PROFESSIONAL LEARNING AND DEVELOPMENT THROUGH REFLECTIVE PRACTICE: LIVED EXPERIENCES OF KENYAN CHEMISTRY COUNTY TEACHER TRAINERS

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Bachelor of Science Education (BEd)

Master of Education (Research and Evaluation)

A thesis submitted in partial fulfilment of the requirements for the degree of

Doctor of Education

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3 JUNE 2020

DECLARATION OF ORIGINAL AUTHORSHIP

I, Mercy Macharia, declare that this Doctorate thesis, entitled, "Professional learning and development through reflective practice: Lived experiences of Kenyan County Chemistry teacher trainers" is submitted in partial fulfilment for the requirement of degree of Doctor of Education. To the best of my knowledge and belief, this Doctoral thesis contains no information that has been submitted previously by another person, for award of academic degree or diploma and published work. This thesis is my own work except where due reference is made.

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ABSTRACT

This study explored professional learning with the aim of improving teaching performance in chemistry in Kenyan secondary schools. The study investigated *how and what Kenyan County chemistry teacher trainers learn from participating in a study where they reflect on their teaching.* Reflective practice is not commonly used in teaching and teacher education in Kenya. Teaching and learning of chemistry at the secondary level in Kenya has received criticism overtime because of students' low achievement and declining numbers of those opting to pursue courses in the university related to the subject. This is partly attributed to inefficient teaching methods. Initial teacher training to some extent does not match with changes in the education sector and the current group of students. Hence, teachers are expected to embrace long-life professional learning to keep abreast with the dynamic changes in the education system in many countries, Kenya included.

The research takes the form of a qualitative case study. Four volunteer, experienced, Kenyan County chemistry teacher trainers, who are *also secondary school classroom teachers*, participated in the study over a period of nine months. The study was situated within a social constructivist view of learning, through which teacher trainers were provided an opportunity to examine their own prior knowledge of teaching and construct new knowledge through the process of shared reflection and dialogue. They reflected on critical incidents they chose from their own classroom teaching experiences they thought they could learn from, individually, and in collaboration with their participant colleagues.

Data were collected from group reflection discussions and interviews. The process of thematic coding was employed to analyse data. The process of developing a coding scheme for data analysis was guided by the research questions and literature related to teacher learning in practice.

The findings revealed that although teacher trainers missed many opportunities to learn from their teaching experiences, reflecting on a critical incident did offer them some opportunities to learn. They individually, and in collaboration with one another, reflected on their teaching and discussed problems regarding pedagogy, content knowledge, and learning resources.

It was found that participants mainly adopted three professional learning activities: reflecting, experimenting and interacting with contact (with students and their participant colleagues) to develop knowledge of teaching methods, student learning needs and subject content.

The findings also revealed that teaching and learning in the teacher trainers' classrooms was affected by a myriad of contextual problems. Although not expected at the outset of the study since the participants were considered to be accomplished teachers with more than fifteen years of teaching experience in secondary school, it was found that in some topics they had limited pedagogical content knowledge. Assumptions about teaching and student learning they made also affected teaching and learning. Moreover, it was found that many students had a negative attitude towards chemistry and lacked knowledge of basic scientific concepts. Teaching and learning of chemistry in the teacher trainers' classrooms was also found to be affected by a lack of time, laboratory facilities, and laboratory assistants. Findings further revealed that many schools in Kenya lacked qualified teachers and newly employed qualified teachers lacked skills to conduct practical lessons. Gaps were also identified in the Chemistry syllabus and in textbooks. Some content in the chemistry syllabus was not aligned with cognitive abilities of the students for whom they had been designed. A focus by the teacher trainers on external examinations also affected teaching because it was found that they did not teach for students' conceptual understanding, but rather, to pass examinations.

The study recommends introduction of school-based in-service training in Kenya, focusing on giving teachers an opportunity to reflect on their practice, increasing the frequency of national and County in-service training for teacher trainers and teachers, from the current one week per year to address the issue of limited pedagogical content knowledge. Findings also indicate a need for the current review of the education system in Kenya to consider better aligning the content found in the syllabus and textbooks with the cognitive abilities of students. Since the County is also in the process of phasing out the use of external examinations, as they affect teaching and learning in the classroom, the study findings provide insights and ideas that can be considered in this process.

ACKNOWLEDGEMENTS

The completion of this thesis is a dream come true for me. God, may your Holy name be praised in making this happen. There are many individuals whom I am thankful for walking along with me in this journey. I am extremely thankful to my supervisors, Associate Professor Gloria Stillman and Doctor Mellita Jones for their supervision in the process of completing this research study. Their continuous guidance and support helped me in making this journey a reality. My special appreciation goes to Professor Bridget Aitchison, Dean ACU Ballarat campus and Associate Professor Janeen Lamb, Director, Higher Research Faculty of Education and Arts ACU for the role they played towards the completion of this thesis, God bless you all.

I would also like to extend my utmost gratitude to my participants, and colleagues, while they need to remain anonymous, the giving of their time and stories of their teaching and learning experiences was crucial to the success of this research study, and I am deeply indebted. Thank you and God bless you. Many thanks go to Australian Catholic University for awarding me a scholarship and support without which I could not have had an opportunity to do my Doctorate. Also, to the Government of Kenya through the Ministry of Education for permitting me to study out of the country and permission to conduct research.

To my wonderful sons Kevin and Mavin, thank you for your patience and love, when I was far away pursuing this study in Australia. The Macharias family, Benjamin Kilonzo, David Kireru, Lucy Njura, Sam Eyamu, Rahab Chira and CEMASTEA staff members, thank you for your support and encouragement, God bless you all. To my Australian friends, Flora, Joy, Amina, Andrew, Wilson, Trish, Lorna, Ann, Tracy, Dylan and ACU Ballarat university staff fraternity, I salute you all. Flora and Dr. Mary Nuttall, what could I have done without your moral, spiritual and financial support in a foreign country, God bless you according to His riches in Heaven.

DEDICATION

This thesis is dedicated to my late father Edward Macharia Githaiga and my mum Esther Muthoni Macharia for struggling and denying themselves 'all' to educate me and all my ten siblings.

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LIST OF ACRONYMS

KCPE	Kenya Certificate of Primary Education
KCSE	Kenya Certificate of Secondary Education
KIE	Kenya Institute of Education
SMASE	Strengthening Mathematics and Science Education
SMASSE	Strengthening of Mathematics and Science in Secondary Education
KNEC	Kenya National Examination Council
OECD	Organization for Economic Co-operation and Development
UNESCO	United Nations Education, Scientific and Cultural Organisation

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CHAPTER ONE
BACKGROUND OF THE STUDY

1.1 Introduction

This chapter presents the background of the study reported in this thesis, which was to explore *how* and *what* Kenyan teacher trainers learn about their teaching, when they engage in individual and collaborative reflection. *Reflective practice* was considered to support the teacher trainers' learning because, whilst it has been used in many countries to promote teacher learning, it is *not commonly used in Kenya.* Included in this chapter is the background to the problem investigated related to the complexity of teaching and learning to teach. The research problem is identified and how it has arisen from the consistent low performance of Kenyan students in Chemistry, the science subject focus of this study. For the reader to understand the source of the problem, and the importance of undertaking this research, an overview of the study context, Kenya, is also presented. Included in the context is a description of the education system followed in Kenya, some issues related to chemistry teaching, information on initial teacher training in Kenya, and professional learning and development that exists for science and mathematics teachers. Finally, the research problem is defined in relation to previous research conducted in Kenya, alongside the purpose, objectives, research questions and the significance of the study. The chapter concludes with a description of the content of the thesis, as presented in Chapters Two to Six.

1.2 Background to the problem

Consistent low student performance in the Kenyan Certificate of Secondary Examination (KCSE) in Chemistry, a test administered at the end of four years secondary schooling, was the impetus for this research study. Poor student achievement in Chemistry in Kenya is thought to partially stem from ineffective teaching methods among practising teachers (Chepkorir, Cheptonui & Chemutai, 2014; Machina, 2012). These consistent low results have placed Kenyan teachers under great pressure to develop more effective teaching strategies that might help to raise students' performance in chemistry. It is therefore necessary to engage Kenyan chemistry teachers in continuing professional learning that can help them to improve on their teaching strategies (Bett, 2016; Sifuna & Kaime, 2007). This study looks to explore the potential of reflective practice as one such strategy to enhance Chemistry teaching, and subsequently, student performance.

Teaching, and learning how to teach, are extremely difficult, complex, and demanding processes, requiring teachers to have a wide range of knowledge and skills (Childs, Edwards, & McNicholl, 2012; Findlay & Bryce, 2012; Loughran, 2013). The intricacies of teaching, as well as the demands placed on teachers, have made teaching an increasingly difficult task over the last few decades (Impedovo & Malik, 2016). For instance, since the late 19th century, there has been a remarkable expansion of knowledge, particularly in science, and also in ways students access that knowledge (Aikenhead, 2006; Vermunt & Endedijk, 2011). Through the internet, for example, students obtain a lot of information, and thus, teachers cannot be said to know everything better than students (Vermunt & Endedijk). Each year's new influx of students brings new challenges and possibilities to schools, and teachers are expected to provide them with the best education to enable their success later in life (Cochran-Smith, 2012; OECD, 2014).

Many countries in the world, Kenya included, have embarked on reforming their curriculum in the education sector, but have provided minimal support for teachers to assist their adjustment to new reforms (Camburn & Han, 2015). One way of addressing the complexity of teaching and learning to teach, and thus respond to challenges in teaching, is to encourage teachers to become lifelong learners who share their expertise with other teachers and education stakeholders (Beijaard, Korthagen, & Verloop, 2007; Rafaila & Duta, 2015). In fact, it is impossible for initial teacher education to incorporate all of the challenges teachers are likely to encounter across their entire career (Vanblaere & Devos, 2016). Continous professional learning can help teachers to increase and improve their professional knowledge and skills, and thus, better ensure student learning is achieved (Finlay & Bryce, 2012; OECD, 2014).

Teachers participate in continuing professional learning in a variety of ways that helps them to build professional expertise (Hoekstra, Brekelmans, Beijaard, & Korthagen, 2009). One such way, adopted in this study, is learning from individual teachers' workplace experiences. Workplace learning, according to Cox (2005), is unique and differentially experienced. This is probably because the knowledge and skills that teachers need to continuously develop themselves are partly entrenched in their daily work (Runhaar, ten Brinke, Kuijpers, Wesselink & Mulder, 2014). Workplace learning can take the form of individual learning activities such as reflection on practice and reading, or knowledge sharing and collaboration with colleagues (Bakkenes, Vermunt, & Wubbles, 2010; Kwakman, 2003). One of the greatest strengths of workplace learning is that it can enable people to learn, interact, and implement what they learn in ways that work for their specific context. Learning initiated by outcomes relevant to the

individuals involved is also more likely to be adapted and practiced (Runhaar et al., 2014; Teunissen, 2015).

Traditionally, the types of courses and workshops that Kenyan chemistry teacher trainers attend are of short duration and do not always facilitate effective professional development (Gathumbi, Mungai & Hintze, 2013). This study was conducted on the assumption that participants would experience learning if they engaged in the workplace learning advocated by Cox (2005), where they reflect on their classroom experiences both individually and in collaboration with their colleagues. It is anticipated that what they learn through this process will enhance the quality of their: 1) teaching, as classroom teachers of chemistry; 2) in-service teacher delivery, as Chemistry teacher trainers; and 3) students' learning and subsequent achievement in Chemisty as a result of their own improved knowledge and practice of effective teaching.

1.3 Research problem identified

The government of Kenya recognises the important role Science and Mathematics plays in any country's development, particularly in realisation of its Vision 2030, the long-term development blueprint they have for the country (Glennerster, Kremer, Mbiti, & Takavarasha, 2011; Republic of Kenya, 2012a). The government has, however, observed that curriculum implementation in the four years of secondary school faces many challenges in key areas such as mathematics and science (Republic of Kenya, 2012b). These challenges partly contribute to the consistently low student achievement in national mathematics and science examinations, which are shown in Table 1 for recent years.

Table 1

Kenya Certificate Secondary Examination in Sciences (2009-2015) percentage mean score

Year	Chemistry	Biology	Physics
2009	19.17	27.15	31.31
2010	24.89	29.19	35.11
2011	23.6	32.44	36.64
2012	27.93	26.21	37.86
2013	24.8	31.6	40.1
2014	32.16	31.83	38.84
2015	34.36	34.80	43.68

Source: Kenya National Examination Council (2016)

Table 1 shows that between 2009 and 2015, students performed poorly in the KCSE in Chemistry, Biology and Physics, with results particularly poor in Chemistry, the subject focus

of this study. There are many issues that potentially contribute to low student achievement in science subjects in Kenya. Menjo (2013) suggests that among other factors, the quality of teaching and learning in these subjects is questionable, a suggestion supported by other researchers and educators in Kenya (e.g., Chepkorir, et al., 2014; Ituma, Twoli, & Khatete, 2015; Keter & Ronoh, 2016; Machina, 2012; Wachanga & Mwangi, 2004).

It has been found that teachers who participate in teacher professional development activities following initial teacher training display significant improvement in their teaching (Anangisye, 2011; Lumpe, Czerniak, Haney, & Beltyukova, 2012). Unfortunately, within the Sub-Saharan African context, there is limited research devoted to understanding how professional development activities might be helping teachers improve their teaching (Akyeampong, Lussier, Pryor, & Westbrook). In Kenya, for example, despite government recognition of the importance of lifelong teacher learning, little has been put in place to institutionalize or advance the quality of teacher professional development programs (Akyeampong et al., 2013; Gathumbi, Mungai & Hintze, 2013; Republic of Kenya, 2012a, 2012b). A policy recommended by Bunyi, Wangia, Magoma, Limboro, and Akyeampong (2011) as a first step to institutionalize continuous teacher professional development has not been enacted. Lack of proper coordination for teacher development at the Ministry of Education level is another challenge (Bett, 2016; David & Bwisa, 2013). Teacher professional development in Kenya, therefore, remains one of the most challenging areas in teacher education (Kafu, 2011). If Kenya is to deliver on its promise to provide quality education, significant inroads need to be made in both initial teacher education and in continuous teacher professional development (David & Bwisa, 2013).

In an attempt to inform the Kenyan government's work in this area, this study sought to investigate a form of professional development to support Kenyan Chemistry County teacher trainers' learning by engaging them in reflective practice to explore and interrogate their teaching. The participants who are both Chemistry teacher trainers and *also classroom Chemistry teachers* themselves, were drawn from one of Kenya's 47 geographical Counties. The study borrows heavily from Schön's (1983) notion of reflection-in-action and reflection-on-action that guides teachers to reflect in and on practice. It is argued that knowledge is generated through experience and collaboration, through which teachers have opportunities to exchange knowledge of their professional learning (Berry, Loughran, Smith, & Lindsay, 2009). In this way, they become "active agents of their own professional growth" (Schleicher, 2011 p. 73). In this regard, the focus in this study is to provide teacher trainer participants opportunities

to reflect on their teaching practice, identify their own practice issues, and seek solutions both individually and in collaboration with other teacher trainers in order to improve their teaching and hence most likely, their performance as trainers of other Chemistry teachers, and the academic achievement of their students (Menjo, 2013).

