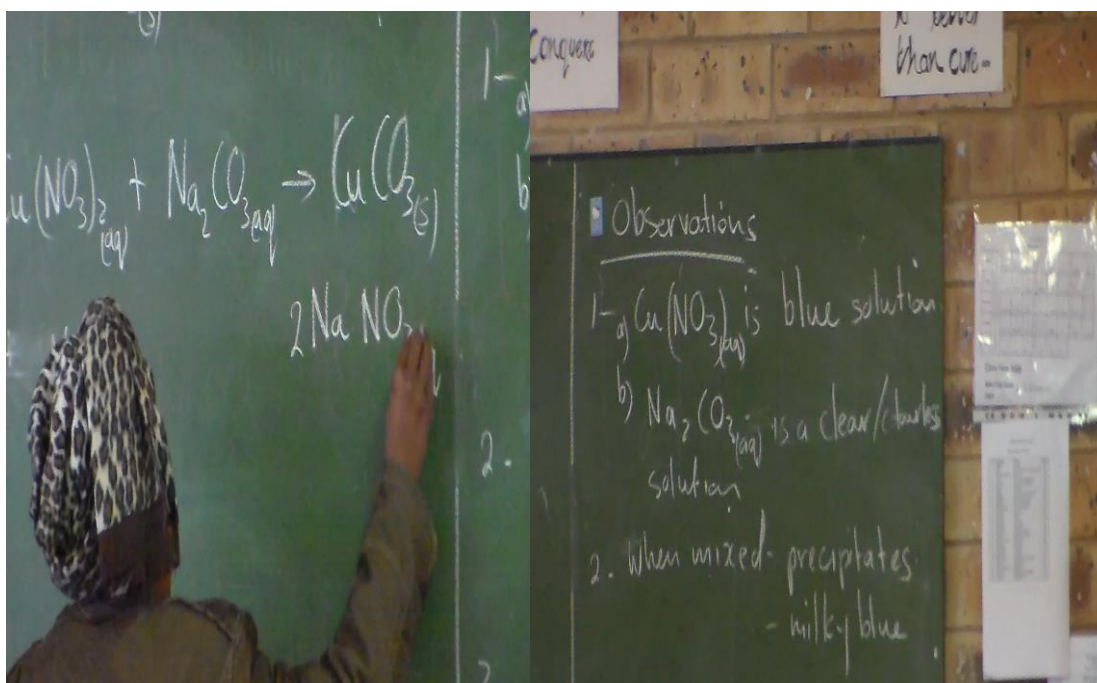
experiments by testing for the products of the chemical reactions in the case of chemistry. If the tests are negative, then learners are made to repeat the whole exercise until they get it right. He feels that this is necessary given that the experiments are for verification of theories that learners already know. Since learners have solutions to the investigative question already, it is possible that they might just write the experiment report without conducting the experiments. Tendai uses a different approach to make sure the learners actually conduct the experiments. She closely monitors every step that they execute during the activities from making sure the apparatus set ups are appropriate as well as the materials they make use of.

Teacher beliefs

This study supports findings from literature reviewed in asserting that teacher beliefs play an important role informing teachers as they implement curriculum programmes (Roehrig et al., 2007; Kang & Wallace, 2005; Upadhyay, 2009; Assaf, 2008). Mapolelo (2003) propounds that teacher beliefs are closely linked to instructional practices. Study findings reveal two types of beliefs. There are teacher beliefs about laboratory work practice that are not reflected in the way they facilitate practical work for learners. Usually teachers cite school site factors (Roehrig et al., 2007; Hick, 2008). Hick (2008) propounds that teacher beliefs on reform should be stronger than school site factors for teachers to successfully implement reform programmes.

Jane (former model C), Kabelo (African township) and Farai (private school) strongly believe that learners should be engaged frequently in laboratory work. However, they have not been able to make this happen citing time constraints. The three teachers have only been able to engage learners in laboratory work two to three times per term. They point out that the time allocated for physical sciences as a subject makes it impossible because it is not enough. It is important to note that Tendai (former Indian school) and Betty (private school) are able to engage learners in laboratory work twice a week in similar conditions as far as time allocation is concerned. With the same time allocation they are able to engage learners frequently in laboratory work. However, they also acknowledge that being able to accommodate the practical activities that have to be conducted in the time allocated is a challenge.

Study findings show that some teachers wish to have learners go through the paces of the experiment with minimal guidance and intervention from the teacher. Teachers wish the learners can get an opportunity to try out procedures of experiments so that they can realise that some methods do not work. However, teachers always have to keep learners focused because the activities have to be completed within the allocated time. Tendai (former Indian school) regrets having to rush the learners through steps of the experiments because sometimes she can no longer afford to let the activities spill over into the next week. The picture below serves to illustrate how Tendai writes a summary of the observations made by the learners during the experiment so that she can further probe them to reach the conclusions during the lesson.



Picture 5.2 Tendai guiding learners as they summarise experiment observations

Kabelo (African township) also acknowledged that learners should be given an opportunity to practice trial and improvement of experiment procedures. He said that this is, however, not possible in the time allocated for science lessons in his school. Melusi (African rural school)

and Jimmy (former Coloured school) have to constantly guide and assist learners because learners may not even be in a position to know what to do.

Study findings showed that teachers believe they should let their learners pose investigative questions for the experiments that they conduct; however, they claim that learners need more time for that. Betty (private school) realises that letting learners figure out the investigative questions is a process in itself that requires some time before learners can start going through the paces of the procedure of experiment. She ensures that learners are able to complete all the tasks of the laboratory activity by providing learners with the questions.

The study revealed eight teacher beliefs that are reflected in the manner in which they facilitate laboratory work for learners. The first belief expressed was that engaging learners in laboratory work is a way of consolidating learners' understanding of scientific concepts. This is after they would have covered the corresponding scientific concepts and theories in class and then laboratory activities are planned to enhance and consolidate learners' understanding. Betty (private school) realises her learners might even have developed some misconceptions that will be dispelled after they observe the scientific phenomena first hand as they conduct the experiments. Melusi (African rural school) realises that learners do not respond to learning methods in the same way. He observed that some of his learners are responsive to practical work more than theory; therefore, when he engages learners in practical work, he is reaching out to those learners.

Second, by engaging learners in laboratory work some teachers felt they were laying a foundation for learners in terms of knowledge and skills that they will use when they seek to pursue further studies in tertiary education. They believe that if learners are to pursue studies in programmes that are science-based then they should also develop related skills and knowledge. For Kabelo, this is a reality that he has personally experienced. He was not exposed to laboratory work when he was at school. When he was in a teachers' college studying to be a science teacher, he said at first laboratory work gave him a lot of anxiety

because he could not do things that were expected of him. He did not possess the basic skills of handling and naming materials in the laboratory.

Third, it was expressed that as learners engage in laboratory work they are being equipped with skills and general knowledge that they need for living meaningful lives by using scientific knowledge to inform them as they make decisions. Jane (former model C school) became very excited when she shared her experiences on how she uses laboratory work activities to show learners how they can apply scientific knowledge to solve some of their everyday problems. Since she teaches girls only she realises that some of them will one day take up the responsibility of preparing meals for their families as well as the cleaning of utensils like clogged kettles. She always tries to link the chemistry they learn with cooking and cleaning processes. Since her ultimate goal is to show learners how science can solve their everyday problems, she sometimes does not need to engage them hands-on but just to conduct a demonstration for them to see.

Fourth, it was believed that learners who engage in laboratory work become motivated and develop an interest in science and laboratory work. It is easier to teach learners who have an inclination towards the subject. Some teachers like Tendai (former Indian school) observe that learners become motivated to learn when they engage in laboratory work activities.

Fifth, study findings revealed that some teachers felt that as they engage learners in practical work they are grooming a generation of laboratory work practitioners who have a solid foundation of skills and knowledge in laboratory work. By engaging learners in practical work Tendai hopes that they consolidate their scientific knowledge and also develop skills in laboratory practice.

Sixth, a belief was expressed that as teachers facilitate laboratory work for their learners they are also going through a transformation in the form of professional development. Tendai realises her teaching practice has exposed her to more laboratory work experiences. For Jimmy (former Coloured school) his teaching practice has served as a professional

development opportunity in laboratory work since his school and university experiences were limited.

Seventh, it was believed that science teaching and learning is about teaching learners the theoretical scientific concepts as well as laboratory work skills and knowledge. Farai (private school) even expressed reservations about making learners to just sit for examinations on theory only.

Last, teachers felt that it is their responsibility to make sure learners go through meaningful laboratory work experiences. Betty (private school) feels that some teachers are reluctant to try chemistry practical activities and, therefore, learners are disadvantaged. Farai also says it is the duty of teachers to structure laboratory work activities in such a way that they successfully, effectively and meaningfully engage learners in inquiry.

Some of these beliefs reflect significantly on the teachers IBLW identity positioning. Teachers who mainly believe that they can use laboratory work to consolidate learner understanding of scientific knowledge were observed to provide learners with the investigative question and procedure of experiments. Learners were left to figure out solutions to the investigative questions by using the data collected. When the learners articulate these solutions, they are actually articulating some of the scientific concepts and theories.

Teachers who strongly believe that science is a two-pronged subject in terms of it being theoretical and practical like Tendai (former Indian school) and Farai (private school) did something in common from the findings of the study. They structured the laboratory activities in such a manner that learners design the steps of experiment procedures.

Interestingly the beliefs expressed by teachers in this study seem to have their origin in some of the science educational goals for laboratory work. They compare well with the science educational goals listed in Hofstein and Lunetta (2003) which are: understanding scientific concepts, interest and motivation, scientific practical skills and problem solving, scientific

habits of mind, understanding the nature of science, methods of scientific inquiry and reasoning, and application of scientific knowledge to everyday life. The fact that teacher beliefs have their source in science educational goals may link the development of teacher beliefs to professional training and development. This is corroborated by Hick (2008) in saying that the teachers' core beliefs do not arise from school site factors but these factors are able to empower or restrict them in their practice.

Teacher commitment

Korhonen and Nevgi (2010) allude to this notion that to study teacher identity is to study how a person is internally motivated and committed to his/her work since performance affects competence. Teacher commitment in this study refers to what teachers put in place as measures to make sure they engage learners in laboratory work even when there are some challenges that inhibit the practice.

Teachers may arrange afternoon lessons after school in which learners can have enough time to conduct the practical activities. Teachers also give clear instructions during laboratory work so that learners do not spend more time figuring things out before they can go through the steps of the procedure of the experiment. Teachers also use purposeful planning to make sure laboratory work becomes a frequent teaching and learning activity. Betty believes teachers should not give excuses such as time constraints when they fail to expose learners to laboratory work on a frequent basis. Betty also makes use of a work book for experiments which is developed before the start of each school year.

Before a laboratory activity teachers and learners may also conduct preparations such as that of materials and equipment so that on the day for laboratory activities everything will be in place and ready for use. Time constraints came out as one contextual factor that inhibits laboratory work practice. Teachers have to find ways of accommodating laboratory work activities in the time allocated for science lessons. Without being committed to the practice of laboratory work by putting into place measures that would offset challenges emanating from

contextual settings teachers may always come up with excuses for not engaging learners in practical work.

Teacher motivation

Elawar et al. (2007), whilst studying the motivational factors that influence teacher identity, contended that learning about teacher identity is to learn about the factors that influence the teacher's sense of purpose, self-efficacy, motivation, commitment, job satisfaction and effectiveness in the classroom. In this study, there are a number of motivational factors that drive teachers as they facilitate laboratory work for learners.

Jane enjoys seeing her learners awed when they realise how they can apply science in their everyday lives. Jane tries to engage learners in practical work activities that have relevance in their everyday lives. Tendai derives her motivation from the transformation that she observes in her learners after exposing them to laboratory work experiences. She feels encouraged when she observes her learners enjoying and being motivated to learn science as they engage in practical work. Jimmy (former Coloured school) is one teacher who is generally demotivated by the conditions in his school whereby learners' behaviour makes it difficult to engage them in the process of teaching and learning. However, he wishes he could do something so that the learners can start benefitting meaningfully from the laboratory work activities. This sentiment becomes his source of motivation.

Kabelo (African township school) was never exposed to laboratory work when he was in school. He wishes that none of his learners would go through the same experience. He works to make sure that learners have laboratory work exposure before they can proceed to tertiary education. This sentiment was echoed by Melusi who, although he had school experiences with laboratory work, works to engage learners in practical work in schools where they would otherwise not have that experience.

Teachers like Betty (private school) who has learners who sit for practical examinations are driven by the need to prepare learners by equipping them with skills and knowledge that

enables them to do well in such examinations. For Farai (private school) laboratory work is part of science content that should be taught to learners alongside the theory. For him teaching science without incorporating the practical component is just doing half of the job in science education.

Teachers' school experiences with laboratory work

Teachers' prior school experiences have been seen to play an important role in the shaping of their sense of professional identity (Flores & Day, 2006). In this study teachers used their school experiences as a personal resource to negotiate teacher professional identities. It was quite evident in reference to laboratory work because teachers remembered vividly how they used to conduct laboratory work at school.

Teachers' school experiences in laboratory work activities played an important role in the IBLW identity positions assumed by teachers. Teachers developed strong beliefs about laboratory work and got their interest kindled towards laboratory work when they were in school. Farai (private school) claimed that he developed a love for laboratory work when he was in school. When he went to teachers' college and later university, he was expecting to experience laboratory work on a larger scale only to find that it was not to be because the main focus was on other issues in science education. He claimed his school experiences were the most significant from his past experiences.

When they did not have meaningful laboratory work experiences in school, teachers may not gain confidence to engage in laboratory work as they pursued tertiary education. This is the case with Kabelo (African township school) who said when he was involved in teachers' college laboratory work it caused him a lot of anxiety. Tendai (former Indian school) also tries to live up to the standards of her school experiences by way of engaging learners in laboratory work activities twice a week just as she said she experienced it. Tendai feels very proud to say that she had a 'solid foundation' in laboratory work because of her school experiences with it.