1.4 Study context

Kenya is a global-south nation situated in East Africa. It comprises 42 African indigenous communities, each with its own distinct mother tongue. English and Kiswahili are both official languages, and English, despite being a second language, is the language of instruction in Kenya's education system (Sifuna, 2007). Although schools are encouraged to use the native language associated with its location, in the first three years of schooling, many teachers use English and Kiswahili in their teaching (Khejeri, 2014; Ongechi & Ongechi, 2002). In Sub-Saharan Africa, Kenya included, the language of instruction has been identified as a key problem, especially in science subjects (Sifuna, 2007). Many African native languages do not possess the terminologies needed for scientific concepts, and when teachers try to coin words, different meanings can prevail. Teachers are therefore faced with two major problems in relation to the language barrier: that of teaching the subject in English; and that of students who are trying to learn the second language (Rollnick, 1998). One way of addressing this problem is for teachers to use a variety of strategies in their teaching, some of which they were not likely to be exposed to during initial training (Ferreire, 2011). Through continuous collaborative models of professional learning, teachers can share their teaching strategies, and it is thought that in this way, they might acquire a variety of strategies from their colleagues (Doppenberg, Bakx, & Brok, 2012; Meirink, Meijer, & Verloop, 2007).

Kenya follows what is called an 8-4-4 system of education: eight years of primary education (ages 6-13), four years of secondary education (ages 14-17), and four years of university (ages 18 and above). Transition from one level of this system to the next is based on student performance in national examinations, namely, the Kenya Certificate of Primary Education (KCPE) and the Kenya Certificate of Secondary Education (KCSE), each conducted at the end of their respective periods of primary and secondary education (Republic of Kenya, 2012a). These examinations are used as a criterion for selection to fill the limited number of places available at secondary and university levels. In 2015 for example, public universities admitted only 16% of all the students who sat the KCSE (Odour, 2016). In this context, assessment in Kenya is not seen as an integral part of the teaching and learning process. The limited

availability of student places in higher education dictates the teaching and learning process towards examinations as opposed to learning for life. As a result, teaching is often theoretical in delivery, with limited, if any, time dedicated to what is taught. A lot of time is spent drilling students for the sake of passing examinations. Practical lessons, especially in Chemistry, receive insufficient emphasis, and students have little opportunity to develop manipulative skills or to engage in problem-solving experiences (Henry, Nyaga, & Oundo, 2014). For this, and other reasons, the quality of teaching and learning is diminished by the examination-oriented approach to teaching and learning that does not take into account the development of knowledge as a process rather than a product.

At the secondary level in Kenya, students are expected to take two science subjects drawn from the cluster of Chemistry, Biology and Physics. In addition, studies in Mathematics, English and Kiswahili are compulsory. In most schools, Chemistry is also compulsory, and it is common to find students doing three science subjects, which in some schools has led to students developing a negative attitude towards the discipline. Due to students' negative attitude, the quality of teaching and learning of Chemistry is affected as teachers spend a lot of teaching time encouraging students to study the subject (CEMASTEA, 2016; Wachanga & Mwangi, 2004). The practical subjects of Chemistry, Biology and Physics are normally accommodated in laboratories. Utilities such as gas, water and electricity are provided in a number of schools; however, some schools do lack basic laboratory facilities. Due to lack of basic laboratory facilities, many science topics are taught theoretically, and therefore, many students are denied opportunities to manipulate materials that assist them to understand key concepts, such as titration in Chemistry (Njagi, 2015; Sifuna, 2007).

1.4.1 Teacher education in Kenya

Secondary school teachers in Kenya are trained at universities and diploma colleges and specialize in two subject areas. There are currently six public universities and two public diploma colleges offering initial teacher training courses (Republic of Kenya, 2012a). Training at the universities is provided through two models known as the concurrent and the consecutive model. In the concurrent model, which is the major route for training teachers in Kenya, teacher trainees study two subjects for content knowledge (e.g., Chemistry and Biology). In addition, they study pedagogy, normally referred to as *teaching methods units*, and after four years of study they graduate with a Bachelor of Education either in Arts or in Science. In the consecutive model, two subject areas are studied over a four-year period, and students graduate with a

Bachelor of Arts or a Bachelor of Science degree. For them to qualify as a trained teacher, they must then undertake a nine-month Postgraduate Diploma of Education (Namunga & Otunga, 2012). The difference in time allocated to subject areas and teaching methods in each model is a matter of concern, as it is argued that teaching methods should be allocated more time than content (Gathumbi & Masingila, 2011; Machina, 2012).

A third, corporate model of initial teacher training, also exits during teaching practice (placement). In the corporate model, pre-service teachers are placed in schools with occasional supervision by university lecturers, and little to no direct supervision from school personnel (Twoli, 2011). This model limits interaction between the pre-service teacher and the university lecturer and fails to provide sufficient theoretical perspectives on effective pedagogies. Due to the three models followed (concurrent, consecutive or corporate), it is argued that pre-service teachers graduate with limited pedagogical knowledge on account that they are not given enough opportunities to connect what they learn in the university coursework to the practical aspects of teaching (Machina, 2012). For this reason, beginning teachers experience many challenges in relating what they are taught in the universities (subject matter knowledge) to the actual teaching practice (general and specific pedagogical knowledge) to promote students' understanding (Gathumbi & Masingila, 2011).

Universities and colleges that offer initial teacher preparation courses in Kenya are facing their own challenges, particularly in science education. Of critical importance is the poor lecturer to student ratio in public university education departments (Gathumbi & Masingila, 2011; Ondigi, 2011; Sifuna, 2010). Currently, class sizes in universities sit at around 1:500, which is too large for lecturers to pay special attention to student learning, and thus comprises the quality of education (Gogo, 2011; Republic of Kenya, 2005). Moreover, some of the education lecturers at universities do not have a teacher trainer education qualification, and many are without recent secondary school teaching experience (Gathumbi & Masingila, 2011). Further, as noted by Gathumbi and Masingila, teacher educators receive no continuing professional development to enable them to keep abreast of changes in the secondary school sector. These challenges have affected the quality of education offered in public universities. They are also thought to be responsible for producing graduates who are ill-equipped for the teaching work (Nyangau, 2014). Some chemistry university graduate teachers, for example, experience difficulties in their classrooms when conducting experiments. This is partly because they are not effectively exposed to practical work in the universities (Sifuna, 2010).

1.4.2 Chemistry teaching in Kenya

Chemistry has been identified as an important subject and has been made compulsory in most Kenyan secondary schools (CEMASTEA, 2016; Machina, 2012; Wachanga & Mwangi, 2004). The importance of Chemistry is emphasized when future career choices of students is being considered at secondary school, as 74% of all courses offered at both public and private universities in Kenya require Chemistry as a core subject (CEMASTEA, 2016). However, despite the prime position chemistry occupies in Kenya's education system, and the efforts made by researchers to promote the subject, student performance is low, as shown in Table 1.

One of the major criticisms of the Kenyan education system noted by Nyatuka (2014), is the rote-style learning that is usually adopted in its delivery, which promotes memorization over understanding, and is examination-oriented. These approaches, according to Nyatuka, are not conducive to student-centred teaching methods that are encouraged in the Kenyan chemistry syllabus. Indeed, the syllabus calls for learning to occur through experiments and other activities that support students' learning through active construction of knowledge (KIE, 2002). Contrary to this expectation, chemistry teaching in many schools is still teacher-centred (Miheso, 2013; Mobegi, Ondigi, & Oburu, 2010; Ogunde, Omolo, & Rest, 2014). A student-centred teaching approach, popularly advocated in Western countries literature, is thought to motivate students to construct meanings in science by actively involving them in learning activities (Vespoor, 2008). In reality, teaching methods that require students to memorize content, with a core purpose of passing national examinations, are deeply entrenched in Kenya (Henry, Nyaga, & Oundo, 2014). They do not motivate learners, and heavily contribute to poor performance in Chemistry (Ituma et al., 2015).

Other factors that are thought to contribute to poor chemistry performance in Kenya include an over-crowded curriculum, a lack of well-equipped laboratories, poor mastery of English language by students, western-world context-oriented teaching, and large classes sizes, usually more than 50 students (Chepkorir, et al, 2014; Kibos, Ogunde, Omolo, & Rest, 2014; Wachanga, & Changeiywo, 2015).

1.4.3 Science professional learning and development in Kenya

Science education is regarded a priority in promoting Kenya's long-term economic development (Republic of Kenya, 2008). However, as indicated in Section 1.3, student achievement in secondary science subjects has been consistently low for a number of years.

This has been of considerable concern to the government of Kenya, so in an effort to address this concern, the government, with the support of the Japanese International Corporation Agency (JICA), initiated the Strengthening of Mathematics and Science at Secondary Education (SMASSE) project.

The SMASSE project sought to remedy low student achievement in science and mathematics at the secondary education level by focusing on teachers' classroom practices through In-Service Education and Training (INSET). Prior to the implementation of the project, a total of 40 secondary school Mathematics, Chemistry, Biology, and Physics teachers (10 per subject) were trained and deployed to work as full time *national trainers*. A baseline survey to identify issues affecting teaching and learning of mathematics and science subjects was also conducted by the Ministry of Education in conjunction with JICA (Nui & Wahome, 2006). From the results of the survey, inappropriate teaching methods used by teachers were identified as among the problems in mathematics and science education that were within the scope of SMASSE operations. The SMASSE project is currently called SMASE (Strengthening Mathematics and Science Education) after primary school science and mathematics became part of the project in 2008 (JICA, 2013). The secondary SMASE is organised around Kenya's 47 geographical Counties and follows a two-tier cascade training system as shown in Figure 1.

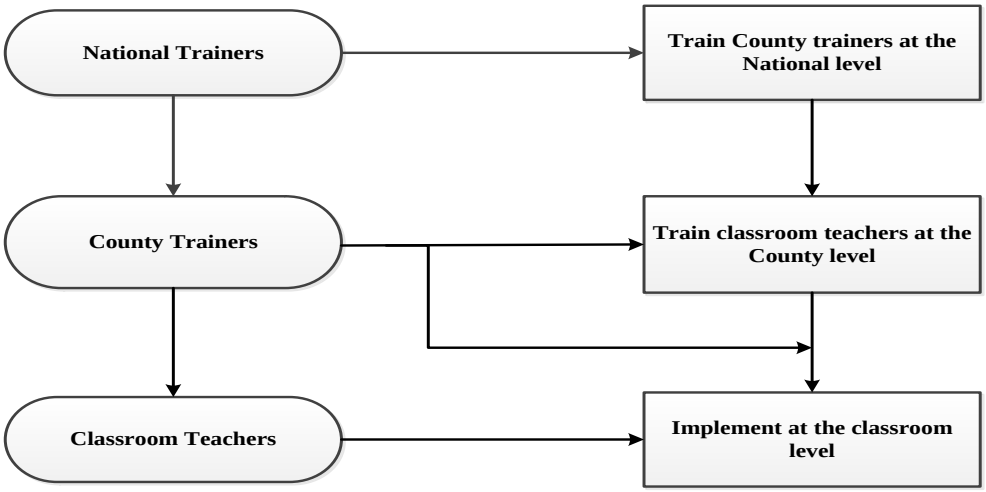


Figure 1: SMASSE cascade model of training

The cascade model follows a "train the trainer" model of professional learning. National trainers from each subject area (Chemistry, Biology, Physics, and Mathematics) train selected classroom teachers who then became known as "County trainers". Four County Trainers are appointed for each of the targeted subject areas, and have a dual role: 1) as a classroom teacher

in their own secondary school; and 2) as a trainer of other classroom teachers in their subject area. Each County trainer is responsible for conducting in-service training for all other classroom teachers in their respective Counties during school holidays. County trainers also occasionally attend refresher courses at the national center. To ensure quality and steady improvement in mathematics and science teaching, the SMASE project promotes the *"Activities, Students, Experiments, and Improvisation"* (ASEI) paradigm shift, from teacher-centered approaches to those that are more student-centered (JICA, 2013; Mobegi et al, 2010). Teachers are expected to involve students in activities and initiate experiments that promote students' active participation. Teachers are also encouraged to "improvise", a term used in reference to the need to utilise locally available materials (e.g., flower extracts as indicators to test acids and bases) when they lack conventional materials and apparatus. Improvisation is also thought to motivate students to learn.

ASEI is propagated through an approach referred to as *"Plan, Do, See and Improve"* strategy where teachers are encouraged to plan, evaluate and improve their lessons based on learners' needs and problems (Nui & Wahome, 2006; Onderi & Malala, 2012). During SMASE training, teachers are trained by the County trainers on how to implement ASEI in their classrooms through the *"Plan, Do, See and Improve."* approach. Teachers also participate in peer teaching and trial lessons (actualization) in selected schools.

Although professional development programs involving active learning and reflection are generally advocated (Clarke & Hollingsworth, 2002; Girvan & Conneely, Tangney, 2016), the SMASE project tends to focus on traditional models of teacher professional learning (Pitsoe & Maila, 2012). Traditional professional learning tends to consist of one-off workshops of a short duration, often using approaches that involve transmission of information from "experts". Irrespective of interest and motivation created within SMASE training environments, little change in educational practice has been evident in either teachers' or County trainers' classrooms (Gathumbi, Mungai & Hintze, 2013; Sifuna & Kaime, 2007). Despite the efforts to provide professional learning and a student-centered framework for teaching and learning, poor results in mathematics and science examinations persist (as illustrated in Table 1). This provides compelling evidence for the need to move away from traditional approaches. Models of teacher professional development that encourage teachers to focus on their own teaching methods may be more appropriate to help them improve student learning outcomes (Mulkeen, 2010; Stuart, Akyeampong & Croft, 2009). A focus on one's own teaching better ensures that teachers have

opportunities to reflect regularly, refine, and expand their practice (Wei, Darling-Hammond, & Adamson, 2010).

1.5 Research problem defined

Although many studies have been conducted on teacher learning in African countries, Kenya included, there are relatively few studies describing teaching practices, and even fewer explaining why teachers teach as they do (Schiefelbein & McGinn, 2013). Previous research, particularly studies around attempts to improve chemistry teaching in Kenya, have concentrated on changing teachers' teaching methods through expert-facilitation utilising models like the cascade model explained in the previous section. These studies lack consideration for what teachers already do, and what they could learn from what they do (Inyega, Thomson, & Chomchid, 2009; Wachanga & Mwangi, 2004). Furthermore, research concentrating on changing teachers' teaching methods in Kenya has received criticism from teachers; they argue that the approaches they are exposed to are not grounded in the realities of their classrooms, and that their voices are not heard (Onderi & Croll, 2008). The Kenyan government, alongside donor agencies, have also supported a range of teacher professional learning programs (e.g., JICA, 2013). These too, have been limited in supporting research on what Kenyan teachers already do (Onderi & Croll, 2008: Wanzare & Ward, 2000). This study attempts to address this gap by exploring teacher learning from their own teaching experiences utilising reflective practice.

Teaching is complex work, and for many teachers, it is work that becomes clearer over time and as a result of learning from reflection on experience (Loughran, 2010). A fundamental assumption that this study is hinged on, is that in the absence of systematic self-reflection or feedback on their teaching experiences, most teachers do not learn a lot about teaching once they are in the classroom. Therefore, they often continue to rely on practices learned during initial teacher training, some of which may not be effective in the current education system (Schiefelbein & McGinn, 2013).

The work of Munby and Russell (2004) offers an alternative to the traditional forms of professional development. In their work, Munby and Russell explain their investigation into how teachers acquire knowledge from their own teaching experiences. Two questions were posed in their work: (1) what particular elements of experience prompt teachers to learn from experience; and (2) is it possible to arrange programs of teacher [learning] so that learning from

experience is encouraged? Further, Munby (2012) suggests that teachers learn to teach by teaching and from interacting with their colleagues, sharing their teaching experiences with an intention of learning from them. This aligns with Wenger's (1998) notion of social learning in a community of practice, where people, such as teachers, learn together from their own experiences.

It was these ideas that formed the impetus for how professional learning and development for Kenyan Chemistry County teacher trainers could be re-developed. Munby and Russell's (2004) questions in particular, appeared relevant to my aim to investigate what and how Kenyan County chemistry teacher trainers learn from their own teaching experiences. Making no empirical claims regarding the value and quality of the knowledge teacher trainers have acquired from their teaching experiences, this study begins with an assumption that teachers have a broad range of knowledge (including knowledge of subject matter; classroom organization, instruction techniques, curriculum content, and students' needs, abilities, and interests). This knowledge base arises from experiences that confront teachers with all manner of tasks and problems. Addressing these tasks and problems requires teachers to draw on a variety of sources and approaches and thus provide a basis of knowledge on which to build (Elbaz, 1981).

This research study is undertaken against this background, including the identified difficulties in teacher education and secondary school teaching of chemistry, and the limited impact of previous and ongoing professional development initiatives in Kenya. I join other researchers, such as Munby and Russell (2004), who have become increasingly interested in what teachers learn from the act of teaching itself, in context. In particular, I borrow from Brandenburg (2008), whose research was structured in a way that teachers could learn about teaching through their own experiences, where meanings were identified and negotiated rather than imposed. As such, in this study I investigate County chemistry teacher trainers' perceptions of their learning throughout and after engaging in individual and collaborative reflective practice on their own and one another's teaching experiences.

1.6 Purpose of the study

The purpose of this study is to explore teachers' professional learning informally as they reflect on their everyday teaching activities, individually and in collaboration with other teacher trainers with a goal to improve their practice. By questioning how teachers learn from their

teaching experiences, this study seeks to generate insights about how teachers learn to enhance their practice in the classroom through the processes of self and group reflection.

1.7 Objectives of the study

The objectives of this study are to:

a) Introduce participants to the use of a critical incident to reflect on their teaching practice individually and with a group of colleagues.
b) Document participants' learning from critical incident reflection on their own and others' teaching experiences.
c) Document participants' intentions to utilise learning from their experiences in this study in their ongoing work as classroom teachers and as County chemistry trainers.
d) Document the common contextual problems faced by Kenyan County chemistry teacher trainers that prevent them from pursuing their pedagogical goals in teaching chemistry.

1.8 Research questions

Literature reviewed from relevant fields relating to how, what, and where teachers learn to teach and professionally develop, led to the major question that guided this research study:
How and what do Kenyan Chemistry County teacher trainers learn from participating in a study in which they reflect on their secondary school teaching experiences? To help articulate the response to the major research question, the following five sub-questions were investigated:

1. How do Kenyan County chemistry teacher trainers address pedagogical critical incidents arising from their lessons through reflection?
2. How does reflecting on pedagogical critical incidents facilitate Kenyan County chemistry teacher trainers' learning?
3. What are the common contextual problems Kenyan County chemistry teacher trainers face that prevent them from pursuing their pedagogical goals in their chemistry classrooms?
4. How do the Kenyan County chemistry teacher trainers say they intend to operationalize their reflection experience to improve teaching and learning in secondary school chemistry in the Kenyan context?
5. How do the Kenyan County chemistry teacher trainers say they intend to operationalize their learning from reflection in their roles as County chemistry teacher trainers?

1.9 Signifiance of the study

The significance of this research lies in its investigation of what Kenyan teachers learn from their work-based experiences as they reflect on their own, context-specific practice. If the practice demonstrated in this study is adopted, it becomes significant to Kenyan County teacher trainer's professional growth, affecting their quality of teaching positively. Also, if any knowledge and skills gained by the teacher trainers is transferred to their secondary teaching and any in-service teacher training they conduct, it is hoped that it will also affect the teachers teaching positively. This aligns with Dias, Eick, and Brantley-Dias's (2014) observation, that, science teacher educators who struggle with the same challenges faced by new or seasoned teachers, better help teachers learn practical strategies, that are immediately needed and have proved more widely applicable.

In addition, the results of this study, which adopts a more contemporary view of teacher professional learning and development, and is the first such research study in Kenya, may be instrumental in informing the development of in-service teacher education in Kenya and further afield. Importantly, reflection on practice, offers a feasible way to explore what teachers learn from their teaching experiences in their own context. The findings of this study will therefore contribute to the body of knowledge in education research, regarding supporting teacher learning through reflective practice, from the context of global-south nations, which is otherwise limited.

1.10 Chapter conclusion

The background of the study presented in this chapter provides information describing the study context of Kenya, the research problem, purpose, objectives, and questions. The significance of the study is outlined. Following this introductory chapter outlining this background information, the thesis is organised into five additional chapters, which are presented as follows:

Chapter Two presents a review of existing research literature related to teacher learning and development in which the present study is situated. The review focuses on: the teaching and learning of chemistry; professional learning and development models; professional learning activities and outcomes; and contextual problems affecting teaching and learning of chemistry.

Chapter Three discusses the research design and methodology adopted to explore Kenyan County chemistry teacher learning through reflective practice. A time-line is presented for the

various stages of the research design. Application of the basic instructional principles central to the cognitive and social constructivist view of learning adopted, are discussed. A qualitative case study approach, adopted to inquire into teacher trainers' learning is explained. Details of an orientation workshop, conducted to induct participants to the study is presented.

Also in this chapter, the process of developing, refining and testing applicability and reliability of a coding scheme for data analysis is outlined. This is followed by a discussion of procedures used to thematically analyse the data collected through group reflection discussion and individual interview. Lastly, ethical issues and strategies of ensuring trustworthiness and reliability in data collection and analysis are outlined.

Chapter Four presents the research findings arising from data analysis. These findings include three professional learning activities that teacher trainers engaged in, individually and in collaboration, to learn from their teaching experiences. Three main learning outcomes resulting from teacher trainers' engagement in the three professional learning activities are reported. Several contextual problems influencing teaching and learning of chemistry identified in data are also presented.

Chapter Five discusses the research findings presented in chapter four and responds to the research in relation to literature regarding teacher learning in practice. Some findings agree with previous research conducted on teacher learning in practice, while others give divergent ideas.

Chapter Six provides conclusions based on the findings of the research. Further to this, the implications of the study are discussed and recommendations for implementation and possible areas for further research are provided.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The background of the study was presented in Chapter One where ineffective teaching methods were highlighted as one of the possible causes of the consistent poor performance of Kenyan secondary school students in Chemistry. Ongoing professional learning for teachers to improve their teaching practice was recommended. As such, professional learning is the focus of this study. In this chapter, review of literature concerned with teacher professional learning that guided the study, is presented. Since there is a large body of literature regarding this phenomenon, this review focuses on topics related to: teaching and learning of chemistry (Section 2.2); teacher learning strategies, specifically on how teachers acquire professional knowledge (Section 2.3); professional learning activities (Section 2.4); professional learning outcomes (Section 2.5); and contextual problems related to chemistry teaching and learning (Section 2.6). Contextual problems in this study are considered as those problems unique to teaching and learning of chemistry in *a particular context*, for example, Kenya. The review is aligned with the five research sub-questions and is illustrated in Figure 2.

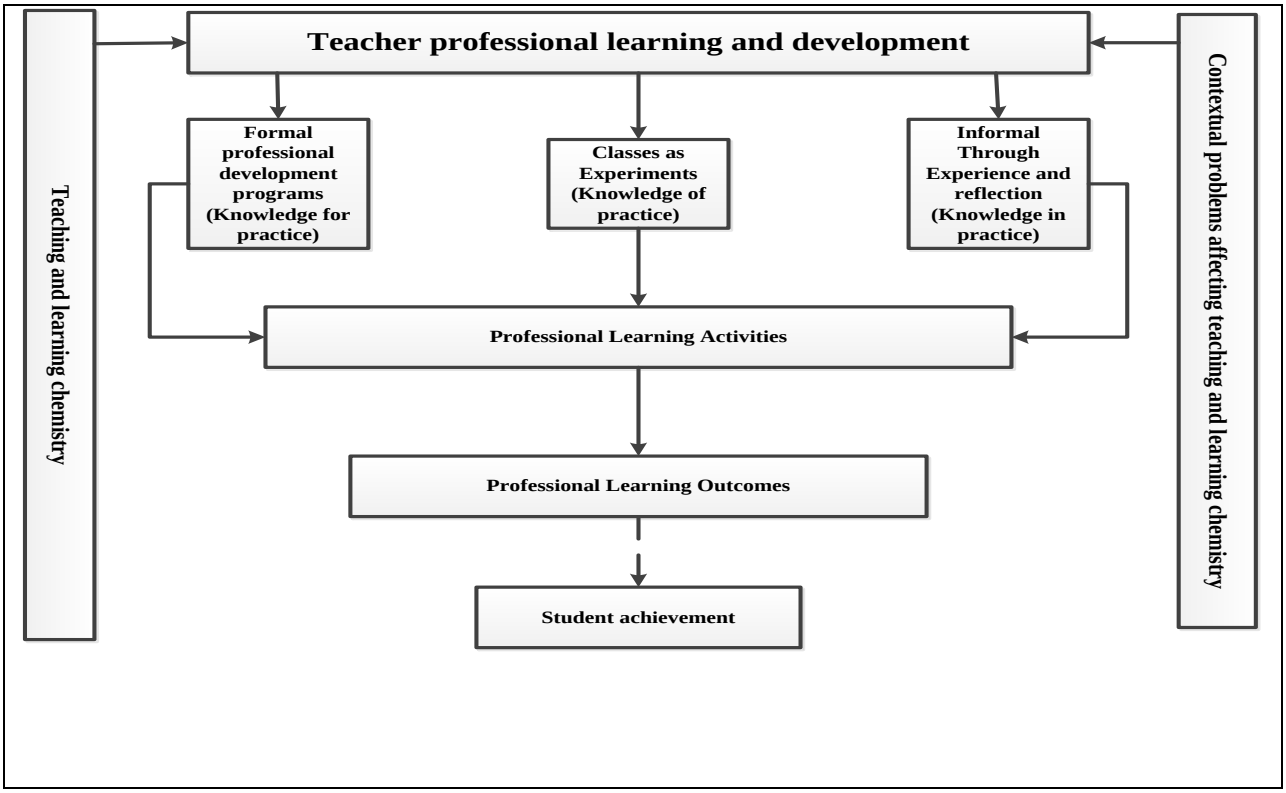


Figure 2: Chapter two structure

The solid lines in Figure 2 show this was researched directly whereas the broken line shows that although students' achievement in chemistry was not researched, it is affected by what teachers know and do in the classroom.

2.2 Teaching and learning of chemistry

Teaching, according to Loewenberg Ball, Thames, and Phelps (2008), is everything that teachers do to support the learning of their students. For this reason, researchers, educators, and teachers have long been searching for methods that could influence daily teaching practices in positive ways (e.g., Korthagen, 2016; Loughran & Berry, 2006; Luft, Dubois, Nixon, & Campbell, 2015). To improve the quality of education, reforms in science education worldwide are focusing on ways to support teachers so that they may make science teaching and learning more meaningful to students, and more connected to everyday life and the community at large (Richmond & Manokore, 2011; UNESCO, 2015). An understanding of science concepts and scientific inquiry is important in modern society, in that, these knowledge and skills empower people to participate in issues of scientific technology that affects everyday life (OECD, 2012). However, despite these efforts, indicators from international reports show that in many countries, students have difficulties in understanding basic scientific concepts and the processes of scientific inquiry (e.g., OECD, 2014). This likely contributes to students' poor performance and low levels of interest in science (Alonzo, Kobarg, & Seidel, 2012).

To address the challenges in teaching and learning in science education, past and current studies have focused on the teaching of science itself; providing descriptions of teachers' and students' actions in the process of classroom teaching and learning (Loughran & Berry, 2006; Petrou & Goulding, 2011; Russell, Munby, Spafford, & Johnston, 1988). Therefore, to investigate how and what Kenyan County teacher trainers learn from their daily teaching experiences in chemistry, in this study, it is important to understand the content of the subject, how it is taught, and some of the challenges specific to its teaching and learning.

As noted in Section 1.4.2, teaching of Chemistry in Kenya is faced with many challenges. For example, in many Kenyan secondary schools, for various reasons, chemistry teaching through experimental investigations is not practiced (Sifuna, 2010). Instead of helping students develop scientific investigative skills, many chemistry teachers focus on students' acquisition of content knowledge. If and when practical work is undertaken, it tends to see students following prescriptive procedures (i.e., "recipe" type experiments). As Kim and Chin (2011) note, recipe-

style practical experiments are limited in developing students' scientific reasoning as students are simply involved in doing, which does not require deep thinking. Students are therefore not able to interpret readings they record and observations they make from practical activities, resulting in low student motivation and achievement (Ituma et al., 2015). This suggests that Kenyan secondary school students' low achievement and negative attitude in Chemistry may be, at least partly, attributed to the way the subject is taught (Kibos et al., 2015).

Another factor that generally affects teaching and learning of chemistry is the abstract nature of the subject, making it difficult for teachers to teach and for students to learn (Özmen, 2008; Sirhan, 2007; Taber, 2014; Woldeamanuel, Atagana, & Engida, 2014). Chemistry teachers are usually surprised and dissapointed to learn that, despite their best efforts to simplify concepts in chemistry, many students do not grasp important, basic ideas, and this can interfere with subsequent learning (Meyer & Land, 2006; Osman & Sukor, 2013). For this reason, a large proportion of students perceive chemistry as a difficult subject, and in many places, students are opting out of chemistry-related courses (Johnstone, 2000; Reid, 2008). Woldeamanuel et al. (2014), for example, found that students regard chemistry as difficult and a subject in which they resort to memorization for the sake of passing examinations. This impedes meaningful science learning, which requires conceptual understanding rather than rote memorization (Adadan, Trundle, & Irving, 2010).

King and Ritchie (2012) support context-based chemistry learning programs that aim to connect the students' daily knowledge with the content that they learn in school to promote meaningful learning. Such programs have been developed and implemented in recent years in some schools in an effort to improve the linkage of chemical concepts and the real lives of students. King and Ritchie (2012) contend that the study of chemistry, related to everyday life, is likely to change students' motivation and attitude towards the learning of chemistry. They therefore, encourage teachers to bridge between events in daily life and chemistry.

According to Johnstone (1991), the fact that many students find science difficult to learn might be due to science learning involving what he refers to as a "mutilevel thought", in which students are expected to think and make connections between differnt things at the same time. Johnstone argues that a lot of effort has been directed to the methods and materials used, but little attention is given to how students learn. Johnstone states that teaching and learning of science opereates at three levels: macroscopic, sub-microscopic and symbolic, between which

teachers are expected to help students make connections in order for them to understand scientific concepts, which does not always happen. To make connections around the three levels, Suat, Coþtu, and Alipaþa (2010) suggest that teachers should use concrete and analogical models, particularly those integrated with technology. Teachers should, however, be careful when using such models as they are depicted in the textbooks, as many students develop misconceptions as a result of the many over-simplified models being presented (Nahum, Mamlok-Naaman, Hofstein, & Taber, 2010; Taber, 2013).