Teachers who have experienced laboratory work in school get a chance to reflect on their current practice of laboratory work by way of making comparisons between what they experienced and what the learners are experiencing. As Melusi (African rural school) reflected on his own school experiences, he revealed that the science content he covered during his schooling was more complex than what his learners are supposed to cover. He said, however, that things have changed since the time he attended school in terms of laboratory equipment used in experiments. He said during his school years conventional equipment was used in the laboratory as compared to the technologically advanced equipment he uses with his learners. Melusi incorporates computer technology in laboratory work. For example, some measurements are automatically recorded by the computer by way of gadgets like current probes and voltage probes instead of the conventional ammeters and voltmeters.

About teacher school experiences with laboratory work it may be concluded that they enhance and enrich teachers' exposure to laboratory work practice. Those experiences contribute to the positioning of IBLW teacher professional identities.

Teacher narratives

Bramberg (2012:2) attempts to explain what narratives are and what they can do in the following way, "When narrators tell a story, they give 'narrative form' to experience. They position characters in space and time and, in a very broad sense, give order to and make sense of what happened...or what is imagined to have happened." Literature abounds with affirmations of how teacher narratives shape their professional identities (Burns & Bell, 2011; Lee, 2012; Smit & Fritz, 2008; Zembylas, 2003; Settlage et al., 2009; Beauchamp & Thomas, 2009). There are even research efforts that focus on the representation of teacher professional identity through teacher stories (Smit et al., 2010; Burns & Bell, 2011; Smit & Fritz, 2008).

This study is no exception. One of the main data collection tools was teacher narratives. Through teacher narratives data on teacher experiences with laboratory work as determined by personal identity positions, professional development and training, current laboratory and contextual settings was successfully elicited. The data collected through narratives compared

very well with data collected through on site observations. Teacher narratives are a very effective way of getting insights into teachers' past experiences with laboratory work practice. Through narratives teachers communicated their perceptions and beliefs in laboratory work practice and I was able to find answers to research questions as well as other questions that were important to ask during the course of this study.

5.2.5 Teacher IBLW professional identity positions

This section discusses the IBLW teacher identity positions assumed by teachers participating in this study. As part of the secondary research questions the study set out to establish teacher identities in the practice of IBLW in school chemistry. On reading this section it is important to take into account findings from reviewed literature which characterises teacher professional identity as evolving and not 'static' (Beauchamp & Thomas, 2009; Beijaard et al., 2004; Assaf, 2008; Upadhyay, 2009; Varghese et al., 2005). This applies to IBLW positions displayed by teachers in this study. Findings from literature also demonstrate the multiplicity of teacher professional identity by stating that it consists of sub-identities which originate from contexts and relationships (Akkerman & Meijer, 2011; Beauchamp & Thomas, 2009; Forbes & Davis, 2008; Tsui, 2007; Morgan, 2004; Beijaard et al., 2004). The sub-identities can also be referred to as role identities (Tsui, 2007; Forbes & Davis, 2008; Beijaard et al., 2004; Akkerman & Meijer, 2011). This allows the study to consider how teachers facilitate IBLW as role identities. Akkerman and Meijer (2011) further says that teacher professional identity can be fragmented into subject matter expert, pedagogical expert and didactical expert.

Literature reviewed before conducting the study had revealed that teachers may facilitate laboratory work at four levels of inquiry which depended on the teacher and learner actions on formulating an investigative question, designing the procedure and articulating the solution of the experiments. The categorisation of levels of inquiry was defined by Bretz and Fay (2008) and Fay et al. (2007). At the lowest end of the continuum would be level 0 where learners are provided with the question, procedure and solution of the experiments. They may take part in the execution of the steps of the experiments. In level 1, learners would be provided with the question and the procedure of the experiments while they figure out the solution of the

experiments. In level 2 learners are expected to do more. The teacher provides them with the investigative question while they figure out the procedure and the solution of the experiments. In level 3, which is the highest level according to Bretz and Fay (2008), learners take charge of the whole inquiry process by determining the investigative question, design the procedure and find solution to the experiment.

IBLW teacher identity positions may be regarded as how teachers give guidance to learners since in this study there are no cases where teachers left learners to formulate all the three aspects of inquiry which are formulating questions, designing procedures and articulating solutions. This would be open inquiry according Schoffstall and Gaddis (2007) and Kirschner et al. (2004). In secondary schools guided inquiry may be what teachers use as they engage learners in the laboratory work because some authorities like Kirschner et al. (2004) propound that it is more effective. Observations made in this study reveal that in terms of laboratory work learner knowledge and skills in secondary schools are still in different stages of development.

As observed in this study learners may not be able to successfully conduct laboratory work if they do not receive guidance and support from teachers. This is why teachers provide learners with what they lack in terms of knowledge and skills in laboratory work as well as content. Melusi (African rural school) and his learners confirm that before learners can engage in practical work relevant content should be covered. Melusi is also responsible for designing the experiments and gives learners the investigation question and the procedure and helps them as they follow the steps of the procedure and collect the data. Learners are only expected to draw conclusions from the data collected and articulate the solution to the investigative question.

Melusi believes that by facilitating laboratory work in this manner he will be able to consolidate learner knowledge of scientific concepts by enhancing their understanding. Other interpretations of having teachers facilitate laboratory work in this way may point to what other authors may term 'verification experiments' where practical work is conducted to confirm theory. However, if this is the case it is against a background where learners are

struggling to understand the scientific concepts in such a way that they may neither be able to use the content provided nor the results of experiments at times to find a correct solution to question.

Based on the observation made above it may be argued at this point in the discussion that from the point of view of learners the practical activities may not constitute verification of already known facts because they have not yet mastered them. The practical activities further serve to expose learners to what they have to learn hoping that they may eventually assimilate the scientific concepts. Melusi may have observed the same thing when he said that learners have different learning styles whereby some learners may understand when the teacher is explaining in class and others may only understand after directly observing the scientific phenomena in the laboratory.

Tendai (former Indian school) and Farai (private school) observe that practical work becomes verification of theory since scientific concepts are taught as theory before learners can be made to engage in practical work. They realise that the learners already have solutions to investigative questions of the practical activities that they intend to engage in because they have already covered the content. The two teachers realise they have to structure the practical activities in a manner that engages learners in some kind of inquiry work. They ask learners to look for something that has not been discussed in lessons. Learners are requested to design procedures for experiments for which they know the solutions. Learners work in groups to design the procedures which they then execute hoping to get the expected results that lead to the known solution. Farai does not interfere by checking whether the procedure will work but leaves the learners to try their procedure and he only comes to check the result by way of testing the products of the chemical reactions. If tests for gases and other reaction products are not positive, the learners will repeat the exercise.

In the laboratory activity in which Farai was observed facilitating for his learners, he gave them a problem which required them to design an experiment to investigate the effect of surface area on the rate of reaction given hydrochloric acid, zinc granules and zinc powder.

Learners were able to formulate the question of the experiment from the available information. Using the content covered they could also give the solution to the question. The inquiry activities now constitute learners working together to devise the steps of the procedures and determining the materials to be used. This is in contrast to situations where the teacher will give the procedures to the learners which they execute to confirm what they already know.

All the teachers in this study expose learners to corresponding science content before engaging learners in practical work. This is in line with what Buck et al. (2008) propounds that in inquiry activities through laboratory work learners can either be provided with content or they may develop the content depending on how the practical activities are structured. Besides giving learners the content teachers may also decide on what they can provide to the learners in terms of question, procedure and solution during laboratory work activities. How teachers give the question, procedure and solution is explained through IBLW teacher identity positions in this study.

On comparing study findings with reviewed literature it was clear that some of the teacher IBLW identity positions did not fall under the classification propounded by Bretz and Fay (2008). The seven teachers in the study displayed four teacher IBLW professional identity positions. Four of the teachers from former model C, former Coloured, African rural and a private school engaged their learners at level 1 of Bretz and Fay's rubric (2008) of characterising inquiry. They provide learners with the investigative question and the procedure of the experiment and learners are expected to articulate the solution to the experiments.

Close to this is how Kabelo (African township school) facilitates laboratory work for his learners. He only provides learners with the procedure of the experiments while he lets them figure out the investigative question from the content made available and the solution of experiments after analysing and interpreting results. This approach does not fall under any of the four levels in the rubric to characterise inquiry by Bretz and Fay (2008).

A number of reasons can be put forward to explain why teachers decide to provide questions and experiment procedures for learners. First, they see this as way of making sure laboratory activities can be conducted and finished in the time allocated for science lessons. Teachers cite time constraints. Second, teachers realise that the learners have underdeveloped skills and knowledge in laboratory work and, therefore, they may not know what to do. By providing learners with the question and procedure they are enabled to follow the steps of the procedure and thereby manage to collect results that they can later analyse.

Third, enabling learners to collect results is in line with the philosophy guiding teachers as they work to use laboratory work activities to consolidate learners' knowledge of scientific theories and concepts. The most important task would be for learners to collect results that they would use to determine the solutions to investigative questions by way of drawing conclusions. This way, learners are able to discover trends and patterns that point to particular scientific concepts and theories.

Fourth, for teachers who are guided by the philosophy that seeks to show the relevance of science in the society like Jane (former model C school), the main aim is to demonstrate how science can help to solve everyday life problems. For this learners can be provided with both the investigative question and the procedure so that at the end they may just draw conclusions from what they observe.

Another teacher displayed an IBLW professional identity position that is different from the categorisation described under the rubric neither by Bretz and Fay (2008). Tendai (former Indian school) provides her learners with the investigative question and solution of the experiment. Close to this is Farai's IBLW professional identity position. Farai provides his learners with the solution and he expects them to figure out the investigative question as well as the procedure of the experiment. A number of reasons can be put forward as to why Tendai and Farai structure the laboratory work activities in such a manner that learners design the procedures of experiments.

First, Tendai aims at grooming her learners to become a generation of laboratory practitioners like herself by making sure that they know their way around the laboratory. For learners to be able to design experiments they should be well acquainted with laboratory equipment and materials so that they can set up different apparatus. Giving learners the step by step procedures of experiments will not give them an opportunity to meaningfully develop skills and knowledge in laboratory practice.

Second, Tendai and Farai interpret the subject policy as instructing teachers to facilitate verification experiments for learners after exposing them to scientific concepts and theories in class. The teachers realise that learners may already know the solution to the investigative problem by figuring it out from the theory provided. It is expected that the investigative question may also be apparent from the theory. Procedures of experiments may be the only thing that is not discussed when learners are being taught the scientific concepts and theories. Therefore, to make the inquiry activities more meaningful Tendai and Farai request learners to design experiments.

Third, study findings reveal that Tendai and Farai are strongly guided by a philosophical standing that regards science as a two-pronged discipline by being both a theoretical and practical subject. This is emphasised by authorities like Tsaparlis (2009) who consider science, and in this case chemistry, as a practical subject. Tsaparlis (2009:111) stated:

Chemistry is basically an experimental science, hence the contact, especially through the laboratory and practical work, with concrete examples of substances, their reactions and other properties, is an essential part of chemical education. The laboratory is the proper place for keeping chemistry tangible.

Besides learning the scientific theories and concepts learners should also learn to be laboratory practitioners. Therefore, allowing learners to design experiment procedures exposes them to meaningful experiences that help learners to develop skills and knowledge in laboratory work practice. Farai allows the learners to work in the laboratory for more than two hours after school until they can figure out how to conduct the experiments. For chemistry laboratory activities he even tests for the gases and other substances that come as products of chemical

reactions. This helps him to check whether learners actually went through all the steps of the practical activity. If the tests do not come out positively, he instructs the learners to conduct the laboratory activities all over again until they get it right.

5.3 Differences

This section discusses the differences that are apparent between the literature reviewed and the findings of the study. The differences observed between the findings of the study and what is contained in the reviewed literature are very slight. They cannot be considered to be major differences but rather subtle. These differences may emanate from having this study conducted in different settings to those of other settings in which similar studies were conducted.

5.3.1 IBLW teacher identity positions in the South African context

This study established some of the teacher IBLW professional identity positions used by teachers as they facilitate laboratory work for learners in some of the South African schools. Teachers may provide investigative questions and procedures for learners expecting learners to figure out the solutions to the investigative questions using results collected during the experiment. Teachers may design procedures for experiments and instruct learners to formulate investigative questions from the theory provided and articulate solutions from the results collected during the experiments. Teachers may provide learners with investigative questions and their solutions and then ask learners to design the procedures for experiments. Teachers may also provide solutions for learners and ask learners to formulate investigative questions and design procedures of experiments. This is a variation from the rubric available in the reviewed literature that characterizes inquiry.

Study findings show teacher IBLW identity positions that are divergent from the rubric propounded by Bretz and Fay (2008) and Fay et al. (2007). Although the majority of teacher identity positions in this study fall under level 1 of the rubric there is Kabelo (African township school) who designs experiment procedures for his learners and lets them formulate questions from the theory provided and articulate solutions using the results of experiments. There is also Tendai (former Indian school) who provides questions and solutions for her

learners and asks them to design experiment procedures. Last, there is Farai who first gives learners the solution to the investigative question from the theory already taught to learners and asks learners to formulate questions and design experiment procedures.