Many students also very commonly develop alternative ideas about science concepts. These alternative ideas and views may be correct, but often they are significantly different from accepted scientific knowledge, and thus fail to correctly explain scientific concepts (Loughran, Berry, & Mulhall, 2012; Stojanovska, Soptrajanov, & Petrusevski, 2012). These alternative ideas about science concepts are commonly known as "misconceptions" (Keeley, 2012; Millham & Isabelle, 2013; Özmen, 2008; Suat, Coþtu, & Alipaþa, 2010; Taber, 2009). Unfortunately, misconceptions create barriers to students' further learning. Students may develop misconceptions prior to formal education by interacting with people and the physical enviroment, or as a result of interaction with misleading information from teachers and books in the classroom. It can be hard for teachers to accept that misconceptions might arise from their teaching (Keeley, 2012), yet many students do not have the basis for constructing knowledge about some concepts, such as atoms and ions. Without suggesting that teachers teach concepts incorrectly, when students develop misconceptions in such areas, it seems that teaching plays a part (Taber, 2009). For example, teachers can propagate misconceptions when they fail to represent scientific concepts in ways that students understand (Erman, 2017; Gudyanga & Madambi, 2014). In fact, Keeley (2012) believes that most students' misconceptions in chemistry do not arise from their outside classroom experiences, but rather, stem from the meaning they construct from activities experienced in the classroom. Language is also thought to be one of the factors contributing to the development of misconceptions (Millha & Isabelle, 2013), because science, and especially chemistry, is laden with scientific terminology that causes many problems for students (NRC, 2006).

Researchers consider teachers' knowledge of students' conceptions, misconceptions and learning difficulties in specific subject matter, and ways of adressing them, as important (Berry, Depaepe, & van Driel, 2016; Shulman, 1986; Tümay, 2016). A study conducted by Sadler and Sonnert (2016) found that students of teachers who could identify misconceptions, registered a

larger acheivement gain than those whose teachers only knew the correct answers of the items administered. Pfundt and Duit's (2004) earlier work also illustrated the importance of teachers not only becoming aware of students' alternative conceptions, but also being skilled in addressing them. Shulman's (1986) conception of pedagogical content knowledge (PCK) is essential for teachers to be effective in addressing misconceptions and for teaching specific subject matter that students tend to find difficult (Berry, Depaepe, & van Driel, 2016). In this regard, Taber (2009) recomended that teachers should be up-to-date in their subject area through access to continuous learning. In addition, it has been suggested that in-service courses should incorporate opportunities for teachers to share and discuss students' preconceptions (Meyer & Land, 2006). This is considered important given that "what the learner knows" has been identified as the greatest single factor influencing student learning (e.g., Johnstone, 2000; Reid, 2008; Sirhan, 2007).

2.3 Teacher learning

Teacher learning is said to lie at the centre of efforts to improve the teaching and learning of science and student achievement (Wallace & Loughran, 2012). Opportunities for teachers to learn are therefore something of concern to researchers and educators (Ambler, 2016; Long & Labone, 2016). In particular, it is argued that quality teaching methods contribute to a large variance observed in student learning outcomes. This is essentially because students' learning is influenced by what happens in the classroom as they interact with teachers, other students, and curriculum materials (Ball & Forzani, 2011; Cross, & Lepareur, 2015; Kuijpers, Houtveen, & Wubbels, 2010; Lieberman & Pointer Mace, 2010). Students who scored high marks in the 2015 Program for International Student Assessment (PISA) test, for example, reported that their science teachers discuss, explain, and demonstrate scientific ideas. Further, teachers of high performing students adapted lessons in response to student needs and provided assistance in areas of difficulty (OECD, 2016). In this regard, professional learning that focuses on improving teaching quality has been given increased importance in recent years (Jaquith, Mindich, Wei, et al., 2010; Labone & Long, 2016). Moreover, for teachers to cope with ongoing change and the increasing demands witnessed in education sectors of many countries, engagement in life-long learning that promotes continuous revision of classroom practices and new pedagogical approaches is encouraged (Meirink, Meijer, Verloop, & Bergen, 2009; Opfer & Pedder, 2011; OECD, 2012; UNESCO, 2015; Vermunt & Endedijk, 2011).

The National Academies of Sciences (2016) view science teacher learning as a dynamic and long-term process that does not follow a straight and defined route after teachers' initial training. They understand that once teachers start teaching, their learning is influenced by several factors such as the teaching context, availability of teaching and learning resources, school and state policies, and students' needs. They state that the new vision set for current students represents a significant departure from traditional teaching approaches. For this reason, all teachers, regardless of their teaching experience, require new knowledge and skills to supplement their teaching approaches.

Loughran et al. (2012) and Luft et al. (2015) noted that despite the importance placed on teacher learning, so much of the role of the teacher seems to focus on the teacher *doing the teaching* and little time allocated for teachers to develop their professional knowledge. The focus of teacher learning, until recently, has also been on pre-service and beginning teachers, and little on experienced teachers. In fact, compared to beginning and pre-service teachers, little is known about how experienced teachers learn (Beijaard, Korthagen, & Verloop, 2007). As a consequence, experienced teacher learning about teaching has attracted attention in education research in the last two decades (Bakkenes et al., 2010; Hoekstra et al., 2009; Kwakman, 2003; Lohman & Wool, 2001; Meirink, Meijer et al., 2009; Van Eekelen, Boshuizen, & Vermunt, 2005).

The terms "professional learning" and "professional development" are used interchangeably in much of the literature on practising teacher learning. The term professional learning is becoming increasingly popular as it focuses on activities undertaken by teachers for their professional growth (Avalos, 2011). Learning, therefore, arguably implies a more constructivist approach in which teachers become active participants who are responsible for their own learning (Clarke, Hollingsworth, & Gorur, 2013). This approach is instrumental for teachers as they can construct learning within their own context (Labone & Long, 2016). Learning embedded in teachers' daily activities, in which teachers are responsible for their learning can be a life-long process (Roesken, 2011). Context-specific learning is important as not all findings from research on teacher learning are applicable across contexts and settings (Teo, Goh, & Yeo, 2014). In spite of this, Kyndt, Gijbels, Grosemans, and Donche (2016) and Hoekstra et al. (2009) note that research investigating teachers' learning from everyday activities in their work place is limited.

Korthagen (2016) notes that for a long time, research on teacher learning has focused on improving teaching through the linking of practice to theory. He further notes that this order is being reversed, and practitioners and researchers are more recently trying to link theory to practice. This shift seems a more promising approach according to Korthagen in that, it focuses more closely on *how teachers learn.* Loughran (2010) found that, through years of practice, and in professional learning with colleagues, teachers can develop professional knowledge by linking theory to practice. In this case, "practice" refers to teaching and learning, curriculum design, and assessment (Teo et al., 2014). This knowledge, according to Wallace (2003), develops gradually in the process of experimenting with classroom strategies, trying out new ideas, refining old ones, and problem solving. In this process teachers learn how to adjust, adapt and construct their teaching (Loughran, 2010).

Wallace found that the primary motivating factor for teachers to engage in professional learning stems from problems experienced at the classroom level rather than from external requirements for change. Although professional development is an ongoing process, and change in teachers' practice does not happen overnight, when teachers use the knowledge they acquire in practice, they are likely to improve their teaching methods, to better understand how students learn, and to develop a deeper understanding of subject content (Ratcliffe & Millar, 2009). In this study, the "burden" of evidence of learning was placed onto the teachers. As Cochran-Smith & Lytle (1999) stated, teachers are "knowers" of their work and that given an opportunity for dialogue, they will share experiences of their learning from their work. Also, in agreement with Cochran-Smith and Lytle, Mkhwanazi (2013) argued that since teachers can take charge of their learning, it is important to give them a chance to explain how they approach and view their learning.

2.3.1 Conceptualizing teacher learning and development

One of the difficulties in conceptualizing teacher professional learning is that it is a complex process, and therefore, what is commonly understood to be professional learning varies significantly (Cole, 2012; Nilsson, 2008). Researchers have interpreted the concept differently depending on the points on which they want to focus. Van den Bergh and Beijaard (2014) have noted that current understandings of teacher learning underscore that teachers' own practices, knowledge and beliefs regarding these practices should be the starting point for organizing teacher professional learning. In this regard, teacher professional learning and development could be conceptualized as a learning process that is embedded in teachers' classrooms within the school context across their entire teaching career (Geijsel, Sleegers, Stoel, & Krüger, 2009;

Putnam & Borko, 2000; Runhaar, Sanders, & Yang, 2010). Within these conceptualizations, professional teacher learning and development programs should not only focus on theoretical knowledge or new information, but also on the perceived problems, knowledge, beliefs, and classroom behaviors of teachers themselves (Verloop, Van Driel, & Meijer, 2001).

Classroom teachers' "behaviors" are, according to Geijsel et al. (2009) and Kwakman (2003), work-related learning activities. Focusing on teachers' behaviors in the classroom is important in order for teachers to have a sense of ownership of the process and the content of the learning (Opfer & Pedder, 2011). Although it is a common view that creating a sustained change or reframing of teachers' behavior, knowledge, and beliefs is very difficult, most conceptualizations of learning generally advocate for a relatively lasting change in behaviour (Fraser, 2010; Nilsson, 2014; Van den Bergh & Beijaard, 2014). Difficulties in changing teachers' behavior are associated with the complexity of teacher professional learning which requires cognitive and emotional participation of teachers in informal or formal professional activities, individually or collectively (Avalos, 2011; Hoekstra & Korthagen, 2011; Loughran et al., 2012).

Hoekstra, Beijaard, Brekelmans, and Korthagen (2007) and Hoekstra, Kunz, and Newton (2017), describe teacher professional learning as engaging consciously or unconsciously in learning activities that can result in a change in behavior and cognition. Doppenberg, Bakx, and den Brok (2012) concur with Hoekstra et al. (2017) in their definition but add a social-cultural perspective to teacher learning. They define teacher learning as the process through which teachers learn by undertaking a variety of learning activities together with colleagues that result in teachers' change in cognition and behavior at the individual or group level. Doppenberg et al. frame teacher learning within the social constructivist paradigm in which knowledge is constructed within social interaction (Postholm, 2012). Within this framework, learning is perceived to be a contextual, social process, and occurs through interactions between individuals, and therefore, teachers need to be brought together so that they can learn from each other (Meirink et al., 2009; Postholm & Wæge, 2016). Such a focus on collaborative learning does not mean that individual learning should be completely neglected, as teachers engage in many self-directed learning activities (Kwakman, 2003). Both individual and collaborative learning play a significant role in teacher development, although there is a growing call for collaborative learning (Lamb, Kabes, & Engstrom, 2011; Wei et al., 2010). Most teacher learning definitions are associated with changes in knowledge, behavior and beliefs, however,

it is important to note that teacher learning may also strengthen existing knowledge and skills, and confirm beliefs (Cranton & King, 2003; van Driel, Beijaard, & Verloop, 2001).

Kwakman (2003) states that, from a cognitive perspective, teachers can learn from knowledge they construct directly from their own teaching. This learning is influenced by teachers' existing knowledge and beliefs and is context-specific (Borko & Putnam, 1996). In the literature, there are discrepancies regarding the process of change in teachers' cognition. Some scholars argue for a drastic shift in teachers' cognition, while others acknowledge that change is gradual and cumulative in nature. Issues have also been raised in regard to which of teachers' change, cognition or behaviour, should precede the other. Guskey (2002), for example, argued that cognitive change should not precede behavioral change. As teachers' beliefs and attitudes are not the only factors that determine whether teachers will adopt new behaviors (Lamie, 2004). Clarke and Hollingsworth (2002) proposed an interconnected model of teacher development through which teachers' change in cognition and behavior are interconnected through a mediated process of enactment and reflection, implying that professional learning is continuous and embedded in practice.

2.3.2 Teacher continuous professional learning and development

The importance of continuous professional learning and development for teachers is widely acknowledged and is now considered as a worldwide education reform aimed at improving the quality of teaching and student achievement (Bakkenes et al, 2010; Guo & Yang, 2012; Republic of Kenya, 2012a; van den Bergh, Ros, & Beijaard, 2015). In Kenya, for example, as of 1998, all science and mathematics teachers are expected to attend in-service training once each year for one or two weeks (JICA, 2013; Nui & Wahome, 2006).

Although research has shown that teacher formal professional learning and development in some places have yielded disappointing results (Gathumbi, Mungai & Hintze, 2013; Opfer & Pedde, 2011; Simon, 2013), its importance remains without question (Guo & Yang, 2012; OECD, 2009). Research evidences that professional development programs considered to be of *high quality* can help teachers to deepen their knowledge of effective teaching strategies in their subject content area, hence, enhancing the quality of teaching (Buczynski & Hansen, 2010; Council of Teacher Advisory, 2016; Fishman, Marx, Best, & Tal, 2003). The major problem to date is not a lack of professional development opportunities for teachers, but rather that the

quality of existing programs has often been questionable (Loucks-Horsley Stiles, Mundry, Love, & Hewson, 2010).

Researchers have noted that many professional development programs are not aligned to how teachers learn at work and do not consider teachers' own professional knowledge of practice. Many have detached the learning opportunities from real contexts and from practice (Borko, 2004; Bruce, Esmonde, Rosse, Dookie, & Beatty, 2010; Loughran, et al., 2012: Mitchell, 2013). Thus, many professional development programs fall short of helping teachers learn how to teach for understanding (Kwakman, 2003). As suggested by Luneta (2012), it is important to recognise knowledge and experiences that teachers bring to professional learning programs, and together with teachers, build on these knowledge and experiences when designing programs. In this regard, Nilsson (2014) suggested a shift in professional learning activities from those that focus on what should be done to teachers to those that are done with and by teachers. Furthermore, authors of professional learning programs need to consider that learning is social in nature and is influenced by the contexts in which it takes place (Putnam & Borko, 2000). Professional learning should, therefore, be based on teachers' perceived problems in their own classrooms and their knowledge, beliefs, skills of practice (Opfer & Pedder, 2011; Van den Bergh, Ros, & Beijaard, 2014).

There tends to be an assumption by some that teacher professional learning programs will have an immediate impact in changing teacher in practice (Bausmith & Barry, 2011). However, this does not always occur because there are other contextual factors that need to be considered to effect change (Guskey, 2002). Also, many programs follow traditional models of professional development that are characterized by off-site workshops of short duration and passive approaches to learning (Bowe & Gore, 2017; Harwell, 2003; Killion & Hirsh, 2013; Loucks et al., 2010). Such programs do not adequately consider how teachers make sense of their teaching experiences through reflection. They also rarely provide teachers with enough time and opportunity to reflect on their day-to-day teaching, and to try out new knowledge (Drago-Severson, 2012; Camburn & Han, 2015). Hunzicker (2011) notes that programs like these are becoming less effective, as information gained is not likely to be remembered, and even less likely to be applied once teachers return to their schools. For this to change, Opfer and Peddler (2011) believe that teacher professional learning should be conceptualized as a complex process rather than a one-time event (Harwell, 2003). This links to Postholm and Wæge's (2016) assertion that "intellectual and pedagogical change requires professional development activities

that take place over a period of time in school" (p. 24). Many teacher learning programs have probably been unsuccessful because they have simplified the process and have not taken these factors into account (Hunzicker, 2011).

Numerous review studies have been carried out to determine characteristics of successful professional programs that do impact teachers' change in practice, knowledge, and to some extent, students' achievement (Borko, Koellner, Jacobs, & Seago 2011; Desimone, 2011; Earley, 2010; Hunzicker, 2011; Van Driel & Berry, 2012; van Driel, Meirink, Van Veen, & Zwart, 2012). Several characteristics across these reviews include: active learning, collective participation, content focus, coherence, and duration. A shift is therefore distinguished from earlier conceptions of teacher learning as a single event with teachers as passive participants to a life-long process where teachers are actively involved in the learning process. In this process, teachers should actively engage in analyzing their own problems and solutions, discussion, planning, and practice (Van Driel et al., 2012). Activities planned for professional learning should incorporate teachers' existing knowledge regarding their own classroom practices. This type of learning should focus more on the learning process rather than outcomes of the process (Meirink et al., 2009). Activities should be ongoing and situated in teachers' classrooms, as professional learning is likely to yield instructional improvement if it is based on investigation of teachers' practices (Little, 2007). These activities should lead to development of teachers' new knowledge of practice, including how students learn, and of content knowledge (subject matter).

2.3.3 Models and opportunities of teacher professional learning

Many models and opportunities have been prescribed on how practising teachers learn to improve their practice through formal, informal, planned and unplanned activities (Borko, 2004; Clarke & Hollingsworth, 2002). In these models and opportunities, different views about how, when, and where practicing teachers learn how to teach have been proposed. Cochran-Smith and Lytle (1999) note that the effectiveness of initiatives for teacher learning depend primarily on how the ideas presented in these initiatives are interpreted and conceived by the teacher. Most studies on teacher learning reflect one of two dimensions: individual teacher learning and collaborative teacher learning. In both dimensions, learning opportunities include teachers participating in workshops, action research, communities of practice, and reading groups (Lave & Wenger, 1991; Little, 1993; Louck-Horsely et al., 2009). Situated teacher professional learning programs are preferred because they are said to offer teachers with

multiple and immediate opportunities to trial (experiment) newly acquired skills/or knowledge (Kwakman, 2003; Meirink et al., 2009). Also noted by Borko (2004), informal activities provide teachers with more learning opportunities, although they are rarely documented in ways that can be understood and acknowledged.

Loughran (2010), supporting Borko (2004), asserted that teachers can learn from knowledge they have accumulated in practice. He argued that teachers' work of managing dilemmas and tensions associated with different students in the classroom serve as a basis for teachers acquiring specialist knowledge of practice. However, according to Loughran (2010), this knowledge is tacit and is often misunderstood and not recognised. Further, and possibly due to their busy classroom teaching schedules, there has not been an established tradition of teachers talking about their knowledge of practice, nor do they get time to talk about why they teach the way they do. Loughran (2010) believes that teacher knowledge of practice is fundamental to the quality of classroom teaching, and therefore, should be recognized, developed, and shared. Little (2007) suggests that there is a need to exploit teachers' daily experiences for the purpose of their professional learning and development. Teachers can employ various artifacts such as stories to filter the professional knowledge they acquire through experience. The questions one would ask is whether teachers' accounts of experiences represent actual practice, and are they acceptable, useful or valued accounts for evidence-based decision making about practice.

Ambler (2016), for example, in a study involving six primary school teachers, showed that teachers' stories of their day-to-day activities in the classroom were a source of professional learning. Ambler found that teachers' stories represent their classroom experiences, describing the specific details of the teaching situation and were used to explain actions and decisions taken by the teachers during practice. What teachers learn from reflecting and interpreting their stories is as varied as the experiences from which they are created and are uniquely contextualized within different classrooms. Ambler (2016) suggests that the way teachers interpret their day-to-day classroom activities is important and should be considered by policy-makers and school administrators because they can make a positive impact to both student and teacher learning.

Borko (2004) notes that, apart from learning from their classroom experiences, teacher learning can also occur through other aspects including school community, professional development programs, and incidental social interactions with colleagues. She suggests that for one to

understand how teachers learn, it is worth considering learning within these multiple contexts, particularly taking into account both the individual teacher learning and the learning that occurs through collaboration. According to Niesz (2010), collegial teacher learning encourages active participation and supports shared communication. Niesz concurs with Lave and Wenger's (1991) claims that learning takes place through participation in legitimate communities of practice. Le Cornu and Peters (2009) obseverd that as teachers talk about their practices with their colleagues, they develop a "new language". They considered development of "new language" as evidence of enhancing their *professional knowledge*, and thus, progress towards changing their practice.

2.3.4 Teacher professional knowledge

Teachers' professional knowledge is said to be key to their professional performance (Desimone, 2009; De Wever, Vanderlinde, Tuytens, & Aelterman, 2016). In order for science teachers to teach in ways that their students can understand scientific concepts, they need to regularly update their professional knowledge, including knowledge of instruction, subject matter, and context (Nilsson, 2008, 2014). Education research literature has documented science teacher "learning teaching", to enhance professional knowledge (e.g., Cochran-Smith and Lytle, 1999; Loughran, 2012; Nilson, 2014; Van Driel & Berry, 2012). Lampert (2010) prefers the term "learning teaching" when describing teacher learning rather than learning to teach. Learning to teach, according to Lampert, suggests the action of teaching is to take place in the future, after learning has occurred. "Learning teaching", he says, suggests the possibility that learning can occur *while* teaching.

Cochran-Smith and Lytle (1999) presented three concepts of how teachers learn that, they say, are not mutually exclusive. The three concepts demonstrate how teachers acquire *knowledge for, of, and in* practice from constructivist-oriented professional development programs. Their work provides a lens through which other researchers have examined teacher learning (e.g., McLeskey & Waldron, 2004; Paavola, Lipponen, & Hakkarainen, 2004). Paavola and colleagues, for example, used three metaphors (acquisition, participation, and transformation) to explain development of these concepts of knowledge to explore teacher learning. Earlier, Shulman (1986) had suggested that knowledge for, in, and of practice enables teachers to develop pedagogical, content and assessment knowledge. He argued that the three types of knowledge are integrated and work hand-in-hand.

Researchers have used different methods to explore teacher professional knowledge. Some, like Alonzo (2012) and Cross (2010), reason that teachers' professional knowledge stems from their actions in the classroom. Mixed methods, that combine teachers' reflections and classroom observations, have also been used. Observational methods for determining the extent of teacher professional knowledge have been criticised for their limitations around the fact that teachers might use only part of the knowledge they have accumulated in a particular observation event (Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001). Perhaps for this reason, Cross and Lepareur (2015) prefer to utilise self-reported approaches to ascertain teachers' professional knowledge, as these give a broad understanding of teachers' own experiences in acquiring knowledge for, in, and of practice.

2.3.4.1 Knowledge for practice

The concept of teachers acquiring knowledge for practice has been used for many years as the basis for teacher learning. Knowledge *for practice,* sometimes termed as formal knowledge or theory in practice, is knowledge teachers acquire during initial training and from professional learning and development programs when they start teaching (Cochran-Smith & Lytle, 1999; Van Eekelen et al., 2005). This kind of teacher learning is often linked with *acquisition* of knowledge, where teachers are passive participants (Hodkinson & Hodkinson, 2005). Teachers are therefore seen as "collectors" of knowledge (Gess-Newsome, 2015). It is assumed that teachers attain knowledge for practice from best practices in a single event. In this regard, as noted previously, they hardly improve their teaching practices or adapt to changing teaching practices. However, studies have shown that redefined professional learning and development programs, grounded in communities of practice and based on constructivist approaches, can change teachers' practices (Borko, 2004). Nevertheless, Borko proposes that more research is needed to examine how and what teachers learn in these redefined teacher learning and development programs.

2.3.4.2 Knowledge in practice

Knowledge in practice, also referred to as *practical knowledge,* is the type of knowledge that is work specific and is acquired through experience and reflection (Cochran-Smith & Lytle, 1999, 2012; Loughran, 2010). Wallace (2003) believed that teacher knowledge, and hence learning, is situated in particular classrooms leading to the notion of knowledge *in* practice. Teacher learning through this perspective is based on a relationship between the knowledge teachers have acquired through experience and how this knowledge influences what they do in the

classroom. Following initial teacher education, teachers' professional knowledge develops through teaching practice. This type of knowledge is often tacit, meaning professionals often find difficult to articulate (Schön, 1983, 1987). Tacit knowledge, according to Batatia, Hakkarainen, and Morch (2012), results from individual experience and is influenced by personal beliefs and perspectives, which are difficult to reach. Nevertheless, this seems to be a more promising approach of acquiring knowledge, as teachers can learn in their work places. The learning involves an active, constructive, and mostly problem orientated process, largely grounded in social interaction between teachers and their students (Beverborg, Sleegers, & van Veen, 2015; Loughran, 2012). Therefore, knowledge in practice is mostly attained through participation in learning activities, individually, in groups, and in context. Grangeat and Kapelari (2015) argue that learning should not be separated from the context in which it is intended to be applied. Therefore, in this process, teachers are central in the learning process as they work together to reflect and improve their practice.

Researchers have confirmed that life experiences are sources of learning from which we learn and develop our knowledge, skills and attitudes (e.g., Dewey, 1938; Merriam & Bierema, 2013; Nelson, 2008). The concept of learning from experience is deeply rooted in history. Dewey (1933), is quoted saying that "all genuine education comes about through experience" (p. 25), and therefore, he called for education to be grounded in real experience. Nelson (2008) demonstrated that life experiences have educative power if we inquire into them intentionally through reflective practice. Schön (1983) also asserts that experience plays a central role in developing professional knowledge in that it provides the data for reflection-on-action. Many professional development activities for teachers, however, are thought to have *not* adequately considered how teachers learn through this sense-making of experiences (Drago-Severson, 2012).

Learning through experience and reflection can be considered as ongoing and lifelong rather than an as a single event (Harwell, 2003). To be life-long learners, it is suggested that teachers need to meet, ask each other questions, and develop contextualized knowledge (Cochran-Smith, 2012). To develop contextualized knowledge, van Driel et al. (2001) proposed learning through (a) collaboration, (b) net-works, (c) action research, and (d) case development as potentially powerful strategies. Through these strategies, teachers may become members of a learning community, something that Lave and Wenger (1991) propose, counts as evidence of learning.

Findlay and Bryce (2012), in a four-and-a-half-year study involving six physics secondary teachers from Scotland, found that teacher participants experienced enhanced pedagogical knowledge from their experience of teaching, which became increasingly student-centred over the study period. This corroborates earlier studies conducted with science teachers where pedagogical content knowledge in terms of understanding student learning, significantly improved through increased teaching experience (e.g., Lee, Brown, Luft, and Roehrig, 2007). From these studies, there seems to be agreement between researchers that experience can improve teachers' professional practice. Grangeat and Kapelari (2015), however, note that teaching experience does not always result in effective teaching. Dewey (1963) and Beard and Wilson (2006) also warn that not all experiences lead to new insights and new learning. For example, Friedrichsen, Abell, Pareja, Brown, Lankford, and Volkmann (2009) found that teaching experience made little difference when comparing the practice of experienced and novice Biology teachers. Wrenn and Wrenn (2009) suggest that even if experience is considered a source of knowledge, this knowledge can be enhanced when it is integrated with knowledge for and of practice.

2.3.4.3 Knowledge of practice

Knowledge *of* practice, according to McLeskey and Waldron (2004), is constructed in context. Teachers acquire this knowledge when they: (a) intentionally treat their classrooms as sites for investigations or by treating their lessons as experiments (Hiebert, Morris, & Glass, 2003) and (b) treat knowledge and theories acquired from other people as generative materials for cross-examination and interpretation. When teachers intentionally consider their classrooms as locations for investigation they learn to closely observe their teaching, their students' learning and students' learning needs. When teachers consider each other's knowledge of practice as useful material for cross-examination and interpretation, they often work as a community of practice (Wenger, 1998). In these ways, teachers can learn by constructing knowledge of practice from their own classroom and by working collectively with other teachers; locally within their schools and broadly, with other communities that share similar interests (Cochran-Smith & Lytle, 2001; Wenger, 1998). Knowledge for practice developed by working in professional communities of practice, informs implementation of new teaching methods and improvements in student learning (Darling-Hammond & Bransford, 2005).

Some teacher actions in classrooms appear quite obvious, but they form the bases of developing strategies and approaches to teaching that are conducive to quality learning (Loughran, 2012).

Therefore, as a starting point in thinking about learning from teaching, Loughran suggests that teachers must become keen observers of their own behaviours, of other teachers, and of their students. These observations should then be used purposefully to influence their practices. It is suggested that through such processes of ongoing inquiry in their classrooms and from other sources, teachers grow professionally, acquiring knowledge that can be used to address problems of practice (Darling-Hammond & Bransford, 2005).

Cochran-Smith and Lytle's (1999) conceptualisation of teacher learning through knowledge in and of practice is closely related to the constructivist view of learning. In this view, teachers actively construct new knowledge by making sense of their teaching through their prior knowledge and beliefs (Putnam & Borko, 2000; Van Eekelen et al., 2005). Teachers participate in the learning where the focus is on the process rather than the outcomes of learning (Meirink et al., 2009). Also, the context is considered in the participation concept which is important for learning (Meirink et al., 2009; Sfard, 1998). These authors argue that learning activities should be considered alongside the context in which the activities normally take place.

Cochran-Smith and Lytle's (1999) three conceptions of teacher learning (knowledge for, in and of practice) can be viewed as learning by acquisition, construction and by participation (Sfard, 1998). The choice of which learning approach is adopted has consequences for how and what is learnt. Sfard suggests that combining two or more approaches could lead to better learning. Further, Hodkinson and Hodkinson (2005) suggest that teachers could experience enhanced learning and improvement in their teaching if they combine participation and acquisition approaches. The combined approach is likely to not only assist teachers' use of effective teaching methods, but also support reflection and revision of teaching practices and construction of new practice knowledge (Butler, Lauscher, Jarvis-Selinger, & Beckingham, 2004). This literature suggests that professional learning programs should engage teachers in a variety of professional learning activities in a community of learners to help them construct knowledge as individuals and to acquire knowledge from others (Beverborg et al., 2015). In this regard, this study is aligned to the assumption that knowledge needed by teachers to learn and continue to improve their practice, is embedded in the classroom and the activities they undertake while teaching (Cochran-Smith & Lytle, 1999). Further, by evaluating their own teaching through reflection, both individually and in collaboration, teachers can improve their practice (Darling-Hammond & Bransford, 2005).

2.4 Teacher professional learning activities

Schön (1983) demonstrated that professional learning impacts on practice and is informed by the way professionals understand and conduct their work (Bound, 2011). In this way, professional learning is differentiated from other forms of learning in that activities conducted and resulting outcomes are job related (Mitchell, 2013; Opfer & Peddler, 2011). Although engaging in workplace-embedded learning activities does not always result in improved practice, practising teachers have reported that they learn informally from various activities they undertake during teaching (Hoekstra, et al., 2007; Lohman, 2006). Despite these claims, not a lot is known about the specific professional learning activities teachers engage in their everyday work that lead to changes in cognition and/or behaviour (Kyndt et al., 2016; Vermunt & Endedijk, 2011). Considering the importance of continuous teacher professional learning, more needs to be known about these activities and their learning outcomes (Borko, 2004; Lohman & Woolf, 200; Meirink, et al., 2009).