Table 5.1 Rubric for characterizing inquiry by Bretz and Fay (2008)

Level	Question	Procedure	Solution
0	Given	Given	given
1	Given	Given	not given
2	Given	not given	not given
3	not given	not given	Not given

Table 5.2 Inquiry according to study findings

	Question	Procedure	Solution
Level 1 of Bretz and Fay (2008) rubric	Given	given	not given
Diverging	not given	given	not given
Diverging	Given	not given	given
Diverging	not given	not given	given

In the South African context Hattingh et al. (2007) conducted a similar study in which the authors designed a rubric on the levels of inquiry employed by teachers in South Africa as they facilitate laboratory work for learners. Hattingh et al. (2007) describes four levels of inquiry, the lowest of which consists of teacher demonstrations where learner actions are limited to observing with the ultimate aim of gaining conceptual understanding. This approach has similarities with the level 0 inquiry described in Bretz and Fay (2008) where the teacher provides learners with the question, procedure and solution. The difference may be that the practical activities may not be as teacher demonstrations but conducted by learners. This form of inquiry through teacher demonstrations was confirmed by both teachers and learners to be

common practice in this study. Teachers admitted to resorting to engage learners in laboratory work through teacher demonstrations due to time constraints or shortage of resources and also because they see it as a teaching and learning strategy.

Hattingh et al. (2007) describe the next level of inquiry after teacher demonstrations to be when learners are allowed to perform what the authors call 'cook book' practical work since learners are provided with the step by step procedures. Learners communicate the results of the experiments they conduct by way of tables and graphs. Although this level may not be explicitly matching any of the inquiry levels by Bretz and Fay (2008), it forms part of the approaches used by teachers in this study. Five teachers out of seven in this study engage learners in step by step execution of experiment procedures and expect them to communicate results presented in tables and graphs. They also expect learners to draw conclusions from the graphs, thereby articulating the solutions to investigative question. For Kabelo (African township school), learners are expected to come up with the question and solution when conducting laboratory activities but he provides them with the experiment procedures which represent the 'cook book' type of practical work. Learners were observed presenting data collected in tables and graphs.

The third level of inquiry in the continuum by Hattingh et al. (2007) has learners perform what the authors describe as guided discovery type practical work in groups and they are expected to write scientific reports in which learners develop conclusions based on the data collected. This approach is similar to levels 1 and 2 propounded in Bretz and Fay (2008) whereby learners may be provided with the question only or be provided with question and procedure. This form of inquiry also speaks to the findings of this study because teachers choose how they guide learners by way of making available some of the aspects of the practical work activity such as content, question, procedure and solution. Learners in this study were expected to write reports for the practical activities that they were observed conducting.

The fourth and ultimate level in the rubric developed by Hattingh et al. (2007) is what the authors term 'open ended' investigations whereby learners are expected to design experiments in which data collected is used to support competing theories and explanations. This approach

is similar to level 3 of Bretz and Fay's rubric in which learners should come up with an investigative question, design the experiment procedure and articulate the solution to the question. Designing of experiments in this manner was partly reflected in the study findings. Teachers realise that learners in secondary schools may not be ready for open inquiry; therefore, they have to give learners some form of guidance.

In one of the private schools and the former Indian school the teachers structured the laboratory work activities in a way that prompts learners to design experiment procedures. The designing is only limited to experiment procedures because learners already know the question and the solution since they can easily figure them out from the content taught to them. This is as a result of teaching the scientific concepts before conducting the corresponding laboratory activities to verify the theories. Teachers see that for the said laboratory activities to be meaningful they should structure the activities in a manner that engages learners in some form of inquiry. The inquiry they decided upon consisted of the design of experiment procedures which, however, falls short of designing whole experiments.

Findings by Dudu and Vhurumuku (2012) in study conducted in South African secondary schools confirm that teachers facilitate laboratory work in varied degrees of inquiry which, however, fall short of the highest form of inquiry which is open inquiry. The authors mention that teachers are faced with challenges that stand in their way towards open inquiry with learners. Some of these challenges in the South African context are mentioned by Stoffels (2005) who propounds that teachers develop worksheets to be used during laboratory activities instead of using problem-solving experiments designed to be conducted by learners because they want to maintain their control over learners in the face of learner disruptions and discipline issues.

What is mentioned by Stoffels (2005) on how learner disciplinary issues inhibit the effective practice of IBLW in secondary schools was observed in the former Coloured school. Jimmy (former Coloured School) revealed how he struggles to control his learners in the face of their rowdy behaviour. The learners also have a tendency to vandalise and even take away materials

and equipment from the laboratory. For this reason Jimmy has to monitor learners closely as they handle materials and equipment by mounting one apparatus that groups of learners use to conduct experiments by taking turns. Learners are not left to work with the materials if the teacher is not present.

Findings by Mudau (2007) on how teachers practice laboratory work in South Africa reveal that some teachers use practical work to develop conceptual knowledge while others use practical work to develop procedural knowledge. These findings compare well with findings made in this study because five of the teachers use practical activities to consolidate learner understanding while the other two, on realising that learners might already have achieved considerable conceptual understanding through other pedagogical strategies, use laboratory work so that learners can develop skills in laboratory work as they design procedures for experiments.

5.3.2 Verification experiments

McDonnell et al. (2007) and Domin (2007) speak of traditional methods of facilitating laboratory work in which learners only engage in verification of known results. The authors characterise what they term 'traditional methods' as lacking in inquiry. It is posited that verification experiments do not present learners with inquiry opportunities. By bringing out this issue the aim is not to dispute what the authors propound because verification experiments exist, which are used to confirm known scientific facts and theories. The scientific facts and theories are known to learners because corresponding content might have been previously covered before the experiments could be conducted. Bretz and Fay (2008) also speak of level 0 inquiry in which learners are provided with all in terms of questions, procedures and solutions during laboratory activities. If the solutions are revealed to learners, then the experiments conducted are just to verify what is known.

What this discussion is driving at is to invite the reader and all those interested and involved to look closely at some of the things that pose as contextual settings as these seemingly verification experiments are being facilitated for learners. Two scenarios played out in this

study which raise questions on whether these seemingly verification experiments are lacking in inquiry opportunities for learners.

First, Farai (private school) and Tendai (former Indian) in the wake of their perception of the introduced CAPS syllabus stipulating that experiments should now be conducted to verify what learners already know about scientific concepts and theories have difficulties embracing this because of the beliefs that they hold about practical work. They hold beliefs that learners should learn science by discovery as they engage in laboratory work. The two teachers are seen to assume an identity position in which they abide by the subject policies and at the same time act according to how they think laboratory work should be facilitated for learners. These two teachers are aware that for their learners the practical activities would be primarily for verification.

Farai and Tendai teach the science content to learners in line with what they believe the subject policy is stipulating. On posing the investigative questions for laboratory work activities they realise learners may be able to figure out the solutions from the content that they have been exposed to already. They then structure the practical activities in such a manner that learners are required to design experimental procedures that will lead them to the known outcomes. This task is not easy for learners because they are forced to go all out and research on the steps of the procedures, materials and equipment to be used as well as how to set up the apparatus. One of Farai's learners grumbled that everything that he knows about how to conduct experiments was through his own efforts as he claimed he received little assistance from the teacher. Koketso (private school) cried, "I think I would enjoy it if maybe the teacher helped us out a bit more. If he gave us a bit more guidance I would enjoy it a lot better."

Tendai was also seen to be putting considerable pressure on her learners as they engaged in the designing of the experimental procedures because learners complained that she gets tough by pushing them to make sure they successfully complete the task with minimal assistance from her. These learners sentiments may be compared with the sentiments expressed by learners

from the former model C school where Jane due to time constraints provides her learners with clearly spelt out instructions on how to conduct the experiments. Under these conditions learners acknowledged that conducting experiments is very easy since it is a matter of following steps. They said that they only struggle with drawing conclusions from the data collected because they are left to do that on their own.

Second, the findings of the study point to the notion that teaching learners scientific concepts and theories in class using pedagogical strategies other than laboratory work may not guarantee that learners have mastered them. Unlike in the cases of Farai and Tendai discussed above, learners may even have developed some misconceptions in such a manner that they fail to use the content to give solutions to the posed investigative questions. In this case, teachers use laboratory work activities as an alternative avenue to help learners to master the scientific concepts and theories. With this scenario in perspective it may be considered that the seemingly verification experiments are not as such to learners because the process of assimilating the concepts is not yet complete in them. Only during or after conducting the laboratory activities the learners may be aware of what teachers intended for them to learn.

Betty realises that with chemistry being what she calls an abstract discipline learners find it very difficult to assimilate the concepts without being afforded the opportunity to observe the chemistry phenomena first hand in the laboratory. Therefore, as her learners engaged in a laboratory activity in which she had provided them with both the investigative question and the procedure of the experiment they were not confirming anything that they already knew despite having been taught about the scientific facts theoretically. The practical activity worked to dispel misconceptions so that understanding is achieved. This is the trend that was observed with five of the seven teachers whereby learners may not be able to use available content to figure out solutions to posed investigative questions. The following extract from a teacher interview serves to confirm teacher experiences on how they work to make learners understand:

When I looked at what they predicted it is quite different to what they measured....
I had taught them everything about the ionic compounds. There are ions and free electrons in metallic compounds and all that. That was not enough they were still

confused about it so what they measure and what they see is quite different from the pictures that they had in their heads so it's a way of getting rid of the misconceptions allowing them to understand what's really happening. (Betty, private school)

From the extract, if this was to be a verification experiment then learners were supposed to get their predictions right and the practical activity would be used to confirm what the learners already knew. However, this was not the case because the learners actually learn concepts that they failed to learn previously in other teaching and learning activities prior to the practical activity. Authentic inquiry by learners in these practical activities according to the assumptions of this study consists of learners using data collected to interpret and draw conclusions and, therefore, coming up with a solution to the question.

In this study to assume that at times engaging learners in laboratory work activities after exposing learners to the content aspects under study through other pedagogical strategies may not translate into practical work for verification purposes can be explained by considering one of the fundamentals of the conceptual framework. Boghossian, (2006) and Miller and Miller (1999) propound that inquiry-based strategies are rooted in theories of constructivism in which one of the assumptions is that learning should occur in the mind of a learner. If the learner cannot demonstrate that they have assimilated the concepts as intended then learning has not occurred in the mind of the learner. The concepts to be learned might still be available in other locations such as learners' notebooks and even textbooks among other resources because supposedly the content has already been covered through other means. However if the learners are not yet in a position to figure out the solution of the investigative question it may be concluded that for the learner the experiments that they conduct are not for verification of what they already know because they don't know it yet.

5.4 Areas of silence in the study

This section describes aspects related to the study that are salient from the reviewed literature but were not observed in study findings. Study findings generally matched features of the theoretical framework and the conceptual frame used in this study. The emerging themes

aligned themselves with conceptual underpinnings of the social identity theory and inquiry-based instruction as a conceptual framework. After a careful comparison of the summary of findings compiled during the review of literature and the study findings a few aspects appeared not to have manifested themselves in this study.

5.4.1 Insufficient teacher pedagogical and content knowledge

All the teachers in this study considered themselves to be well prepared for their work to facilitate laboratory work for learners. If they at times feel that they are not well acquainted with any experiment that they should facilitate for learners, they use structures in place in their school contexts to get the necessary support. There is evidence in this study that teachers are exposed to professional development exercises in aspects of laboratory practice. The teachers also play mentoring roles to other teachers in laboratory practice. Jane (former model C) and Farai (private school) play facilitator roles in teacher development exercises for teachers in their districts.

Teachers may consult with colleagues and subject advisors. Therefore, while literature (Cheung, 2007) talks about teachers who are ill prepared to facilitate laboratory work for learners, in this study that did not come out significantly. In the South African context, Stoffels (2005) mentions that one of the challenges in the practice of IBLW is that teachers lack mastery of content in some topics in science. This was not apparent probably because this was not directly the focus of this study and, therefore, the data collection tools used were not appropriate to bring out such information. Also, a convenience sampling was used to select teachers who are known to practice IBLW.

5.4.2 Levels 2 and 3 of inquiry according to Bretz and Fay (2008)

Second, levels 2 and 3 of inquiry according to Bretz and Fay's (2008) rubric for characterising inquiry were not part of the IBLW identity positions displayed by teachers in this study. Teachers assumed other IBLW identity positions than giving learners an investigative question so that they can figure out the procedures and solutions as they conduct experiments. Teachers also were not observed to allow learners to formulate all the stages of inquiry, which is

figuring out the question, procedure and solution as they engaged in practical work. Dudu and Vhurumuku (2012) also found that in the South African context teachers in secondary schools fell short of facilitating inquiry in its highest form where learners would determine and control the whole process.

It is assumed in this study that learners also experience level 0 of inquiry whereby teachers provide the questions, procedures and solutions of experiments. This position is reached after realising that participants reveal that there are several instances in which teachers conduct demonstrations while learners' activities are limited to only observing. This was not made part of the summary of how teachers facilitate IBLW for learners because the focus of the study was on laboratory activities in which learners are hands-on.

5.5 Engaging findings with the theoretical frameworks of this study

This section discusses how teacher IBLW professional identity tenets in this study reflect the tenets of the social identity theory which was used as a theoretical framework and the inquiry-based strategies which were used as a conceptual framework. The theories and concepts were used as a framework onto which the arguments of this study were hanged. A discussion is developed on how the emerging themes of the study are characteristic of the social identity theory and inquiry-based strategies.

5.5.1 Social identity theory reflected into emerging themes

Findings from reviewed literature had established that teacher professional identity is a field of study that branched out from the identity theory as a major field of study (Luehmann, 2007; Zembylas, 2003). With a number of identity theory strains in existence due to its application in many fields, it became necessary to align the study with the social identity theory. The emerging themes in this study fall under some of the tenets that characterise the social identity theory. Three broad themes have emerged in this study. First, there is teacher personal identity expressions in which teachers discuss how their past experiences and present experiences with IBLW, their perceptions and beliefs as well as how their commitment and motivation positions

shape their professional teacher identity in IBLW. Personal identity is one of the major shapers of teacher professional identity (Beauchamp & Thomas, 2009; Settlage et al., 2009).

Second, the study confirms that contextual settings and learner populations interface with teacher IBLW professional identity positions. Contextual settings which include learner populations in the case of this study have the potential to promote or inhibit action by teachers (Milne et al. 2006). Third, there is teacher IBLW professional identity positioning whereby teachers show an inclination towards particular teacher IBLW professional identities. The social identity theory conceptual underpinnings have been used to explain how teachers develop particular identity positions in IBLW.

A review of literature has established that teacher professional identity is a psychological, socio-cultural and philosophical construct (Kelchtermans, 2005; Zembylas, 2003; Lasky, 2005; Varghese, 2005; Akkerman & Meijer, 2011; Lee, 2012). What is remarkable about the findings of this study is that the teacher professional identity facets that interact with the practice of IBLW emanate from these three broad constructs. From the psychological construct, the study findings demonstrated how teacher knowledge and skills in IBLW practice, teacher perceptions and beliefs and teacher commitment and motivation play an important role in identity positioning and shaping. A discussion on how teacher perceptions and beliefs, commitment and motivation shape teacher IBLW professional identity has already been presented earlier in the discussion.

Teacher IBLW professional identity has also been observed to possess socio-cultural tenets. This was evident in the two African schools that were used as contexts in this study. Historically it has been established that the African schools once fell under the categorisation of Black education under apartheid policies (Selod & Zenou, 2003). The schools were disadvantaged in terms of resource allocation. Although the dawn of independence came with policies that seek to redress the situation, some of these schools are still struggling to secure materials and facilities for educational processes like laboratory work practice.

For instance the African rural school in this study does not have a science laboratory. It relies on external intervention programmes from donor organisations which seek to expose learners to laboratory work. The African township school in this study has only one laboratory in the school which was donated by an organisation from the corporate world. The African schools are still the worst hit by the shortage of resources as compared to schools from other contexts. There are some implications regarding the laboratory time available for African learners. These contexts still have some characteristics that were brought about by apartheid policies in terms of resource allocation and you find that the learners in the two African schools have the least contact with materials and equipment that are used in laboratory work (Selod & Zenou, 2003).

Teacher IBLW professional identity in this study has also been observed to be a philosophical construct. There are three philosophical standings that have been observed to drive the actions of teachers when they are facilitating laboratory work for learners. First, teachers are driven by the need to demonstrate the relevance of science in society through laboratory work activities. This may have come as a direct result of efforts made during a teacher's past experiences to develop an identity position that seeks to employ the Science-Technology- Society Education (STSE) philosophy in the teaching and learning of science. These efforts are usually made during teacher training (Predetti et al. 2008). This comes about when teachers believe that the practical activities that they facilitate for learners will help them to use scientific knowledge to solve problems in everyday life and also prepare them for tertiary education if they choose to study science-based programmes. The STSE philosophy has been part of the reform drives in the history of science education (Solomon & Aikenhead, 1994). It aims to demonstrate how science can be used to improve the lives of people as they make sound decisions which are informed by science knowledge (Aikenhead, 2003). Jane (former model C school) always makes an attempt to link chemistry with cooking and the cleaning of utensils in the kitchen. She sees this as relevant to the girls that she teaches because she is quite certain most of the girls will assume roles of preparing meals for their families one day.

Kabelo also hopes that his efforts with laboratory work may yield citizens who are able to use science concepts to inform them as they go about their day to day lives. In his narrative he alluded to how he hopes learners will be able to use Boyle's law if they were to pass through a garage with their cars one day to increase pressure in the tyres by pumping in air. He was hoping that the learners will be able to decide on a tyre pressure that is safe for their cars.

The second philosophical position that drives teachers as they facilitate laboratory work was evident through the efforts made by Tendai (former Indian school) and Farai (private school). This philosophical standing proposes that science is a two pronged discipline by being both practical and theoretical. Hofstein and Naaman (2007) point out that the teaching and learning of science can only be meaningful if learners are engaged in practical work experiences. While learners are learning scientific concepts, they should also learn scientific methods on how to conduct scientific inquiry. Farai goes to great lengths in his narrative charged with emotion to explain why teachers should not exclude the practical component when they are teaching science. He is of the opinion that learners who are exposed to theory only when learning science may pass their matric examinations with flying colours due to the nature of the examinations without possessing a comprehensive knowledge of scientific concepts and skills. He feels that it is unfair for the learners because they would have been denied an opportunity to learn science properly.

Tendai (former Indian school) revealed that she is grooming her learners in laboratory work so that they can develop skills in the scientific methods of inquiry in the laboratory. She makes efforts to push her learners to know their way around the laboratory by way of familiarising them with the materials and the processes. Learners confirm that they are constantly engaged in these inquiry experiences in which they are left to their own means sometimes.

Teachers in this study who were not exposed to laboratory work when they were in school are well aware that they missed out on that aspect of science. Kabelo (African township school) feels that his learners should not go through the same experiences. He makes efforts using the few resources available and computer technology to at least afford learners the opportunity to observe scientific phenomena although their interaction with materials and laboratory

equipment may be limited. Jimmy (former Coloured school) realises that his university experiences with laboratory work were not meaningful since he said they only engaged in laboratory work just to get a mark for practical work. When he narrated this his voice was full of regret as if to show that he did not have a proper experience when learning science. This is after he revealed that he never had laboratory work experience when he was in school.

The third philosophical position is that of using laboratory work activities to consolidate the understanding of science concepts. Most learners in this study believe that practical work activities help them to understand scientific concepts that they may fail to understand when teachers are just explaining in class. They claimed that they understand better when they are allowed an opportunity to observe the scientific phenomena. This claim may be supported by an observation that was made during this study.

Most of the teachers teach the theoretical aspects of the topics first before they engage learners in practical work. The experiments that they conduct with learners are supposedly to just confirm the theory which, in this case, is what they know already. To add to that in some cases learners are provided with the investigative question as well as the procedure of the experiment. Some teachers even go a step further to demonstrate how they should follow the procedure of the experiment. It may appear as if learners have been provided with everything in terms of the question, the procedure and the solution to the question, which may actually make the practical activities verification experiments. The surprising thing is that learners are still very anxious on whether they may be able to draw the correct conclusions to the experiments.

Jane (former model C school) gives her learners the investigative question and the procedure as well as what she calls clear instructions on the practical activities so that they don't have to waste the scarce available time trying to figure out what to do. It is clear that the worksheet comes with the design of the experiment in the form of the steps of the procedure, the list of apparatus and a diagram of the apparatus setup. That is why the learners say that the easiest thing when they are conducting laboratory activities is to follow the steps of the procedure.

However, they are unsure of the observations and readings that they record and they become anxious to know whether the interpretations that they make and the conclusions that they draw are the expected ones. Jane confirmed this by saying, “They sometimes they don't get right results because they were talking or didn't count right.”

Betty observed that when learners are taught the theoretical concepts in class they may develop some misconceptions that may be dispelled once they are afforded an opportunity to observe the scientific phenomena during practical work. Therefore, some experiments that may appear as if they are for verification because the theoretical concepts have been taught before the practical activities may not be verification exercises at all for the learners. The practical activities are an opportunity for learning through analysing and interpreting the results that they collect and then drawing conclusions from them.

Melusi (African rural school) is also evidently guided by this philosophy because if he realises that the learners have not covered the topics for which he intends to facilitate laboratory work, he suspends the activity and turns to teaching the theoretical concepts. For him conducting the practical activities first will not work because he feels the learners will benefit more if they can have an opportunity to consolidate their understanding of the scientific concepts that they have been exposed to in class. He also believes that the matric results of the schools that he is giving his services to are improving because of his efforts.

The use of the social identity theory as a theoretical framework suggests that IBLW teacher professional identity is a social identity position. Korte (2007) and Reicher et al. (1995) point out that social identity results when individuals join a group or groups where they have shared beliefs, values, norms and experiences with the other members of the group. Findings of this study reveal some of the teacher perceptions, beliefs and experiences that are inherent in IBLW teacher identity positions.

5.5.2 Inquiry-based instruction as a conceptual framework

Alongside the social identity theory as a theoretical framework this study also uses inquiry-based instruction as a conceptual framework. Hofstein (2004) says when learners engage in

IBLW they ask questions and hypothesize, plan experiments, conduct the planned experiments, analyse results, ask further questions and present the results in a scientific way. This is reflected in this study by making an assumption that focuses on three aspects of inquiry as learners engage in laboratory work which is the formulation of an investigative question, the designing of the procedure and the articulation of the solution to the question.

During the literature review for the study six basic tenets of inquiry-based instruction in laboratory work context were identified. First, Boghossian, (2006) and Miller and Miller (1999) propound that during inquiry learners actively construct knowledge and this construction occurs in the mind of the learner. For this study the yardstick that was used to measure the construction of knowledge in the minds of learners was to look at their ability to formulate investigative questions, design experiments and procedures, and articulate solutions during laboratory work activities. If learners managed to do one or more of the above actions then it would be concluded that learners have constructed knowledge in their minds and, therefore, they have engaged in inquiry. They were a group of learners who engaged in inquiry by articulation of solutions. There was a group of learners who engaged in inquiry by formulating questions and articulating solutions. Another group of learners engaged in inquiry by designing procedures of experiments and, finally, some learners engaged in inquiry by formulating questions and designing procedures of experiments.

Second, Doolittle and Camp (1999) point out that the construction of knowledge should be achieved through learners' experiences in authentic environments to result in unique and multiple meanings for participants. In this study the laboratory work was considered to present meaningful inquiry actions for learners in which learners were able to directly observe scientific phenomena by handling materials and manipulate equipment. One condition that was to be met for the site and participant selection was the assurance that teachers would facilitate laboratory work in which learners conducted the practical activities. Therefore, the environments consisted of materials and equipment used to mount apparatus for the practical activities.

Third, Doolittle and Camp (1999) propound that learning should be relevant resulting in learners developing behaviours that make them capable of undertaking further education, work and everyday life in general. The evidence of the fulfilment of this educational goal emanated from the teachers' beliefs as they facilitated laboratory work for learners. Teachers like Jane (former model C), Kabelo (African township), Melusi (African rural) and Tendai (former Indian) believe that by engaging learners in laboratory work they demonstrate how science is relevant to everyday life and that they are laying a foundation of knowledge and skills in learners that they will use when they are pursuing further education.

Fourth, Schoffstall and Gaddis (2007) and Kirschner et al. (2004) point out that during inquiry activities learners should take considerable control of their learning while teachers play the important role of facilitating and guiding the process of learning and instruction. In this study teachers provided guidance as learners engaged in practical work by way of giving them the necessary information for them to successfully engage in some form of inquiry to varying degrees. Allowing learners to construct knowledge through figuring out what the question, the experiment procedure and the solution should be gave them a certain degree of control over their learning process. The teachers' responsibility was to facilitate this process.

Fifth, as an assumption for this study the activities considered as inquiry in this study are those when learners pose questions, design procedures and articulate solutions to investigative questions (Bretz & Fay, 2008). This assumption was defined in order to delineate the focus of the study in the wake of raging debates on what constitutes inquiry. It was important to limit the focus of the study to what constitutes inquiry in laboratory work because the three aspects are not the only inquiry activities in which learners can engage.

Sixth, Doolittle and Camp (1999) point out that inquiry has a social nature characterised by collaboration, cooperation and communication amongst learners. In this study learners were organised in groups as they engaged in laboratory work activities. Although learners managed to complete the laboratory work tasks in groups, they expressed concerns about the size of some of the groups. Learners prefer to work in small groups or better still in pairs. They realise that if groups become too big their chances of getting into contact with materials and

equipment become less. Learners also admit that more opinions are shared in a group than in pairs. Although this is line with the underlying principles of inquiry rooted in theory of constructivism (Miller & Miller, 1999), learners lament the longer time it takes to arrive at a consensus.

5.6 Generation of new knowledge

The findings of this study contribute to the debates in the conceptualisation of inquiry in the context of school laboratory work. Earlier on in section 2.5.1 on page 43 three ways in which inquiry is conceptualised from literature reviewed. This discussion was made against an observation that teachers understand inquiry in different ways (Barrow, 2006). In the context of the current CAPS syllabus in South Africa to define inquiry by using the criteria of whether experiments are for verification or not would render practical work in school physical sciences devoid of inquiry. Content is taught before practical work and experiments are prescribed (Department of Basic Education, 2011). Some authors consider the prescription of experiments as ‘cookbook’ methods of conducting practical work (Witteck et al., 2007; Hofstein, 2004; Hofstein & Lunetta, 2007) which they argue lack inquiry opportunities for learners. What is important to note here is that this appears to be so because of the definition of inquiry used. Also important is the realisation that school laboratory work is not for discovery of new concepts but for learners to learn established systems of knowledge. However the learning may be facilitated inductively through teaching strategies like laboratory work so that learners may discover the known systems of knowledge on their own.

The use of other definitions of inquiry in which authors place inquiry on a scale that sees it move from simple to complex suggests that learners can practice some form of inquiry as they conduct verification experiments. The definitions portray inquiry as a process that can be broken down into much simpler inquiry actions giving learners opportunities to learn inquiry actions progressively. For this study if learners could perform question posing, experiment procedure design and/or solution articulation they would have performed inquiry to some measurable extent according to available rubrics (Bretz & Fay, 2008; Fay et al., 2007).

It can also be argued here that in school chemistry suggesting that inquiry-based practical work is one in which learners discover conceptual and theoretical concepts on their own is not an all-encompassing definition. Learners do not learn theory only but they also learn practical skills. Practical work is used both as a methodology for teaching and learning chemistry concepts and theories on one the hand and it is also a system of scientific content on the other hand (Tsaparlis, 2009; Hofstein, 2004; Millar, 2004). “Chemistry is basically an experimental science, hence the contact, especially the laboratory and practical work” (Tsaparlis, 2009:111). If learners are able to cooperatively work together to devise an experiment procedure for a verification experiment, they would have successfully engaged in inquiry as they seek to learn experimental work. Two teachers in this study used this approach of structuring laboratory work in a manner that learners work in groups to design experiment procedures to achieve known solutions. The teaching and learning of experimental work in science is very important. It enables learners to develop skills in the application of scientific knowledge to come up with useful innovations in technology. After all, one of the goals in science is for learners to realise that scientific knowledge should be applied in everyday life to improve the people’s lives (Aikenhead, 2003).