Researchers have used different instruments and methods in an attempt to study the kind of learning activities teachers engage in, including interviews, digital logs, questionnaires, observation, and logbooks (Bakkenes et al., 2010; Hoekstra et al., 2009; Kwakman, 2003). These studies have resulted in the identification of a number of categories of professional learning activities (Eraut, 2004; Kwakman, 2003; Kyndt et al.; Lohman & Woolf, 2001), which fall primarily on observable activities such as reading, browsing the internet, teaching in the classroom, and exchanging classroom experiences with colleagues (Bakkenes et al., 2010; Vermunt & Endedijk, 2011). Bakkenes and colleagues (2010) recommend a focus on both visible and invisible activities, such as a teacher's thinking about their practices and student learning.

Most studies on teacher learning show that teachers engage in five core professional learning activities. These are: keeping up to date, experimenting, providing feedback, reflecting on their practice, and sharing information (de Vries, Jansen, & van de Grift, 2013; Geijsel et al., 2009; Hoekstra et. al, 2007; Kwakman, 2003; Lohman & Woolf, 2001; Meirink et al., 2009; Van Eekelen et al., 2005). Keeping up to date involves exploring and maintaining professional knowledge by reading professional literature. Experimentation refers to teachers' efforts in trying out new methods of instruction and teaching and learning materials to establish what works best with their students. Kwakman (2003) considers experimentation as an individual learning activity through which teachers learn by "doing". Reflection on practice refers to

consideration of, or thinking about, practice with the sole aim of gaining insights to improve future practice (Bakkenes et al., 2010; Kwakman; Runhaar, Sanders, & Yang, 2010). Providing or asking for feedback is considered a social professional learning activity. When teachers request feedback from their colleagues, they gather information they can use to improve practice (van Woerkom, 2004). Sharing of information is also a social learning activity in which colleagues exchange ideas and knowledge. Sharing helps teachers to not only make knowledge explicit, but also to consider how this knowledge might be used to improve practice (Cochran-Smith & Lytle, 1999).

2.4.1 Studies examining teacher professional learning activities

Kwakman (2003) studied teacher learning by exploring the extent to which secondary school teachers participated in routine professional learning activities, and what factors influenced their participation. She used two complementary studies: a survey and a literature review. From the literature review study, she found that teachers often learn in their practice by engaging in one or more of the following categories of professional learning: reflecting, experimenting, collaborating, and reading. From the survey, in which teachers responded to a questionnaire, teachers mentioned that: (1) they read to keep abreast of new professional information such as new teaching methods and new subject matter; (2) while teaching (doing), they gain new teaching experiences and also experiment on new teaching methods and learning materials; (3) when reflecting on their practice, they address their own ways of teaching, a kind of self-feedback; (4) collaboration with colleagues is important as it not only supports learning, but also provides an opportunity to receive feedback, gain new ideas and work through challenges.

Lohman and Woof (2001) distinguished four ways in which teachers learn by exchanging knowledge with their colleagues in schools. These were: collegial conversations, observation, collaboration, and sharing resources. Their study involved 22 experienced teachers from elementary, junior and senior high schools. Data were collected through semi-structured interviews through which teachers reported that they gained information and insights from their colleagues through collegial conversations that helped them to manage both student and instructional problems in their classrooms by exploring alternative strategies. These collegial conversations were informal in that they were not planned; rather, teachers encountered each other in the course of their normal day's work, such as in the hall during periods of class change-over, class corridors, during tea breaks, and in shared office spaces.

Many teachers in Little and Woof's (2001) study also reported that they learnt a lot through collaboration with their colleagues during special education work and study groups, especially when they themselves elected to participate in such activities. Teachers indicated that they gained most when they worked with other experienced teachers that teach in the same subject and grade level. This alignment provided a common contextual experience for the things they were trying. Although school schedules were inhibitive for activities such as peer observations, they reported these to be beneficial in developing their teaching skills when they were able to observe through attendance or standing outside the door of perceived "good" teachers during their free time.

Sharing of learning resources was another activity that teachers reported using to exchange knowledge in Little and Woof's (2001) study. In addition to learning from their colleagues, teachers reported that they also learnt from interaction with their students. They reported gaining different perspectives on subject content and students' learning difficulties from these interactions. Findings from the same study also showed that teachers reflected in and on action to develop professional knowledge. The majority of secondary school teachers reported reflecting on their practice by themselves and using these reflections as the basis for experimentation to develop their skills and knowledge. Elementary teachers tended to differ in method, using group activities to reflect on their practice. They identified and discussed significant activities that helped them to improve their teaching skills. They also reported that they reflect in action during their teaching, by monitoring, evaluating and adjusting their lessons during the teaching process. Both secondary and elementary teachers reported reflecting in action in other activities outside the classroom, for example, when experimenting with new computer skills. They also stated that they sourced professional information by scanning external sources such as the internet, professional journals, and educational publications.

Formal teacher professional learning programs may provide opportunities for teachers to learn, but research has shown that practicing teachers also learn from self-initiated activities in their schools (Van Eekelen et al., 2005). Self-initiated learning activities were defined by Lohman and Woolf (2001) as "experiences that teachers initiated and participated in that, in their perceptions, resulted in the development of their professional knowledge and skills" (p. 60). Learning from self-initiated activities mostly stemmed from an individual teacher's desire to understand an incident or concept. Teachers involved in this kind of learning are responsible for their own learning and have the freedom to consider the content and process of the learning

experience (Beach, 2017). Therefore, it is important to examine the type of self-initiated learning activities that teachers engage in for professional development (Beach, 2017; Lohman & Woolf, 2001).

Van Eekelen et al. (2005) studied self-regulated learning activities, learning outcomes, and environmental factors that stimulated or inhibited teachers' learning processes. This study involved 15 experienced higher education teachers who participated in semi-structured interviews and a "digital" diary. Data were analysed using a phenomenographic method. The most frequent self-initiated learning activities reported were: "doing'" (by figuring out something alone) and in interaction (with students in class, and formally and informally with colleagues). Other less frequently reported learning activities included reading (newspapers, books and articles) and thinking (taking time to think and reflect about school issues). Results reported by Van Eekelen (2005) and colleagues are supported by those from experienced teachers in Lohman's (2006) study where teachers indicated that they preferred interactive learning activities such as sharing materials and talking with others, especially colleagues with whom they shared similar experiences. These collaborative learning experiences were favoured over more independent activities such as reading professional publications and searching the internet. These findings correspond with most adult learning and constructivist theories that advocate for learning that is socially situated, problem-solving oriented, active, self-directed, and takes place throughout adults' lives (e.g., Jarvis, 2012; Knowls, 1980).

Lohman and Woolf (2001) argue that teachers are likely to depend on self-initiated learning activities for two reasons. Firstly, research has shown that teachers are not likely to improve their teaching practice as a result of formal professional learning programs; and secondly, most teachers work in isolation from their colleagues, and their teaching schedules often inhibit them to attend formal professional learning and development workshops and training courses. Self-initiated activities can promote on-going and life-long professional learning, and because they are embedded in the workplace, they could be considered as addressing the challenge of teacher isolation that many teachers report (Beverborg et al., 2015; Feldhoff, Radisch, & Klieme, 2014).

Meirink et al. (2009) used interviews and digital logs to investigate learning activities undertaken by teachers in the workplace. They involved 34 experienced Dutch teachers who worked in five teams across different secondary schools and departments in the Netherlands. Teachers were able to select their own ways to achieve the goal of active and self-regulated

learning in their classrooms. Questionnaires, derived from previous research on teacher learning, were used to determine their preferred learning activities. Digital logs were used to record the actual learning activities adopted to promote students' active and self-regulated learning in the classroom. Learning experiences were described in story-form, describing what and how learning occurred. The teachers emailed the researchers at least one learning experience every six weeks and each teacher submitted six digital logs during the one-year study period. Results from the questionnaire analysis indicated that teachers often reflected on their practice individually when they encountered puzzling or problematic situations in their classrooms; and they often acted on perceptions or asked advice from colleagues.

Bakkenes et al. (2010) also examined how teachers learn from their teaching through active and self-regulated learning in secondary schools in the Netherlands. They based their research on previous studies (e.g., Kwakman, 2003; Lohman & Woolf, 2001; Van Eekelen et al., 2005) that distinguished several learning activities: (a) experimenting; (b) in interaction; (c) using external sources; and (d) thinking or reflecting on one's own teaching. They did not consider learning in interaction as a distinct category; arguing that the other categories (experimenting, reflecting and using external information from external sources) could be conducted by an individual teacher or by a group of teachers working together. Participants included 94 experienced teachers who used digital logs to track learning experiences over a period of three years. Every teacher was asked to describe six learning experiences in relation to: their intentions; their feelings and thoughts about the learning experiences; how they learnt; the cause of the learning experience; the relationship between the learning experience and self-regulated learning; and the people involved. In addition, teachers were interviewed; observed in their classrooms teaching; and completed a questionnaire that was used to elicit their beliefs and intentions.

Content analysis of learning experiences reported by the 94 teachers in this study discerned six main categories of professional learning activities: (1) experimenting (trying new approaches in the classroom); (2) considering their own practice (situations teachers reflected on from their own teaching methods and students' learning); (3) getting ideas from others (taking and evaluating other peoples' views, ideas and practices); (4) experiencing friction (discrepancies noticed between what they expected and what happened in the classroom); (5) reverting to old ways of teaching (trying new teaching methods but finding themselves reverting to old ones); and (6) avoiding learning (engaging in activities that inhibited them from learning about new

teaching methods). Categories of experimenting on new ideas and considering one's own practice were frequently reported.

Similarly, almost all of the 27 teachers who participated in Hoekstra's et al. (2009) study reported to have experimented at least once with new teaching methods and materials. Although some teachers' reports indicated that they experimented with colleagues, most experiments reported were conducted by teachers individually. One teacher in this study conveyed that she experimented with what she termed as "student lessons" where students were asked to prepare and teach a part of a lesson. The teacher related that her students learnt well from this, and that she would continue using this method in future. Another teacher in the same study stated that, together with other science teachers, they developed a task in which groups of students selected a science topic and designed, conducted, and reported on an investigation. The success of this saw teachers adopting this practice in subsequent years. From these studies, it can be concluded that experimentation, arising from individual or collective reflection, plays a central part in teacher learning about teaching.

2.4.2 Reflection and learning

Scholars have found that reflection can help both pre-service and in-service teachers to evaluate and clarify ideas about their teaching, with an intention of improving their teaching practices (e.g., Çimer, Çimer, & Vekli, 2013; Loughran, 2013). Reflection can be conducted alone or with others (Ghaye, 2011). The importance of reflection was first suggested by Dewey (1910). It was further emphasised by Schön (1983) and has recently been used and researched widely in teaching and teacher education (e.g., Bolton, 2010; Brandenburg, Glasswell, Jones, & Ryan, 2017; Farrell, 2008; Lupinski, Jenkins, Beard, & Jones, 2012). Dewey (1933) believed that reflection enriches the process of learning from experience and noted its importance for people to think about the consequences of their teaching actions. He regarded "learning by doing" as insufficient for progressive learning and argued that we can learn more, and something new, when we reflect on what happens as a result of our actions, especially when reflecting in collaboration with others. He believed that some abilities are stimulated during collaboration with others. In this study, teacher trainers reflected on each other's classroom experiences during the group reflection discussions.

Schön (1983) purported that reflection improves professional activity through both reflection-in-action and reflection-on-action. Of these, he emphasised the importance of reflection-in-

action and stressed the value of individual self-awareness and continuous learning in practice. By reflecting on one's own practices, teachers often recognise good ideas and gain a clearer understanding of classroom events. Mezirow (1990), in recognising Schön's work, placed reflection at the centre of learning. He believed that it is by reflection that people become aware of the ways in which they interpret reality and give meaning to actions and behaviour. Brookfield (1995) introduced the notion of "assumption hunting" through reflection. Brookfield asserts that assumption hunting is best when the investigation is collaborative through interaction with colleagues. In this way, taken-for-granted ideas that can be held subconsciously can be challenged in positive ways through the eyes of a respected other.

Korthagen (2016) and Larrivee (2008) note that the concept of reflection is often problematic and carries diverse meaning to different researchers and educationalists, despite the overarching importance placed on it regarding learning. Some have even questioned its usefulness in promoting teacher learning. Scholars seem to have partly drawn their conceptualizations of reflection from Dewey (1933). Reflection, according to Dewey arises from a puzzling experience encountered when one is faced with a problem and/or doubt in practice. Many teachers are likely to encounter puzzling situations in the classroom while teaching and may reflect in or on those puzzling situations. Dewey considers such situations as key moments for learning, as they trigger reflection in order to find solutions. He anticipated that in the process of trying to look for solutions, people are likely to learn something new or to gain a better understanding of the problem.

Loughran (2010) asserted that a problem invites attention, and provokes further consideration, and thus presents an opportunity for learning. Therefore, instead of considering *a problem* as *a mistake,* as it is often viewed, it should be considered as a starting point for learning (Dewey, 1933; Loughran, 2010). Many strategies for reflection according to Jannsen, Hullu and Tigelaar (2008) focus on a negative situation. However, they argue that reflection can be triggered by positive as well as negative situations. They are supported by Schechter, Sykes, and Rosenfeld (2008) who found that reflecting only on difficult situations, deprives teachers from learning from their successful teaching practices. Their investigation in biology teaching and learning showed that student teachers who reflected on positive experiences made more innovative resolutions. Further, they were more highly motivated to implement these resolutions compared to when reflecting on problematic experiences. In both positive and negative situations,

reflection acts as a tool for professional learning, playing a critical role in learning from experience (Helyer, 2015; Mathieson, 2016; Mezirow, 1990; Peterson & Chapman, 2013).

Reflection, according to Loughran (2012), can give teachers opportunities to look more deeply into their actions, not to only justify particular actions, but also to consider how and why they happened and to see them from a different perspective. The notion of seeing practice from a different perspective through reflection in and on action is what Schön (1983) referred to as "reframing". Loughran stated that through reframing of practice, teachers can question what they take for granted in their practice and are likely to develop new perspectives; new ways of looking at their own actions, and a new awareness or understanding of their own behaviours (and subsequently develop from technical to genuine expertise). In this way, reflection is considered a source of knowledge, helping teachers to better understand what they know and do as they develop their knowledge of practice (Husu, Toom, & Patrikainen, 2008; Loughran, 2010). This makes reflection a crucial professional learning activity that can result in alternative and improved teaching practice (Korthagen, 2016; Schön, 1987; Vermunt & Endedijk, 2010).

2.4.2.1 Types of reflection

Husu et al. (2008) used guided reflection to investigate the quality of teacher reflection. Based on their findings, different types of reflection might be utilised by teachers when analysing their practice. Supporting Husu et al., Ghaye (2011) asserted that there is more than one type of reflection, and each type performs different jobs and takes place at different times. Scholars have coined different terms for reflection such as: reflection-in-action, reflection-on-action, reflection-for-action, reflection-about-action, and reflection-with-action (Eraut, 1995; Ghaye, 2011; Schön, 1983).

Schön (1983) popularized the notion of the reflective practitioner by coining reflection in and on action to distinguish two core types of reflective practice. Reflection-in-action, according to Schön, is thinking about what one is doing whilst doing it. This demands one to be constantly aware, and monitor work as it develops (known colloquially as "thinking on your feet"). Schön asserts that this kind of awareness permits people to adjust practice as the situation demands (reframing). The action happens quickly, and practitioners make on-the-spot adjustments in the midst of action, something commonly referred to as *improvisation* (Ghaye, 2011; Schön, 1983). However, Ghaye noted that people are frequently unconscious that they are reflecting-in-practice. Reflection-in-action has been criticized, with Eraut (1995), for example, claiming that

it is not possible to reflect in practice due to insufficient time. Eraut identifies time as an important variable in understanding professional behaviour. Regardless, reflection-in-action has remained influential in the reflection discourse and is distinguished from other kinds of reflection due to its immediate significance for action (Schön, 1987).