The use of rubrics to characterise inquiry is very useful in evaluating inquiry as a process by giving a measure of learner autonomy necessary as learning takes place. If inquiry is only defined on the basis that learners discover scientific concepts and theories on their own during learning, then we may not also be able to evaluate the induction process that led to the discovery of the concepts. In this study the four teachers who provided learners with investigative questions and experiment procedures had learners interpret the results of experiments. During the interpretations learners were able to discover patterns and relationships and they drew conclusions which culminated in the discovery of concepts and theories. However teachers may have provided learners with instruction sheets containing investigative questions and experiment procedures as necessary support as they gave guidance to learners. The availing of worksheets with experiment procedure instructions may be viewed as one of the ‘cookbook’ ways of facilitating laboratory work. Despite that learners may

discover scientific concepts and theories by recognising patterns and relationships as they analyse data collected during experiments. The above discussion has made an effort to establish some notions that enrich the debates in defining inquiry in the school science laboratory. First, the school science laboratory is a space for learning both scientific concepts and inquiry itself in a gradual progressive manner. It makes inquiry a process both in its capacity as a learning and teaching strategy as well as a system of conceptual knowledge. It is a process marked with important milestones in the form of inquiry actions. Second, it is suggested here that inquiry should not be defined only on the basis that learners should discover scientific concepts and theories on their own. Learners can perform some inquiry actions during verification experiments by way of designing experiment procedures to achieve known solutions and suggest investigative questions. Likewise, ‘cookbook’ experiments by way of being prescribed or the use of worksheets with step by step instructions present inquiry opportunities for learners. Learners can still work together in groups and inductively learn some inquiry actions that form part of practical work as a system of scientific knowledge.

This study is positioned in contrast to cases in literature where researchers would use a teacher identity lens to investigate inquiry strategies versus what they termed ‘traditional’ strategies of teaching laboratory work (Roehrig et al., 2007; McDonnell et al., 2007; Hofstein, 2004; Domin, 2007; Limnou et al., 2007). These studies highlighted how the continued practice of ‘traditional’ methods or ‘cookbook’ style laboratory work limits how learners can benefit from laboratory work (Witteck et al., 2007; Hofstein, 2004; Hofstein & Lunetta, 2007). Their main concern was the use of verification experiments arguing that learners should discover concepts and theories during learning. This study explored possible inquiry opportunities for learners during the practice of verification and ‘cookbook’ style experiments in the school science laboratory space. Other important works for the identification of a grey area to position this study are the rubrics designed to characterise inquiry in levels by Bretz and Fay (2008) and Fay et al. (2007). Authors realised that it is not always possible for learners to exercise complete and total autonomy over their learning since they still receive some degree of guidance from their teachers. Also important are studies conducted to highlight barriers to laboratory work because they highlight teacher identity issues that are relevant to this study

(Stoffels, 2005; Chueng, 2007; Hofstein, 2004). This study was a case of bridging the gap between inquiry practice characterisations and teacher identity issues. This study contributes to the body of knowledge by using a teacher identity lens to investigate how these issues interface with the practice of IBLW in secondary schools by placing special attention on particular aspects of the inquiry process in laboratory work. The findings corresponding to the grey area identified at the beginning of this study are discussed as teacher identity positions in question formulation, experiment procedure design and articulation of solutions. Teachers in this study were aware that learners should formulate questions, design procedures and articulate solutions during laboratory work activities. What follows at this point are specific manifestations of how teacher identity issues interfaced with the three inquiry actions considered in this study. This is an important contribution in light of defining inquiry in the school science laboratory as a process marked with significant inquiry actions and the lens that was used.

First, it was observed that if the teachers are guided by the need to fulfil the educational goal of cognitive development through consolidation of learner knowledge they may provide learners with the investigative question and steps of the experiment procedure so that they may use the collected data to give solutions by identifying patterns and relationships that define the scientific concepts and theories. Time constraints, under development of learner skills and knowledge in laboratory and assessment issues, also strengthen teachers' decisions to provide learners with both the investigative question and experiment procedures.

Second, it was observed that some teachers are strongly guided by the science educational goal of developing practical skills and motivation through laboratory work and, therefore, they structure the activities in such a manner that learners engage more in apparatus setup by allowing them to design experiment procedures after they are provided with the solution to the investigative question. The investigative questions may be provided for the learners or they may not be provided. What is significant is that learners are allowed to design the steps of experiment procedures.

There are also other issues that seem to support the teachers' decision to let learners design the steps of the experiment procedures. Teachers perceive the CAPS syllabus as stipulating that learners should cover corresponding content before they can engage in laboratory work. After exposing learners to the scientific concepts in classroom settings, teachers realise that experiments are now for verification since they observe that their particular learners may be able to answer investigative questions without conducting the practical activities. The teachers involved are the ones who believe in grooming learners to be the next generation of laboratory practitioners and they are faced with learners who already know solutions to possible investigative questions. To make laboratory work more meaningful they engage learners in figuring out what has not been availed to them which are the steps of the experiment procedures.

In the second case learners' understanding of scientific concepts is such that they were able to give solutions to questions posed which is in contrast to the first case where learners may not give solutions to the investigative questions even after being exposed to content through optional teaching and learning strategies. What follows now is a discussion dwelling on each of the three inquiry actions considered in this study and how teachers make pedagogical decisions around them.

5.6.1 Teacher identity positions in the formulation of the investigative question

Teachers decide to provide learners with investigative questions during laboratory work because they claim to be time constrained most of the time. They see this as the way of managing laboratory session time so that learners may be able to complete the tasks of the experiments during one lesson. Teachers may also provide learners with investigative questions and procedures of experiments because they realise that learners may not be able to successfully come up with their own questions and procedures because of poorly developed laboratory skills and knowledge. Teachers may also provide learners with investigative questions and procedures of experiments in the case of laboratory activities that form part of assessment because they want to make sure all learners successfully collect results that they can analyse and draw conclusions from so that they can write experiment reports. If learners

fail to collect results because they cannot come up with a question and procedure, they may end up not being able to submit the continuous assessment tasks in time.

5.6.2 Teacher identity positions in designing procedures of experiments

Teachers who structure laboratory activities in such a manner that learners are required to design procedures of experiments expressed the same sentiments that seem to lead them to assume that IBLW identity position. They worry that the current subject policies seem to stipulate that laboratory work should be conducted to verify and confirm scientific theories. They realize that after covering the content in class learners may be able to give solutions to possible investigative questions even before they conduct the experiments. In an effort to make the inquiry activities more meaningful the teachers instruct the learners to engage in figuring out parts of the experiments that may not have been discussed during lessons. Learners are made to design experiments before they conduct them.

The teachers also share a strong belief that science is about developing practical skills and knowledge in laboratory practice. Giving learners an opportunity to design experiments exposes them to learning more laboratory skills such as naming of materials and equipment and knowing their functions, mounting of apparatus and being aware of the safety precautions that need to be taken into account.

The teachers, unlike other teachers who provide experiment procedures for learners, also try to align the way they facilitate laboratory work the way that they experienced it in school. One of the teachers said that she had a ‘strong foundation’ in laboratory work practice which she acquired while she was still in school. The other teacher believes that his laboratory experiences in school were more significant than what he experienced later in tertiary education. The two teachers developed strong beliefs about laboratory work from the time they were in school.

Teachers who design steps for experiment procedures for learners cite time constraints because they use that as a measure to manage the limited time. They also realise that learners’

skills and knowledge in laboratory work are under developed; therefore, they may not successfully complete the task. The issue of assessment came into play. For all learners to go through assessment activities in the laboratory successfully in the limited time, teachers provide learners with the steps of the experiment procedures.

5.6.3 Teacher identity positions in the articulation of solutions

Five of the seven teachers in this study expect learners to articulate solutions to investigative questions. They may provide learners with the investigative question and the procedure of the experiment. What is common about these teachers is the need to use laboratory activities to consolidate scientific knowledge in learners. Teachers perceive that although they may have exposed learners to the scientific concepts by way of other pedagogical strategies in class learners might still be having misconceptions. Therefore, by exposing learners directly to how the scientific phenomenon manifests itself, it is hoped that learners will ultimately internalise the scientific concepts and theories to which they are being exposed. As alluded to earlier on in the discussion, from the point of view of the learners practical activities conducted in this manner may not necessarily be for verification of known theories but present an opportunity for learners to learn. Betty (private school) pointed out that the drawing of conclusions from the data collected is very important for her because it presents learners with an opportunity to learn,

A teacher must go back and say look at your data. What can you conclude from the data and also very often pupils would say I expected this but I got this and then I always say to them record what you see. You have to because today they expected the tap water to give a conductivity reading but it didn't but I always say record what you see and then afterwards we discuss the conclusion.

Two teachers in this study realise that if they expose learners to the scientific concepts first before making them to engage in laboratory work learners already have solutions to some of the investigative questions that may be posed. For this reason they structure laboratory activities in such a manner that the solution becomes part of the information used to guide learners. Learners are now required to engage in inquiry by working in groups to design experiment procedures which include figuring out the materials to set up the apparatus for experiments.

5.7 Conclusion

The analysis and discussion of findings showed how teacher professional identity as determined by their personal identities, contextual settings and teacher IBLW identity positions interfaced with the practice of IBLW in school chemistry. The chapter gave insights into what informs teachers as they plan teachers' and learners' activities as they engage in inquiry activities during laboratory work. The study only focused on three aspects of inquiry in laboratory work activities which are the formulation of investigative questions, the designing of the procedure and the articulation of solutions.

As teachers planned learner and teacher activities in question posing, procedure design and articulation of solution in this study they were informed by the following: time constraints, learner populations, their own school experiences, professional development and training experiences, the perceptions that they have about laboratory work, beliefs that they hold about laboratory work, their sense of commitment, motivational factors, science subject policies in the schools and subject policies about laboratory work, assessment issues, their guiding philosophies in the teaching and learning of science and their capacity to act in the school environments in which they find themselves. A comprehensive summary of the study findings is presented in the following chapter of recommendations and conclusions.

CHAPTER 6

RECOMMENDATIONS AND CONCLUSION

6.1 Introduction

This chapter presents the summary of emergent themes and findings, discusses the limitations and significance of the study, revisits research assumptions, draws conclusions from the findings and outlines recommendations the study makes on IBLW instructional practice for further research. It thus serves as a conclusion to the research study.

6.2 Summary of emergent themes and findings

This study set out to explore how teacher identity influences the practice of IBLW. The investigation focused on the interface between identity positions in IBLW and teacher professional identity. IBLW practice was considered as an identity position which resulted from teachers' experiences as they participated in the teaching and learning process as learners, student teachers and as practicing professionals.

6.2.1 Teacher identity positions in IBLW

What are the teacher professional identity positions in the practice of IBLW in school chemistry? The study established how teachers facilitated inquiry in the chemistry laboratory in accordance with a secondary question generated in support of the main research question. Findings of this study revealed four ways in which teachers facilitated inquiry. The study assumed these four ways to be role identities (Tsui, 2007; Morgan, 2004; Akkerman & Meijer, 2011) displayed by teachers. Similarly, literature findings assert that teacher professional identity is multi-faceted and that it consists of sub-identities (Beijaard et al., 2004; Tsui, 2007). The sub-identities are evident when teachers take up roles such as subject matter masters or pedagogical experts (Akkerman & Meijer, 2011). Accordingly this study considered how

teachers facilitated inquiry in the chemistry laboratory as role identities and IBLW teacher identity positions at those particular times. Literature also reveals that teacher identity is not static but continuously evolving (Varghese et al., 2005; Beijaard et al., 2004). The identity positions were characterised according to the amount of information made available to learners on the practical activities to be conducted (Domin, 2007). All seven the teachers availed learners with content in terms of corresponding science concepts before laboratory activities were conducted. Theory was taught before laboratory activities could be conducted. The first identity position was when teachers facilitated laboratory work by providing learners with the investigative question and the steps of the procedure of the experiments and learners were supposed to figure out the solution to the investigative question. The second identity position was when teachers provided learners with the steps of the procedure and learners were expected to figure out the investigative question and its solution. The third identity position was when teachers provided learners with the investigative question and its solution and learners were expected to design the procedure of the experiment. Last, teachers provided learners with the solution and expected them to formulate the investigative question and design the procedure of the experiment.

6.2.2 Teacher personal identity and identity positions in IBLW

How do personal identity traits influence teacher identity positions in IBLW practice? The following teacher identity traits emerged to be interfacing with teacher professional identities in IBLW; teacher training and professional development, prior school experiences in IBLW, teacher sense of agency and teacher perceptions, beliefs, commitment and motivation. In the same vein findings from literature concur that teacher professional identity is a psychological, socio-cultural and philosophical construct (Kelchtermans, 2005; Zembylas, 2003; Lasky, 2005; Varghese, 2005; Akkerman & Meijer, 2011; Lee, 2012). Teacher narratives revealed that training and development was crucial because the practice of IBLW is a specialised area. Teachers needed to go through instructional processes that empowered them with knowledge and skills in both IBLW and IBLW instruction (Hofstein & Lunetta, 2003). Teachers concurred that without the training and continual professional development that they received in IBLW practice it would be difficult for them to facilitate laboratory work for their learners.

Teachers needed to be masters of chemistry conceptual knowledge, have skills in practical work in chemistry, as well as safety precautions and pedagogical strategies that can be employed in IBLW for them to successfully and meaningfully implement laboratory work in school chemistry.