Reflection-on-action involves the analysis and evaluation of activity after the act (Schön, 1933), and the results of this reflection inform subsequent action. Ghaye (2011) advanced another dimension of reflection-on-action where one focuses on a significant aspect of an event, claiming that it is not possible to reflect everything. In this case, one has to be selective and examine the significance of a selected incident, and why it caught the person's attention, or why it was retained in memory. Another third type of reflection not discussed by Schön is reflection-for-action (Eraut, 1995; Ghaye, 2011). These scholars argue that it is important to indicate the purpose of reflection. Eraut contends that the purpose of Schön's reflection-in-practice was to monitor action currently in progress, although Schön did not mention it directly. Reflection-for-action is about reflecting on a past action for a particular reason (Ghaye, 2011). Kolb's (1984) prime purpose for reflection-for-action is learning from experience to affect future actions rather than on those actions that are in progress as Schön discusses. Reflection-for-action is important for planning purposes when one wants to understand, improve or change something to enhance overall practice. The planning aspect, according to Ghaye, is important, as one might think of alternative ways to do something better. Van Manen (1991) referred the act of planning-for-action as *anticipatory reflection*.

Another type of reflection is reflection-with-action, a conscious action undertaken for future action (Ghaye, 2011). Ghaye understands that the main purpose for reflecting-with-action is weighing options and making a decision about how to act when performing a specific task. Ghaye interpreted the notion of "with" to mean acting alone or with others, although he notes that when people work as a group, better outcomes are likely to result. On the surface, reflective practice in teaching may appear quite simple, however, when considered in relation to developing alternative perspectives through framing and reframing, it takes another meaning and is a much more demanding exercise than it first appears (Loughran, 2010). This raises the question as to which models of reflective practice might best guide the process of reflection, and what tools might be used within these models to best achieve set objective(s).

2.4.2.2 Models of reflection

There are many models in the literature that scholars have used to promote reflective practice. These include structured, cyclic, and hierarchical models (Johns, 1995; Kolb, 1984; Korthagen, 1985). Kolb, for example, placed reflection at the centre of acquiring knowledge for practice through his cyclic model of experiential learning theory. This model has four stages (experiencing, reflecting, conceptualizing, and experimentation) that encourages practitioners to reflect on their experiences. According to Kolb, reflection is an active process that leads to generation of information that is either accepted or rejected through experimentation. As such, Kolb implies that reflection facilitates learning from experience. Kolb's model has attracted immense criticism for not paying sufficient attention to the process of reflection, and for not recognising that all stages he identified can take place at the same time. Such criticisms imply that the model should not be cyclic (e.g., Jarvis, 1987; Kayes, 2002). However, its contribution to experiential learning through reflection cannot be underestimated and Kolb's model is thought to have influenced other scholars in the development of subsequent reflection models (e.g., Brookfield, 1995; Johns, 1995; Korthagen, 1985; Smyth, 1991).

This study was guided by a structured model of reflection adapted from a variety of models in the literature. These include: Smyth's (1991) critical reflection model on classroom practice, Korthagen's (1985) ALACT model, Kolb's (1984) experiential learning cycle, Johns's (1995) structured model, and Brookfield's (1995) four complementary lenses. The resulting amalgamation is illustrated in Figure 3 and involves four stages: Describing (D), Reconstructing 1 (R1), Reconstructing 2 (R2), and Informing [I]. It is denoted herein as DRRI. The resulting amalgamation model was considered suitable in assisting participants learn more as it allowed them to explore deeper their teaching experiences. Prompt questions, for example, adopted from some of the models (e.g., Johns, 1995) but lacking in others (e.g., Korthagen, 1985) guided the participants on the reflection process and how learning might take place. Further, in some models used in the literature, practitioners are expected to trial their actions (e.g., Korthagen, 1985); this was not provided for in the research design due to time constraints.

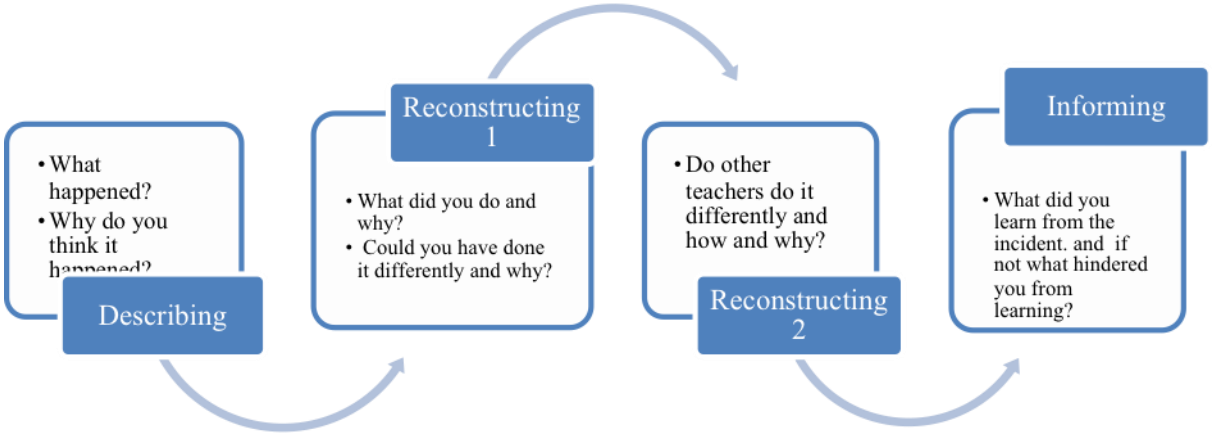


Figure 3. A model of reflection on classroom practice (DRRI)

In the first stage, *Describing*, of this model, teachers reflect (Kolb, 1984; Korthagen, 1985) and describe their teaching experiences (Smyth, 1991). This stage assists teachers to unpack and identify essential aspects of their teaching (Korthagen, 1985). Following this is the first *Reconstruction* stage in which teachers individually try to construct meaning from their teaching experiences (Smyth, 1991) and consider alternative methods of action (Korthagen, 1985). In the third stage, referred to as *Reconstruction 2*, teachers work collaboratively to share their experiences with their colleagues (Johns, 1995) in order to gain their colleagues' perceptions of their actions (Brookfield, 1995; Johns, 1995). Reflections from the first three stages inform the final *Informing* stage (Smyth, 1991). During *Informing*, teachers reflect on what they have learnt from their experience of and reflection on the selected event, what might have hindered their learning, and how they might use subsequent learning to improve future lessons (as classroom teachers) and training (as County teacher trainers).

Various tools have been used to facilitate reflection such as: critical incident analysis (Mohammed, 2016; Tripp, 2012); journaling (Clarke, Burn & Kettula, 2012); on-line discussion (Whipp, 2003); critical conversations (Brookfield, 1995); and narratives or stories (Webster & Mertova, 2007). These tools may be used in written or oral form, and in individual or collaborative reflection (Osmond & Darlington, 2005). Some tools, for example journaling, are onerous and not easily established, whereas others, such as critical incidents, can be quickly recalled and recorded (Tripp, 2012). Critical incident analysis was adopted in this study to facilitate teacher trainers' self and group reflection on their teaching practices.

2.4.2.3 Reflection tools: Critical incident

Critical incidents are suited to busy people, like teachers, to constitute manageable and rich data (Tripp, 2012). In teaching, it is not easy to reflect on everything that occurs in the classroom, and therefore critical incidents can be of help in selecting a focus (Mohammed, 2016; Tripp, 2012). Although some people take critical incident analysis as no more than constructive self-criticim of one's action; it can be used to explore in-depth ideas about practice, and to consider the cause(s) of a particular teaching event through the process of structured reflection. This can allow for the generation of possibilities for improved future action (Mohammed, 2016).

The term "critical incident" comes from the past where it was used to refer to events or situations that had noteworthy impacts on, or formed turning points in an institution, social occurrence, or a person's life (Brookfield, 1995; Tripp, 2012). Such specific events are critical in people's lives and are key determinants of how people recall their life experiences. If such events are used as a main focus for research, they are likely to provide valuable data for getting to the core of what is important in that research (Webster & Mertova, 2007). One recommendation for use of critical incidents according to Webster and Mertova is that they are retained in memory and thus are easily recalled. In relation to teaching, Farrell (2008) describes a critical incident as an unplanned event that occurs in the classroom. Therefore, for teachers, a critical incident is not an emergency, but rather an ordinary, everyday event or situation that occurs in everyday classroom practice that they would like to understand better, and that has the potential to deepen their understanding of students' thinking and learning (Tripp, 2012; Yan & Ricks, 2011).

Some critical incidents may appear to be commonplace rather than critical, but as Tripp (2012) notes, incidents become critical because someone sees them as such through an interpretation process that gives the incident meaning. The criticality of a particular incident is, therefore, based on the justification, importance, and meaning given to them by an individual (Angelides, 2001; Tripp, 2012). For teachers, the nature of decisions or judgments they make is important because so much of what they do directly influences students' learning and relates to ways in which they respond to students' needs and concerns (Loughran, 2010). When teachers choose particular incidents from their classrooms that they think are critical to them, it is assumed that these incidents include the basic elements of these teachers' own ways of thinking and acting in a particular teaching context (Husu et al., 2006).

Critical incidents have been used in the past for collecting data about practice for the purpose of bringing about improvements (Angelides, 2001). Tripp (2012) encouraged people to videotape, conduct interviews, or hold reflective discussions to record their critical incidents, rather than adopting the more common procedures of just writing them down. According to Tripp, these additional methods facilitate a deeper understanding and analysis of the phenomenon under investigation. Tripp asserts that critical incident reflection has helped teachers and teacher educators to elicit ways of improving their teaching through the identification of pre-conceptions. Identification of critical incidents has been used to promote reflective practice in teaching in many places (Finch, 2010), although it is not commonly used in Kenya. They are considered important as they give teachers an opportunity to express themselves, and when used in collaboration, provides opportunities for discourse between practitioners on the subject of their personal and individual practice (Tripp, 1994). Such an approach supports research on teacher learning and development that consistently acknowledges the importance of teachers learning together (Andrews-Larson, Jonee, & Larbi-Cherif, 2017; Dogan, Pringle, & Mesa, 2016).

2.4.3 Teacher learning in collaboration

Effective professional learning in communities has the potential to change experienced teachers' practices in ways that make them more effective in their teaching (Bausmith & Barry, 2011). More specifically, when collaborative learning is content-specific and undertaken over a period of time rather than in a one-off session, it can lead to the development of new and diverse knowledge among teachers (Doppenburg, Bakx, & Brok, 2012; Horn & Little, 2010; Kennedy, 2011; Postholm & Waege, 2016; Schechter et al., 2008; Vrieling, van den Beemt, & de Laat, 2016). The importance of collaboration was illustrated in the OECD Teaching and Learning International Survey (2014) by teachers who engaged in professional learning activities collectively at least five times a year. Those teachers reported that they were more confident and satisfied with their work and in their teaching abilities.

Teacher learning in collaboration is defined variously in the literature. Doppenburg et al., (2012) refers to teacher learning in collaboration as the act of teachers undertaking learning activities with colleagues, resulting in teachers' change in cognition and or behaviour, at an individual or group level. This definition relates to learning through the sharing of insights and problems in constructive ways, through dialogue and social interaction, focusing on common issues of professional practice (Brody & Hadar, 2013). Learning through collaboration can also

be theorized from Lave and Wenger's (1991) and Wenger's (1998) notion of communities of practice in which teachers develop *shared practice.* Within these communities, individuals share their personal practices and review each other's practice and behaviour. They use these opportunities to critique each other's practices; they examine and question existing practices, and in the process, are likely to develop new teaching approaches and knowledge. In this way, professional learning and development programs are likely to produce better results than those stemming from individual teacher learning (Lamb et al., 2011; Wei, Darling-Hammond & Adamson, 2010). It is also acknowledged that conditions for improving teaching and learning are strengthened when teachers question their existing assumptions about teaching and learning in collaboration with one another (Bausmith & Barry, 2011; Little, 2002).

Teacher learning in collaboration can take many forms, ranging from teachers working together with colleagues in formal, informal, planned or unplanned settings (Kennedy, 2011). What is viewed common in these forms of collaboration is that they nurture social learning activities within which teachers take an active and reflective role in group settings. In these groups, teachers exchange ideas, experiences, try new ideas, and co-construct knowledge about teaching and learning that can facilitate their professional development and ultimately, enhance student learning outcomes (Brody & Hadar, 2013; Rahman, 2011; Vrieling, van den Beemt, & de Laat, 2016). The aim of grouping teachers is to increase their learning opportunities in recognition of the view that social learning can enhance learning beyond the classroom (Kwan & Wong, 2014; Vrieling, Bastiaens, & Stijnen, 2010). Through engaging in collaborative learning activities, teachers acquire ideas related to their own classroom practice (Van den Beemt, Ketelaar, Diepstraten, & De Laat, 2014). Professional learning communities may be comprised of a group of teachers from the same department of the same school, or from different schools and/or different departments (Desimone, 2009; Doppenberg et al., 2012; Hofman & Dijkstra, 2010). During their everyday work, teachers can collaborate with each other by teaching a class together, or by finding information for a certain subject or topic. In this way, collaboration can be an effective tool for teachers to exchange ideas and give and receive feedback about their teaching practices (Kwakman, 2003; Little, 2002; Little & Horn, 2010).

Teacher learning in collaboration has been studied for a long time; however, there is need for more research, as findings of most of these studies seem to focus on types of collaborative activities, settings, and improvements in teachers' collaboration, rather than on teacher learning outcomes (Doppenberg et al., 2012). There is also little research that focuses on teacher learning

opportunities and possibilities from their daily work. In light of such findings, in recent decades, research on teacher learning in collaboration has shifted to day-to-day activities of teachers in their classrooms and in the broader school context (e.g., Little & Horn, 2010). This shift is possibly due to the ineffectiveness of the many professional development programs that are disconnected from teachers' practices in the classroom (Hunzicker, 2011).

The school has been acknowledged as a powerful context for teacher learning in collaboration, however, researchers have observed several challenges associated with collaborative professional learning in schools. It is still not certain whether schools are in a position to sustain collective learning among teachers (Schechter et al., 2008). Organizing professional learning dialogue in schools is sometimes difficult because of the way teachers' work is organised (Daniel, Auhl, & Hastings, 2013; McLaughlin & Talbert, 2006). Many teachers' schedules do not provide them with time or opportunities to sustain in-depth collaborative discussions about their teaching or about their students' learning (Council of Teacher Advisory and National Academics of Science and Medicine, 2016; Shank, 2002). Some schools also follow old-school traditions that have characterized teaching as an individual and isolated profession (Loughran & Berry, 2006). Teachers in such schools work in their classrooms in isolation from one another, and therefore cannot easily access the benefits of collaborative learning (Runhaar, ten Brinke, Kuijpers, Wesselink, & Mulder, 2014; Wei et al., 2009). To address this problem, schools are encouraged to embrace more collective models of teaching and learning among their teachers (Schechter, et al., 2008). Teachers for example can be facilitated to form professional learning groups (Vrieling, van den Beemt, & de Laat, 2016).