Teacher training and development played a crucial role in the teachers' philosophical standings in the practice of IBLW. Purposeful efforts directed at moulding teacher identities towards particular orientations in IBLW (Edwards & Blake, 2007; Malderez et al., 2007; Monereo, 2010) were evident in the study findings. Some teachers facilitated practical work activities with the aim of demonstrating to learners the application of chemistry in everyday life in accordance with STSE science reforms (Solomon and Aikenhead, 1994; Aikenhead, 2003; Predetti et al., 2008). Some teachers used practical activities as a pedagogical strategy to consolidate learner knowledge and understanding of scientific concepts by providing authentic environments in which learners could experience science as informed by the theory of constructivism (Doolittle & Camp, 1999). Some teachers frequently incorporated laboratory work to fulfil the educational goal that stipulates that chemistry is a practical subject (Predetti et al., 2008; Hofstein & Lunetta, 2003).

Study findings showed that the philosophical standings of teachers translated into perceptions and beliefs that they used to inform their decisions as they facilitated inquiry in the laboratory for learners. The beliefs and perceptions in turn informed teacher commitment and teachers' sources of motivation and inspiration in the way they facilitate inquiry during laboratory work. Teacher perceptions and beliefs, teacher motivation and teacher commitment were observed to play a central role in informing teachers on which IBLW teacher identity position to display. From the emerging themes, IBLW teacher identity positions could be grouped in two major categories according to whether learners are provided with the steps of the experiment procedure or whether they are required to design them.

Teachers who strongly believed that laboratory work should be used as a pedagogical strategy to consolidate learner understanding of scientific concepts provided learners with the steps of

experiment procedures. Learners would also be provided with an investigative question. The teachers perceived that learners had under-developed skills and knowledge in laboratory work. Teachers also perceived that some of their learners had developed some misconceptions or simply may not have completely grasped the scientific concepts even after the use of other instructional strategies to expose learners to the content before engaging them in laboratory work. They believed that after engaging learners in laboratory work activities learners' understanding of scientific concepts would improve. The teachers found motivation in being able to use laboratory work activities to help learners understand scientific concepts better.

Teachers who strongly believed in the incorporation of Science-Technology-Society-Education (STSE) philosophy in science teaching and learning were observed to provide learners with experiment procedures. This may be because they were driven by the need to show learners what science can do as in how it can be used to solve real life problems. The teachers held the hope that this belief would cascade to learners as motivation to learn science to achieve related career goals.

Providing learners with the steps of experiment procedures was considered as an act of commitment to the successful implementation of IBLW practice in this study. As alluded to earlier in section 5.2.2 of chapter 5, in all the schools and contexts to which this study was undertaken teachers complained of time constraints. Some of the learners also had under-developed skills and knowledge in laboratory work. All this compounded with assessment needs and physical sciences subject policies that require learners to be engaged in laboratory work compelled teachers to negotiate an identity position in IBLW. In order to successfully comply with policy stipulations in the face of challenges teachers provided learners with steps to follow during laboratory activities. This enabled learners to collect results that they could present in tables and graphs, analyse, interpret and draw conclusions from as part of inquiry actions. By drawing conclusions and figuring out solutions learners improved their understanding of scientific concepts and theories.

Teachers who designed laboratory activities in such a way that learners figured out the steps of experiment procedures as an inquiry action held the strong belief that chemistry is a two-pronged subject in which knowledge of theory should be developed alongside skills and knowledge in laboratory work. The teachers also perceived the CAPS syllabus as stipulating that content should be taught first before learners could be engaged in laboratory activities in the form of experiments. To them these experiments would now be for verification of what learners already knew. This perception was in conflict with the teachers' other belief that learners can discover concepts by developing them through inquiry activities in which they engage in the laboratory. They realised learners would be able to give solutions to investigative questions that were posed before they engaged in practical work. In an effort to engage learners in meaningful laboratory work with improved chances of inquiry practices, teachers asked learners to figure out the information that may not have been discussed in other teaching and learning activities. They asked learners to design experiments for which they may have both the investigative question and the solution.

The strong belief in the educational goal that chemistry is both a theoretical and practical subject and attaching equal importance to both aspects seemed to have partly stemmed from the teachers' prior school experiences in IBLW. The teachers felt that they had received a 'strong foundation' in laboratory work during their secondary school years. The laboratory school experiences consisted of regular engagement in laboratory work which culminated in hands-on practical assessments in the form of examinations. The school experiences aimed at making them develop skills and knowledge in laboratory work by being able to independently select materials and equipment for mounting apparatus to conduct experiments. The teachers also worked to make their learners develop the same kind of skills that they thought they developed when they were in school.

From observations made learners were able to assemble materials, set up apparatus and try out the procedures implying that the learners possessed developed skills and knowledge in laboratory work. This was in contrast to learners who have been alluded to earlier on who possessed under-developed skills and knowledge in laboratory work. It is argued here that for

learners to demonstrate skills and knowledge in laboratory work, they need teacher commitment to that cause. They believed that laboratory work is a practice and learners should be groomed to be the next generation of science laboratory practitioners. The teachers took pride in observing their learners' skills and knowledge in laboratory work get transformed over time as they began to display skills that they did not possess previously. This acted as a source of inspiration and motivation for teachers in laboratory work practice.

Teacher philosophical standings, perceptions and beliefs as well as teacher commitment and motivation translated into teacher sense of agency. A sense of agency was considered as the teacher's capacity to facilitate IBLW in the face of prevailing challenges and conditions in schools. Teacher sense of agency was observed to play a significant role in determining IBLW teacher identity positions in the different school contexts. All school contexts had time constraints as one of the most significant challenges. Time constraints were observed to have a debilitating effect on teacher capacity to engage learners effectively and meaningfully in IBLW. Some teachers found it difficult to engage learners frequently in laboratory work activities. They only managed to engage learners in hands-on activities for not more than three times a term. Other teachers, however, in the face of time constraints managed to engage learners in laboratory work about three times a week. The learners demonstrated that they could handle and manipulate laboratory equipment more easily because of constant exposure. One of the teachers in a private school managed to engage learners frequently because she followed a pre-developed yearly workbook of experiments that she used in conjunction with the work schedule. Learners were also expected to sit for a practical examination twice a year. These two conditions in the school settings seemed to promote frequent engagement of learners in laboratory work. However, another teacher working in another school setting also managed to engage learners in laboratory work about three times a week. There were no pre-developed yearly workbooks for experiments and they had no practical examinations in chemistry. She held the strong belief that chemistry is a practical subject and that laboratory work activities are central to chemistry teaching and learning. Therefore the use of pre-developed experiment workbooks and strong beliefs in chemistry as a practical subject helped teachers to overcome the time constraints challenge.

6.2.3 Contextual settings and identity positions in IBLW

How do contextual settings influence teacher identity positions in IBLW? Contextual settings and learner populations were observed to play a significant role in the shaping of IBLW teacher professional identities. This study was undertaken in five school contextual settings in South Africa, namely, a former model C, a former Indian, a former coloured, an African and a private school. Study findings did not assign any IBLW identity positions to any particular school contextual setting because the same IBLW identity position could be observed across most school contexts suggesting that there could be other factors present in all those contexts that led to the identity position. Time constraints were an inhibiting factor that was cited by teachers in all the school contexts. The common factors inherent in the school contexts include under-developed learner skills and knowledge in laboratory work, learner disciplinary issues and poor assimilation of chemistry concepts by learners.

Findings of the study revealed that time constraints inhibited laboratory practice in all the school contexts. Teachers were compelled to provide learners with investigative questions and experiment procedures so that they could quickly conduct the experiments and collect results during the time allocated for science lessons. Lack of time forced teachers to instruct learners to analyse, interpret and draw conclusions from results as homework that they could do in their own spare time.

Teachers cited time constraints as the reason they engaged learners in laboratory work a few times in a term which was generally thrice. This had a direct impact on the development of learner knowledge and skills in laboratory work. As was discussed in section 5.2.2 of chapter 5, both time constraints and under-development of learner knowledge and skills in laboratory work were pivotal in determining teacher identity positions. These two factors acted as a filter as teachers decided on which inquiry actions learners can perform.

Learner attitudes, knowledge and skills in laboratory work contributed in influencing teacher actions as they planned on the amount of content on laboratory activities they would avail to learners. In cases where learners' knowledge and skills in laboratory work were still under-

developed teachers provided learners with the investigative questions and the steps of the procedures of experiments. This support and guidance ensured that laboratory work was successful. Learners could then follow the instructions to conduct experiments and collect results. The collection of results was very important because learners would analyse, interpret and draw conclusions in order to articulate solutions as a way of engaging in inquiry. This strategic position helped teachers to successfully facilitate laboratory work for learners in order to comply with policy stipulations on practical work, especially in schools where learners should be seen to engage in practical work frequently.

In cases where learners possessed poorly developed laboratory skills and knowledge, providing them with investigative questions and the steps of the experiment procedures ensured that formal tasks were successfully conducted. However, there were situations in which learners possessed developed skills and knowledge in laboratory work and teachers still provided learners with procedures of experiments and investigative questions. Teachers cited time constraints and they feared that learners might be unable to finish the laboratory work exercises in the time allocated for science lessons since they could not commit themselves to do extra lessons with learners.

Learner issues with discipline in the laboratory such as tendencies to vandalise equipment and steal, compounded by scarcity of materials, compelled teachers in those environments to strictly supervise learners. Learners were not allowed to set up apparatus on their own. It followed that if teachers set up the apparatus they also had to provide learners with the steps of the procedure of the experiments. Learner negative attitudes towards group work to the extent that they could not harmoniously work together in a limited space of time may have compelled teachers to provide them with the question and procedure to ensure that they did not waste much time by struggling to reach a consensus on how the experiments should be conducted.

In five of the seven schools, teachers did not assume that conducting laboratory activities after covering the corresponding science concepts in class made the practical activities verification experiments. Teachers claimed that chemistry is very abstract and learners might have failed

to assimilate the concepts or might have developed misconceptions during the time they taught the concepts theoretically. Therefore, to assume that practical activities that were conducted thereafter were for verification of what the learners already knew may not be reflecting a true picture of what is on the ground. Inquiry-based strategies are rooted in the theory of constructivism whereby one of the tenets stresses that learning must occur in the mind of the learner (Boghossian, 2006; Miller and Miller, 1999). It can be argued that if learning had not yet occurred in the mind of a learner before laboratory activities could be conducted, then the practical activities were not for verification. The practical activities would be for developing conceptual understanding by discovering patterns, trends and relationships that point to chemistry theories and concepts. This position allowed teachers in the study to use laboratory work to consolidate and develop learner understanding of scientific concepts and not simply for verification of what learners already knew. These teachers were observed to provide learners with investigative questions and the steps of experiment procedures so that learners could figure out solutions.

All the participants in this study taught scientific concepts first before they engaged learners in laboratory work. Findings of the study revealed that teachers who were really worried that learners might be able to give solutions to investigative questions even before they conducted the practical activities designed the experiments in such a way that learners were required to figure out the experiment procedures. A case in point was one activity in which learners had to conduct a laboratory activity for the investigative question, *What is the effect of surface area on the rate of reaction?* Since learners had already covered the content on surface area and rate of reaction, they were in a position to give the solution to this question. The laboratory activity was made meaningful by asking learners to design an experiment to do an investigation to demonstrate the effect of surface area on the rate of reaction. Learners engaged in inquiry by designing procedures of the experiments.

6.3 Limitations of the study

This study is qualitative in nature and therefore the findings may not be generalised because they have to be considered and understood in the light of the contexts in which the research was conducted. Although the study set out to explore the interface of teacher professional identity with IBLW in school chemistry, chemistry is actually offered as physical sciences; therefore, study findings may actually be for both physics and chemistry or physical sciences. The study was not focusing on particular topics in chemistry but on how teachers facilitated inquiry during laboratory work.

6.4 Significance of the study

The significance of the findings of this study is centred on the contribution that it makes to the practice of IBLW in school chemistry. It gives insights on the interface between teacher professional identity and inquiry actions that learners can be engaged in during laboratory work activities. In the wake of drives to make laboratory work more meaningful and effective by ensuring that learners practice inquiry during practical work, the study revealed some of the premises that enabled teachers to facilitate inquiry for learners. This was, however, limited to three important inquiry actions which are question posing, experiment procedure designing and articulation of solutions to investigative questions.

Teachers as pedagogical experts decided what inquiry actions learners could perform by deciding on the amount of information about the laboratory activities that could be withheld from learners or availed to learners. This served to confirm that inquiry in laboratory work as it is practiced in secondary schools exists in different levels of complexity as determined by how much of the necessary information required to conduct successfully the practical activities is withheld from learners (Buck et al., 2008). The study also contributed by highlighting the critical role played by professional teacher identity in the successful and effective implementation of IBLW in school chemistry.

The study had a methodological significance. The study corroborated literature findings on the importance of teacher narratives in shaping teacher professional identity. Teacher narratives generated most of the data on teacher past experiences in personal and professional identity. However the teacher stories had to be triangulated by learner accounts, lesson observations and other observations made by the researcher in the schools. In the same vein, the taking of the study to former Indian, former coloured, former model C, African and private schools also had a methodological significance because it enriched data collected and gave more weight to the study findings.

6.5 Revisiting research assumptions

A number of assumptions were identified at the initial stages of this study. In this section these assumptions are revisited.

Assumption 1:

Teacher professional identity has a significant bearing on teacher practice by informing teacher choices of teaching and learning strategies(Morgan, 2004; Tompson, 2010; Lotter et al., 2009; Roehrig et al., 2007; Stolk et al., 2010; White et al., 2010).

Similarly, the study demonstrated beyond doubt that teacher professional identity can be used as a lens to investigate IBLW as an instructional practice. IBLW practice emerged as a teacher professional identity position brought about by some of the identity traits as entrenched in literature. Study findings show professional training and development, teacher prior school experiences with laboratory work, teacher perceptions and beliefs, teacher commitment and motivation, teacher narratives, teacher sense of agency and school contextual settings to be significant identity traits in the positioning of IBLW professional identity. What is remarkable about these findings is that they came out as emerging themes that echoed what is available in the literature reviewed.

Assumption 2:

Teacher identity and teacher practice are closely interwoven (Day, 2007; Barrow, 2004; Keys, 2007).

Similarly, in this study it emerged that the manner in which teachers facilitated IBLW for learners could be explained through some traits inherent in teacher professional identities. It was shown that teacher professional identity is a psychological, philosophical and socio-cultural construct. Teacher cognitive and affective dispositions guided by science teaching philosophies and mediated by socio-cultural needs and challenges gave rise to teacher identity positions in IBLW. Factors in the school contextual settings such as learner disciplinary issues resulted in teachers being insecure and risk avert. They did not give learners freedom to formulate questions, design experiment procedures, select and assemble equipment and materials. However, some teachers had strong beliefs in teaching practical work as part of science content as determined by their science teaching philosophies. They gave learners more freedom to handle and manipulate equipment and materials as they designed experiment procedures. Teacher knowledge and skills, beliefs, perceptions, sense of agency, commitment and motivation mediated by factors in school contextual settings influenced the practice of IBLW. The identity traits interfaced with principles of inquiry in practical work to bring about teacher identity in IBLW.

Assumption 3:

Question posing, procedure of experiment design and articulation of solutions during laboratory work activities are inquiry actions (Hofstein & Naaman, 2007; Limniou et al., 2007; Bretz & Fay, 2008; Domin, 2007; Fay et al., 2007).

Likewise this study also found that teachers and learners made use of the scientific method for experiments and practical activities conducted in the laboratory. Question posing, experiment design and articulation of solutions were part of the scientific method. The write-ups of experiments had the same sub-headings in all the school contexts. The sub-headings included Investigative question, Hypothesis, Variables, Aim, Apparatus, Method, Observations,

Results, Interpretations, Conclusion and Evaluation. This pointed to the use of the scientific method in the investigations made during laboratory work.

Assumption 4:

Inquiry in laboratory work can be placed along a continuum in which it progresses from simple to complex (Bretz & Fay, 2008; Domin, 2007; Fay et al., 2007).

Similarly, the study confirmed that teachers do not facilitate inquiry in the laboratory in the same way. The way teachers facilitated laboratory work could be characterised according to the amount of practical work content that the teachers availed to learners. However, some of the teacher practices were divergent from the rubric characterisation of levels of inquiry along the continuum. Four of the seven teachers facilitated inquiry at level 1 of Bretz and Fay's (2008) rubric in which learners are provided with questions and steps of experiment procedures. Three of the seven teachers facilitated inquiry in manners that did not fit the rubric which points to the need to refine the available rubrics to characterise inquiry. It showed that teachers have the freedom to choose which inquiry actions to facilitate for learners. The manner in which they facilitate the inquiry actions may not necessarily be in order of the rubrics that characterise the inquiry continuum. One of the three teachers provided background content on the laboratory activity and steps of the experiment procedure and asked learners to formulate the question and articulate the solution. This was a divergent approach. Another teacher with a divergent approach gave learners the question and the solution and asked learners to design the steps of the experiment procedure. Finally, there was a teacher who just provided learners with a solution and asked learners to formulate a question and design the steps of the experiment procedure.

Assumption 5:

Teacher professional identity is not a 'static' entity; it evolves over time (Beauchamp & Thomas, 2009; Beijaard et al., 2004; Assaf, 2008; Upadhyay, 2009; Varghese et al., 2005).

Similarly in this study teacher IBLW identity was continually being shaped as teachers went through experiences from the time they were in school to present times of teacher practice. Teachers indicated that if they had enough time at their disposal they would allow learners to formulate investigative questions and increase the frequency of laboratory work engagement. If these changes in contextual settings were effected, it would trigger some shifts in the manner in which teachers facilitated laboratory work for learners. Study findings revealed that teachers acted in accordance with how they perceived learner attitudes, knowledge and skills and disciplinary issues. A change in learner population may change the manner in which teachers facilitate IBLW in as far as the amount of information on laboratory activities they choose to avail to learners. The evidence alluded to in the discussion above points to the notion that teacher professional identity is continuously undergoing transformation.

Assumption 6:

Teacher professional identity portrays multiplicity and can be fragmented into sub-identities and role identities (Tsui, 2007; Morgan, 2004; Akkerman & Meijer, 2011).

Similarly, in this study teachers displayed IBLW identity positions as role identities of pedagogical experts which was just part of the totality of their professional identity. Facilitating IBLW for learners is one of the many roles that teachers play in the teaching and learning of chemistry. This made it possible for the study to focus on IBLW practice identity as a fragment of the totality of teacher professional identity.

6.6 Conclusion

The study set out to unravel the intellectual question, *how does teacher professional identity interface with the practice of IBLW in school chemistry?* Teacher professional identity is closely interwoven with the way teachers facilitate IBLW for learners in school chemistry. Teachers used their identity traits mediated by contextual settings as a pedagogical resource. The interface between teacher identity traits, school contextual settings and principles of IBLW as a field of practice gave rise to teacher identity positions. The identity positions were

a characterisation of how teachers facilitated question posing, design of experiment procedures and solution articulation as inquiry actions. A set of conditions gave rise to pedagogical decisions that resulted in learners performing and owning the inquiry actions or having the inquiry actions availed as part of instructional information.

Time constraints, under-development of learner knowledge and skills in laboratory work, poor ability of learners to assimilate corresponding scientific concepts taught to them before practical work and learner disciplinary issues intertwined with teacher beliefs on the use of laboratory work to develop and consolidate learner understanding, lack of teacher commitment to create time for longer laboratory sessions and teacher perception of learner ability to perform inquiry. A teacher identity position in IBLW resulted. Learners received investigative questions and the steps of experiment procedure while they performed inquiry by articulating solutions. Teachers used laboratory activities to develop and consolidate learner understanding of scientific concepts and theories. Although practical work was facilitated for learners after covering corresponding science concepts, the experiments were not for verification because of poor learner assimilation.

Another teacher identity position was when learners designed steps of experiment procedures. Teachers used practical work to develop learner knowledge and skills in laboratory work. Practical work was facilitated for learners after covering the corresponding chemistry concepts. The experiments were basically for verification because learners were in a position to give solutions to investigative questions before conducting the experiments. This was also in conflict with teacher beliefs to use laboratory work for the discovery of scientific concepts. Therefore, learner attitudes, skills and knowledge intertwined with teacher beliefs in laboratory work to bring about the teacher identity position.

The use of teacher professional identity as a lens to study the practice of IBLW enabled the focus to be put on the teacher as a whole person (Olsen, 2008). This meant considering the psychological, socio-cultural and philosophical aspects that make up identity (Kelchtermans, 2005; Zembylas, 2003). The use of the lens revealed how verification and ‘cookbook’

experiments presented inquiry opportunities for learners in school science. Some voices in literature propound that verification and ‘cookbook’ experiments lack inquiry opportunities for learners (Hofstein, 2004; McDonnell et al., 2007). The introduction of the CAPS syllabus in South Africa has come with prescribed experiments (Department of Basic Education, 2011). Some teachers also provide learners with instruction sheets during experiments (Stoffels, 2005). These are some of the characteristics of ‘cookbook’ experiments. However the use of teacher professional identity as a lens and rubrics to characterise inquiry (Bretz & Fay, 2008; Fay et al., 2007) reveal that learners engage in some inquiry actions as they conduct these types of experiments. Although they may have been provided with questions and procedures they may still be able to articulate solutions.

In the context of the CAPS syllabus content may be taught to learners before they can engage in practical work. The subsequent practical activities become verification experiments which may be claimed to be lacking in inquiry (Hofstein, 2004; McDonnell et al., 2007). This appears to be so because of the inquiry definitions used that emphasise the discovery of scientific concepts and theories by learners through the use of inductive methods (Prince & Felder, 2006; Domin, 2007). One such definition says, “Inquiry - based science education - if carried out efficiently-can be a very efficient way to facilitate conceptual understanding of both important scientific ideas and how science works” (Bertsch et al., 2014:20). The emphasis for learners to understand concepts and theories is quite evident although ‘how science works’ may mean practical work or application of scientific ideas. Chemistry is not only theoretical but practical, making practical work part of subject matter (Tsaparlis, 2009). Verification experiments present opportunities for learners to design experiment procedures as part of the process to learn practical work skills. The use of teacher identity also revealed contextual factors that make the seemingly verification experiments not be such for learners because they would not have gained conceptual understanding during activities prior to practical work.

Dudu & Vhurumuku (2012) and Hattingh et al. (2007) are some of the studies conducted in South Africa that recognise that inquiry in the school science laboratory should be placed on a continuum that helps to give a measure of learner autonomy. The use of teacher identity and

rubrics to characterise inquiry have revealed inquiry opportunities for learners in verification and ‘cookbook’ experiments.

6.7 Recommendations for IBLW instructional practice

Although efforts may still be underway to ensure that the practice of IBLW becomes more effective by allowing learners to perform more inquiry actions during laboratory work, teachers may be encouraged to make sure learners practice to perform all the actions by varying the way they facilitate laboratory work. Without making learners pose questions, design experiment procedures and articulate solutions in one laboratory activity, teachers may change what inquiry actions learners perform each time. According to the findings of the study some learners are only made to articulate solutions after being provided with investigative questions and experiment procedures. They may never get a chance to design experiment procedures. Hence the following recommendations:

- 1.** It is recommended that teachers yearly develop workbooks of experiments so that they may be able to frequently engage learners in laboratory work in the face of time constraints as Betty from one of the private schools suggested. If teachers purposefully integrate practical work in their lesson plans, then frequent engagement in laboratory work will be ensured. This will go a long way to enhance the development of learner skills and knowledge in laboratory work because of frequent engagement. Schools should support these endeavours by allowing for longer time periods for laboratory work through putting one to two hour blocks on the timetable for science.
- 2.** It is also recommended that teachers share their experiences in laboratory work as they practice it with their learners in forums like professional development workshops. Teachers may see how teacher commitment, motivation and sense of agency help their colleagues to practice what others fail to practice in the wake of challenges like time constraints and learner population issues.
- 3.** In the wake of inequitable access to laboratory work facilities on the South African secondary school terrain twenty years after the inception of democracy, more should

be done to improve the situation of schools in need. The government, non-governmental organisations and schools could avail more funds to support programmes that engage learners in laboratory work. These programmes include the ones facilitated by Melusi in this study in which mobile science laboratories are made to reach learners in schools that lack facilities.

6.8 Recommendations for future research

Findings of this study point to suggestion for future research. It was observed that teachers only manage to facilitate inquiry for learners by engaging them in some inquiry actions while the other possible inquiry actions are given as information. The practice of question posing, design experiment procedures and solution articulation by learners in one laboratory work session in most secondary chemistry laboratories in South Africa may still prove to be illusive if learners are not given an opportunity to learn and practice all the three inquiry actions. Learners should be able to formulate investigative questions, design steps of experiment procedures and articulate solutions in one laboratory activity after they have been provided with the context and content. It is also important to note that inquiry is in the context of a teaching laboratory in which learners assimilate accepted knowledge and not a research laboratory where scientists push boundaries (Millar, 2004; Domin, 2007). Also inquiry in school science should be defined in context taking into account general goals of science education, the theory of constructivism on which inquiry is based and school contextual settings. Hence the following research questions are posed:

1. What are learner perceptions, beliefs and attitudes about the practice of inquiry in school chemistry?
2. What are School Management Teams' (SMTs) conceptions of the nature and role of inquiry in school science?

The interface between teacher professional identity and the practice of inquiry-based laboratory work was a research that I found to be worthy of studying. The endeavour was rewarding in both my personal and professional capacity just as the findings contributed to the

existing body of knowledge. Important insights on IBLW in school chemistry and teacher professional identity came to light. The existence of the interface between teacher professional identity and teacher practice cannot be overemphasized. It is befitting to end this chapter on the following note:

You can teach a student a lesson for a day; but if you can teach him to learn by creating curiosity, he will continue the learning process as long as he lives (Clay P. Bedford).

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Appendix A: GDE research approval letter



GAUTENG PROVINCE

Department: Education
REPUBLIC OF SOUTH AFRICA

For administrative use:
Reference no. D2013/236

GDE RESEARCH APPROVAL LETTER

Date:	20 November 2012
Validity of Research Approval:	4 February 2013 to 27 September 2013
Name of Researcher:	Tsakeni M.
Address of Researcher:	1456 Block GG
	Soshanguve
	Pretoria
	0152
Telephone Number:	078 640 3218
Email address:	mtsakeni@gmail.com
Research Topic:	The influence of teacher professional identities on inquiry-based laboratory work in school Chemistry
Number and type of schools:	SIX Secondary Schools
District/s/HO	Tshwane North and Tshwane South

Re: Approval in Respect of Request to Conduct Research

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

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

Making education a societal priority

Office of the Director: Knowledge Management and Research

9th Floor, 111 Commissioner Street, Johannesburg, 2001
P.O. Box 7710, Johannesburg, 2000 Tel: (011) 355 0506
Email: David.Makhado@gauteng.gov.za
Website: www.education.gpp.gov.za

Makhado

Appendix B: A Tshwane North District research approval letter



GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

Enquiries: S MAKUBU
Directorate: Policy, Planning & DISM
Tel: +27 (0)12 5431203
Fax: +27 (0)85 585 0044
Ref: 15/2/6

**TO : PRINCIPALS OF SOSHANGUVE AND
HAMMANSKRAAL SECONDARY SCHOOLS**

**FROM : MS SHIRLEY MOLOBI
DISTRICT DIRECTOR**

DATE : 27 FEBRUARY 2013

SUBJECT : APPROVAL TO CONDUCT RESEARCH

District Tshwane North gives Ms. M. Tsakeni permission to do research at Soshanguve Secondary Schools: Soshanguve secondary, Botse-Botse, Makhosini, Kgomotso, Memezelo and Elizabeth Matsemela.

The research topic is "The influence of teacher professional identities on inquiry-based laboratory work in school chemistry."


Please grant her permission to do research after contact time so that the normal programme is not interrupted. The principal must be consulted about an appropriate time when the research may be conducted.

The researcher is responsible for supplying and utilizing her own research resources.

No names may appear in the research report.

Kindly assist her by giving the necessary cooperation.

Regards


MS SHIRLEY MOLOBI
DISTRICT DIRECTOR

P.P.

Appendix C: Tshwane South District research approval letter



GAUTENG PROVINCE
Department of Education
REPUBLIC OF SOUTH AFRICA

Reference : Policy and Planning: Partnerships
Enquiries : Sello George Ngwenya
Telephone : 012 401 8322
Fax : 012 401 8323
E-mail : Sello.Ngwenya@gauteng.gov.za

19 February 2013

Ms M Tsakeni
1456 Block GG,
Soshanguve
Pretoria,
01525
Mobile: 078 640 3218 e-mail: mtsakeni@gmail.com

Cc: The Principal and SGB

Dear Madam

PERMISSION TO CONDUCT RESEARCH: MARIA TSAKENI

Your research application has been approved by Head Office. The full title of your Research: "The influence of Teacher Professional identities in inquiry-based laboratory work in school Chemistry". You are expected to adhere strictly to the conditions given by Head Office. You are also advised to communicate with the school principal/s and/or SGB/s of the targeted schools regarding your research and time schedule.

Our commitment of support may be rescinded if any form of irregularity/ no compliance to the terms in this letter or any other departmental directive/ if any risk to any person/s or property or our reputation is realised, observed or reported.


Terms and conditions

1. The safety of all the learners and staff at the school must be ensured at all times.
2. All safety precautions must be taken by the researcher and the school. The Department of Education may not be held accountable for any injury or damage to property or any person/s resulting from this process. The school/s must ensure that sound measures are put in place to protect the wellness of the researcher and his/ her property.

NB Kindly submit your report including findings and recommendations to the District at least two weeks after conclusion of the research. You may be requested to participate in the Department of Education's mini-research conference to discuss your findings and recommendations with departmental officials and other researchers.

The District wishes you well.

Yours sincerely


Mrs. H.E. Kokana
Director: Tshwane South District
Date : 22 / 02 / 2013

Making education a societal priority

Office of the District Director: Tshwane South District

(Mamelodi/Easterns/Pretoria/Pretoria East/Pretoria South/Afteridgeville/Laudium)
205 Pretorius Street, Pretoria 0001
Private Bag X 198, Pretoria, 0132 Tel: (012) 4016300 Fax: (012) 4016318
Website: www.education.gpg.gov.za

Appendix D: Letter to the District education managers



Cell: 0786403

Email: mtsakeni@gmail.com

2013-04-22

The Senior Manager,
Department of Education
Tshwane South District

Dear Sir/ Madam

My name is Maria Tsakeni. I am a PhD student with the University of Pretoria. I am currently conducting research on inquiry-based laboratory work in school chemistry. I am asking for permission to conduct my study in your school. I need to conduct two interviews with a Grade 10/11 physical sciences teacher; observe a laboratory activity facilitated by the teacher; and conduct one focus group interview with six learners who would have participated in the laboratory activity.

I have been granted permission by the Gauteng Department of Education and the Tshwane North/South District Education Managers to conduct research in your school. The identity of your school and data collected will be treated with strict confidentiality. Your school, teachers and learners will not be harmed in any way.

If you grant permission for this study to be conducted in your school please sign on the space provided below.

Yours sincerely,

Maria Tsakeni

Supervisor

Prof Saloshna Vandeyar

Date

Date

Appendix E: Informed consent letter to the Principal



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

Cell: 0787403218
Email: mtsakeni@gmail.com
2013-04-22

Dear Principal

My name is Maria Tsakeni. I am a PhD student with the University of Pretoria. I am currently conducting research on inquiry-based laboratory work in school chemistry. I am asking for permission to conduct my study in your school. I need to conduct two interviews with a Grade 10/11 physical sciences teacher; observe a laboratory activity facilitated by the teacher; and conduct one focus group interview with six learners who would have participated in the laboratory activity.

I have been granted permission by the Gauteng Department of Education and the Tshwane North/South District Education Managers to conduct research in your school.

The identity of your school and data collected will be treated with strict confidentiality. Your school, teachers and learners will not be harmed in any way.

If you grant permission for this study to be conducted in your school please sign on the space provided below.

Principal _____ Date _____

Researcher _____ Date _____

Supervisor _____ Date _____

Appendix F: Informed consent letter to the physical sciences teacher



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

Cell: 0786403218
Email: mtsakeni@gmail.com
2013-04-22

Dear Grade 10/11 Physical sciences teacher

My name is Maria Tsakeni. I am a PhD student with the University of Pretoria. I am currently conducting research on inquiry-based laboratory work in school chemistry. I am inviting you to participate in this study. I need to conduct two interviews with you as a Grade 10/11 Physical sciences teacher. One interview session will take about 60 minutes. I also need to observe as you facilitate a laboratory activity for your learners. Finally I need to conduct one focus group interview with six learners who would have participated in the laboratory activity.

I have been granted permission by the Gauteng Department of Education, the Tshwane North/South District Education Managers and the Principal to conduct research in your school. The identity of your school and data collected will be treated with strict confidentiality. This also applies to your identity and the identities of your learners. Neither you, your school nor your learners will be harmed by this study.

If you accept to participate in this study please read and sign the consent form below.

Yours sincerely,

Maria Tsakeni

Date

Supervisor

Prof. S. Vandeyar

Date

Appendix G: Informed learner assent letter and consent letter to parent/guardian

CONSENT

In terms of ethical requirements of the University of Pretoria, you are now requested to complete the following section:

I, _____ have read this letter and understand that

- my participation in this research is *voluntary*, and that I can withdraw from the research at any time.
- in line with the regulations of the University of Pretoria regarding the code of conduct for proper research practices for *safety in participation*, I will not be placed at risk or harmed in any way.
- my *privacy* with regard to confidentiality and anonymity as a human respondent will be protected at all times.
- as a research participant, I will at all times be *fully informed* about the research processes and purposes.
- research information will be used for the *purposes of this enquiry*.
- my trust will not be betrayed in the research processes and in dissemination of its published outcomes, and I will not be deceived in any way.

I hereby declare that I give my *informed consent* for participation in this research.

Signature: _____

Date _____

Thank you for your time.



Cell: 0786403218
Email: mtsakeni@gmail.com
2013-04-22

Dear learner

I am a PhD student with the University of Pretoria. I am currently conducting a research on inquiry-based laboratory work in school chemistry. I have been granted permission to conduct this research in the school you are attending by the **Gauteng Education Department, the Tshwane South/North District Education Departments and your Principal**. I am inviting you to participate in a focus group interview and laboratory work lesson in which you will be video-recorded. Your participation and identity will be regarded as completely confidential. You are asked to voluntarily participate and assurance is given that the process is not harmful to you in any way.

If you wish to participate, please sign on the space provided below and take this letter to your parent/guardian for them to give you permission by consenting to this request.

Yours sincerely,

Researcher_____

Date_____

Supervisor_____

Date_____

CONSENT

In terms of ethical requirements of the University of Pretoria, you are now requested to complete the following section:

I, _____ have read this letter and understand that

- my participation in his research is *voluntary*, and that I can withdraw from the research at any time.

- in line with the regulations of the University of Pretoria regarding the code of conduct for proper research practices for *safety in participation*, I will not be placed at risk or harmed in any way.
- my *privacy* with regard to confidentiality and anonymity as a human respondent will be protected at all times.
- as a research participant, I will at all times be *fully informed* about the research processes and purposes.
- research information will be used for the *purposes of this enquiry*.
- my trust will not be betrayed in the research processes and in dissemination of its published outcomes, and I will not be deceived in any way.

I hereby declare that I give my *informed consent* for participation in this research.

Signature: _____

Date _____

Thank you for your time.

Informed consent by parent/guardian

Dear parent/Guardian

In terms of ethical clearance requirements of the University of Pretoria, you are requested to give your permission for your child to take part in the above mentioned research. I am inviting your child to participate in a focus group interview and a laboratory activity lesson. I intend to use the audio and video recordings for the purposes of my studies only. Your child’s identity and information collected will be treated as completely confidential. Assurance is given that the child will not be harmed in any way.

I _____ have read this letter and I do hereby declare that I give my informed consent for my child to participate in this research.

Signature _____ Date _____

Appendix H: Semi-structured interview schedule for teachers

I. Opening

- A. (Establishing rapport) My name is ----- . I am a PhD student with the University of Pretoria. I appreciate that you found it within you to be able to sit for this interview. Thank you very much.
- B. (Purpose) I would like to ask you some questions on your practice as a teacher in the chemistry laboratory.
- C. (Motivation) I intend to use the information in the research that I am conducting on inquiry practices in the school chemistry laboratory.
- D. (Time line) The interview should take about 60 minutes.

II. Body

Background information

- 1. For how long have you been a teacher?
- 2. For how many years have you been teaching chemistry?
- 3. Which experiences have you had with laboratory activities so far in terms of school experiences, college experiences, teaching experiences and professional development experiences?
- 4. Do you think your professional training has prepared you adequately for the kind of work you do in teaching chemistry in the laboratory?
- 5. Which of your past experiences with chemistry laboratory activities have had a significant impact on your current practice?
- 6. Do you think the exposure you have had to laboratory activities has been sufficient to prepare you for your current practice? If not in what ways do you feel the experiences would have been enhanced?

Current experiences

- 1. How often according to the syllabus should learners engage in laboratory activities in a month? Have you been able to conduct them? Has it been possible to do more than the specified frequency? Have you found yourselves not able to meet those stipulations? If so what are the reasons?
- 2. Do you think you have been able to conduct sufficient laboratory activities?
- 3. What role does the laboratory activity play in your teaching of chemistry?
- 4. Do you find any value in the continued practice of laboratory activities?
- 5. What challenges have you encountered as you conduct laboratory activities
 - (a) on the part of learners and
 - (b) within the school settings?
- 6. How have you managed to overcome these challenges?
- 7. What kind of support have you received to ensure laboratory activities are made part of teaching and learning?
- 8. What other kind of support do you feel you should receive to ensure the effective conducting of laboratory activities from

- (a) learners?
- (b) the school?
- (c) the department?
- (d) the curriculum?

C. Inquiry-based laboratory work practice

1. Before conducting a laboratory activity how do you prepare yourself and the learners?
2. What kind of support do learners need before and during the laboratory activity?
3. What kind of support do you need as a teacher before and during the laboratory activity?
4. If we say that inquiry is about posing a question, writing the procedure and providing the solution:
 - (a) What is your role and the role of the learners in posing the question?
 - (b) What is your role and the role of the learners in constructing the procedure of the experiment?
 - (c) What are your role and the role of the learners in giving solution to the problem?
5. How do you experience learners' abilities and skills in posing the question, writing the procedure of experiment and giving solution/s to the problem?
6. Are you satisfied with the way you have been conducting the laboratory activities?
 - (a) If you had the means what changes would you make?
 - (b) What aspects would maintain the way they are now?
6. Do you consider yourself adequately prepared for IBLW?
7. Did you do any in-service training in this regard?

III. Conclusion

- A. (Summarise) I understand that your background experiences with laboratory activities started----- . Currently your experiences with laboratory activities are as follows-----and as far as the practice of inquiry-based laboratory work is concerned you have been able to-----.
- B. (Maintain rapport) I appreciate the time you took for this interview. Is there anything else you feel would be helpful for me to know?
- C. (Action to be taken) I should have all the information I need for now. Would it be alright to call you if I have more questions? Thank you once more.

Appendix I: Focus group interview schedule for learners

I. Opening

- A. Establishing rapport) My name is -----, I am a PhD student with the University of Pretoria. I appreciate that you found it within you to be able to sit for this interview. Thank you very much.
- B. (Purpose) I would like to ask you some questions on your experiences with your teacher in the chemistry laboratory.
- C. (Motivation) I intend to use the information in the research that I am conducting on inquiry practices in the school chemistry laboratory.
- D. (Time line) The interview should take about 45 minutes.

II. Body

1. How often do you conduct chemistry experiments in the laboratory?
2. Do you enjoy them?
3. How do you prepare yourselves for the experiments?
4. What kind of assistance do you receive from your teacher for you to be able to conduct experiments?
5. During the planning of an experiment-:
 - (a) Are you able to pose the problem/question?
 - (b) Are you able to provide the procedure/method of the experiment?
 - (c) Are you able to give solution to the question/problem of your experiment?
6. Are you able to choose the materials and equipment to use during the experiments?
7. What is most challenging when you are conducting experiments?
8. What is easy to do whenever you conduct experiments?
9. Can you describe the support that you must get from your teacher for you to successfully conduct the experiment.
10. What do you think can be done to improve the way in which you conduct experiments in the laboratory?
11. Do you the laboratory activities are useful in the learning of chemistry?

III. Conclusion

- A. (Summarise) I understand that you do the following when you are conducting chemistry experiments in the laboratory with your teacher.
- B. (Maintain rapport) I appreciate the time you took for this interview. Is there anything else you feel would be helpful for me to know?
- C. (Action to be taken) I should have all the information I need for now. Would it be alright to come back to you if I have more questions? Thank you once more.