2.4.3.1 Activities that support collaborative learning

Researchers have used various activities to promote collaboration in teacher learning. From a review that aimed to evidence the impact of *professional learning communities on science teachers' knowledge, practice, and student learning,* Dogan et al. (2016) discerned several activities that support collaborative professional learning; the main ones cutting across the studies included: reflection and guided discussions; sharing accounts of experiences; review and analysis of student work; planning and implementing lessons together (e.g., lesson study approach); mentoring; lesson observation; and analysing video lessons. Findings from most studies reviewed showed evidence of changes in teachers' knowledge, beliefs, attitudes, and practices in science teaching. However, in some studies, the authors did not exclusively

ascertain that noticeable changes stemmed from participation in professional learning communities.

Crippen, Biesinger, & Ebert (2010) combined several activities to try and improve science teachers' instruction and subsequent student achievement. Participating teachers attended a content-focused summer course for two weeks every year, for three years. During the training, teachers were engaged in *discussions* where they *shared ideas* and developed a collective responsibility for student learning. One requirement of the summer course was for teachers to plan an *action research project* which was to provide a lens for *reflective practice*. During the planning sessions, they were encouraged to work in department and school teams. Teachers were *observed* in their classroom on five occasions across the project period. Findings from this study showed that classroom teaching characteristics of the participant teachers changed over the term of the project to include more student-centred approaches and higher levels of cognitive engagement. These changes were reflected in teachers' use of inquiry learning activities and small group and individualised instructions.

Nilsson (2014) investigated how science teachers' pedagogical content knowledge (PCK) can be developed through participating in a "learning study". The learning study group was composed of three secondary science teachers who explored their teaching and identified critical areas needed for student learning. Video-recorded lessons were used to stimulate discussions in which the teachers and the researcher reflected and analyzed several components of their teaching. These included: development of their PCK through the study period, their students' learning, and the effect of the newly acquired knowledge on their own teaching. Findings provided an insight into how teachers develop professional knowledge by questioning their own epistemological beliefs, taken-for-granted assumptions, and purposes and objectives of teaching.

Rahman (2011) employed several collaborative activities to explore secondary science teachers' learning including reflection, discussion, and peer observation. Teachers were asked to use the Predict, Observe, and Explain (POE) approach in their classrooms. POE teaching employs tenets of a constructivist teaching approach, in which students are actively involved in the learning process. Teachers were given opportunities to observe one another teaching and to then discuss their observations during professional learning workshops. In these workshops, teachers reflected on their own and their colleagues' teaching. They identified aspects of the

lessons that required improvement and adjustments. Positive aspects of the lessons motivated teachers and also acted as learning points for others.

Research on teacher conversations in learning communities suggest that much can be understood about teacher learning by analysing their "talk" (Horn & Little, 2010; Little, 2003; Richmond & Manokore, 2011). Little and Horn (2010) in their study noted that "workplace groups are more likely to prove generative for learning if they develop a capacity for talk that centres on dilemmas and problems of practice" (p. 183). The study demonstrated the importance of "teacher talk" in collaborative professional learning. Teachers' talk was characterised by stories they shared about their practices, specific impacts of their teaching, and issues related to their students' learning. They focused on conversational moments entailing teachers' accounts of experience, signalling problems in their professional accounts, pressing each other to explain not only what they do with their students in their classroom, but also why. Teachers' accounts of classroom experience helped them to explore potential learning at what they called an "instructional triangle" which was represented by the relationship between the teacher, the student, and the subject content arising in the conversations.

The studies discussed here demonstrate that professional dialogue and reflection can be considered as effective tools for teacher professional learning (Cochran-Smith & Lytle, 1999; Little, 2003; Rocco, 2010). Reflection "requires practice, intellectual engagement and purpose" (Rocco, 2010, p. 313) which is possibly why many people, including teachers, do not frequently reflect on their practice (Hobbs, 2007). By using reflection and professional dialogue, Simoncini, Lasen, and Rocco (2014) argue that reflection on practice can be enhanced and subsequently, so can teacher learning. Professional dialogue, also referred to as "inquiry conversation", "reflective conversation", "learning conversation" and "professional or collegial discussion" is a discussion between colleagues that allows them to extend their understanding of practice (Cochran-Smith & Lytle, 1999; Earl, & Timperley, 2009; Feldman, 1999; Rocco, 2010). Collegial discussions can allow teachers to grow professionally by learning new knowledge through questioning their practices and unlearning strongly held beliefs, practices, and ideas that are sometimes difficult to uproot (Cochran-Smith, 2003; Corrigan & Loughran, 2008). Little (2003) argues that since teachers largely work out of hearing and sight of one another, narrative accounts are important to construct shared understanding of situations in the classroom that relate to student learning and teacher practice. Students' work can also provide

useful material to stimulate dialogue in teacher learning discussions. Jones, Gardner, Robertson, and Robert (2013), for example, used the DuFour (2004) professional development model that gave teachers an opportunity to learn in collaboration by using student test scores in a particular science topic. Teachers participating in this study were asked to select a common topic they had taught, assess students and avail their students' scores for discussion. They discussed ways of teaching and assessing the selected topic to ensure that each student achieved the required southeastern United States standards of education for the particular science topic.

2.5 Teacher professional learning outcomes

Moon (2004) noted that it is not possible to see learning, only the impact the learning has on practice. However, Guskey (2000) believed that it was possible to collect some "evidence" about teacher learning, regardless of whether or not their participation in professional learning activities contributed to student learning. As Kyndt et al. (2014) suggest, it is important and of great value to render tacit learning outcomes visible. This is because by doing so, according to Kyndt and colleagues, the learning outcomes can be used in improving work-related roles and tasks. While it is important to render learning outcomes visible, King (2014) notes that there is little clarity on how teachers' learning outcomes are assessed and evaluated following participation in professional learning programs except that they are often linked to students' learning outcomes. There is value in linking teacher professional learning outcomes with students' learning outcomes, but it is also important to understand that teaching and teacher learning are complex processes (Opfer & Pedder, 2011). In this regard, Eraut (2004) recommended a holistic approach when categorizing learning outcomes, claiming that they are shaped by broader concepts than student academic achievement alone.

Learning outcomes have been categorized in many different ways in the literature and appear to be dependent on the focus of the particular researcher. For example, four categories of learning outcomes were distinguished by Van Eekelen et al. (2005): (1) gaining insights from reading; (2) making a resolution for next time, where the teacher decides to repeat or alter a behaviour depending on whether it appeared to be effective or ineffective; (3) changing social behaviour; (4) performing a new skill. Bakkenes et al. (2010) also distinguished four behavioural, cognitive and affective categories. These were: changes in knowledge and beliefs, changes in emotions, changes in intentions for practice and changes in actual teaching practices. Generally, learning outcomes are considered as potential changes in teachers' knowledge, skills, and attitudes towards their teaching practices as a result of engaging in learning activity

(King, 2014; Matthews, 1999). This is probably because, as noted earlier, changes in practice take a long time, and often, only the impact of the learning is visible (Moon, 2004).

2.5.1 Changes in teacher practices

Dogan et al. (2016) suggested that the impact of learning should be visible through changes in teachers' science teaching practices as a result of participation in professional learning programs. Such changes imply the use of improved reform-based science teaching practices; for example, shifting to more student-centered approaches. Changes in teacher practice are not often reported in research studies (Dogan et al., 2016; Kyndt et al., 2016). Dutch secondary school teachers who participated in Bakkens et al.'s (2010) study, for example, mainly reported changes in knowledge and beliefs, emotions, and intentions for practice but not changes in actual practice. Intentions to practice, according to Bakkenes and colleagues can be seen as "precursors of change in actual practices" (p. 545). These teachers possibly did change their practices, but as Schön (1983) and Loughran (2012) posit, professional knowledge is tacit and therefore not easily articulated. Bakkenes and colleagues consider two possibilities as to why teachers do not report actual changes in practice: firstly, they think that teachers associate learning with gaining knowledge and insights (assimilating and acquiring knowledge), and therefore report more on cognitive change. The second possibility is that, because behavioural change requires a lot of time (Borko, 2004), the one-year study was probably insufficient to engender observable changes in actual teaching practice.

Changes in teachers' practices were observed in a longer-term study (three years) by Lakshmanan, Heath, and Perlmutter (2011). These authors examined the impact of science content and professional learning communities on science teaching efficacy and standards-based instruction. Findings indicated that there was significant growth in teacher self-efficacy and in the way they implemented inquiry-based instruction in their classrooms. Similarly, changes in teacher practice were observed in classrooms in Crippena et al.'s (2010) long-term (more than three years) study of teachers. These teachers adopted a more student-centered approach which was reflected in their increased use of inquiry learning activities, small groups, and individualized instruction.

2.5.2 Changes in teacher knowledge, attitudes, and beliefs

As noted by Bakkenes et al. (2010), teachers often report more cognitive changes in their practices following participation in professional learning and development programs. For

example, Rahman (2011) found that use of the constructivist approach *Predict Observe and Explain (POE)* encouraged science teachers to change their teaching perceptions which were initially based on traditional teaching methods. Teachers reported that collaborative activities assisted them to identify and overcome perceived difficulties in their teaching and with student learning. Many teachers normally attribute students' failure in learning to their lack of ability, motivation and interest to learn, especially in the sciences and mathematics (Nuthall, 2004). Hattie (2009) argues that teachers need to change their beliefs and attitudes, and become more aware of impact of their teaching on students' learning. In doing so, they are likely to attribute students' failure in understanding to their own teaching.

Findings from Nilsson's (2014) study support Hattie's (2009) argument. Science secondary teachers who participated in her study revealed that reorganization of their lessons; making the introduction "real" through the use of real-life materials; clarifying concepts; and not introducing too many concepts at once; made a difference in their students' learning. These teachers also realised the importance of discussing prior conceptions of scientific ideas with students prior to the lesson. Such discussion enables an understanding of student difficulties in learning specific content. Such diagnostic assessment can help teachers to enhance their pedagogical content knowledge if they take time to carefully consider these conceptions before planning for instruction. From these findings, it can be argued that teaching and learning is influenced by teacher and student characteristics, as well as the teaching and learning materials selected, and the specific context in which the learning takes place.

2.6 Contextual problems affecting teaching and learning of chemistry

Context is an important factor for teachers and students when addressing teaching and learning in the classroom (Ali, 2012). As stated earlier, *contextual problems* in this study are considered as those problems unique to teaching and learning of chemistry in *a particular context*, for example, Kenya.Teachers sometimes do not introduce new ideas and innovations learnt during professional development due to contextual problems in their classrooms (Soebari & Aldridge, 2015). Gaps have been found between what is intended in terms of students' learning in chemistry, and what actually happens in the classroom (Ali, 2012; Ituma et al., 2015). Soebari and Aldridge (2015), for example, found that teachers feared that if they attempted to introduce new innovations learnt in professional learning programs, they would not cover the syllabus. They argued that examinations are set from the syllabus, and therefore if the syllabus was not covered, students would likely fail those examinations. Further, the teachers stated that

inadequate teaching and learning resources, such as books and laboratories, impeded the use of new techniques introduced in the professional learning program. A lack of practical support from the school principal, and also other teachers who had not attended the training, especially those teachers who were teaching in rural schools, also impeded implementation of new innovations.

Chemistry teaching is supposed to be based on an inquiry process, through which students develop conceptual understandings through investigation and reasoning (Ituma et al., 2015). This can only be achieved when students are willing to learn, and teachers use appropriate teaching methods and select suitable teaching and learning resources (Edomwonyi-Out & Abraham, 2011). Teachers face difficulties when attempting to use inquiry approaches in science classrooms (Bevins & Price, 2016) stemming from poor attitudes and beliefs towards science, a lack of availability of laboratory equipment and other materials, time constraints caused by voluminous curriculum content, prescribed assessment methods and procedures, and students' inability to demonstrate sufficient understanding of basic scientific concepts.

2.6.1 Teachers' and students' attitudes towards teaching and learning chemistry

Ejidike and Oyelana (2015) assert that teaching and learning is an engagement that demands voluntary contribution from teachers and students to achieve the desired result of student learning. For example, inquiry-based teaching approaches in chemistry can only be achieved when students are willing to participate in the learning (Edomwonyi-Out & Abraham, 2011). Such a notion is also reflected in an earlier study of Mwamwenda (1995), and in 2006 PISA survey results, confirming that students' achievement is, to a large extent, determined by their attitudes towards the subject. Bybee and McCrae (2011) posit that students' personal attitudes play a crucial role in their interest, attention, and response to science. This points to the important role that attitudes play in determining students' achievement in science (Osborne, Simon, & Collins, 2003). Edomwonyi-Out and Abraham (2011), for example, found that students' negative attitude towards chemistry often leads to the low performance experienced in secondary education in Nigeria. Chepkorir et al. (2014) reviewed and found a similar situation in Kenya. These authors concluded that Kenyan students, to some extent, contribute to their own failure in chemistry due to negative attitudes and a lack of interest.

Teachers factors, such as the teaching strategies adopted, are said to be a significant determinant of student attitudes (Osborne, Simon, & Collins, 2003). Other factors may include: previous

experiences, motivations, classroom activities, and laboratory activities (Ejidike & Oyelana, 2015). Evidence found in many studies (e.g., Chepkorir, et al., 2014: Nui & Wahome, 2006) demonstrate that it is the quality of teaching that most significantly determines students' attitudes towards science. Teachers' attitudes and beliefs towards science have proved to be a critical stimulus for their choices about forms of instruction and adoption of curriculum materials; both of which ultimately influence student achievement (Barnea, 2007; Chen & Wei, 2015). Some teachers have no passion for teaching chemistry because they consider teaching as a "waiting ground for better job". Such attitudes, according to Edomwonyi-Out and Abraham (2011), are reflected in ineffective teaching methods that adversely affect students' performance in chemistry.

In Kenya, teachers are sometimes reluctant to conduct science experiments that they deem to be dangerous, or in instances where an experiment has failed in the past (Nui & Wahome, 2006). Further, poor remuneration and poor staff welfare contribute to teachers' low morale and negative attitudes towards teaching and learning. Students' lack of ability further discourages and challenges teachers in effective implementation of the chemistry curriculum (Mobegi, Ondigi, & Oburu, 2010). Science curricula could contribute to students' difficulties in understanding some scientific concepts that they perceive as difficult. Ali (2012) for example, found the biggest challenge faced by teachers of chemistry in Pakistan was that the majority of high school students lacked basic scientific concepts.

The most common criticism of the science curricula in some countries is that its writers do not take into account students' cognitive abilities. This leads to a mismatch between the curriculum content at various grade/form levels, and the actual cognitive ability of these students to construct and acquire knowledge (Ali, 2012). This situation is possibly exacerbated by a lack of teacher involvement in the development of curriculum content (Chen, & Wei, 2015).

Large class sizes have also discouraged teachers, where teachers have had to spend a lot of time controlling class behaviour, sparing little time for actual teaching. This situation ultimately discourages teachers and affects the quality of instruction and student performance (Chen & Wei, 2015; Edomwonyi-Out & Abraham, 2011). According to Edomwonyi-Out and Abraham (2011), time constraints also contribute to reasons for incomplete teaching of the chemistry syllabus, and minimal or no science practicals being conducted in chemistry lessons. Time constrains are due to crowded syllabus content, the number of lessons allocated per week for

chemistry, and scientific inquiry strategies followed in teaching and learning. (Chen & Wei, 2015).

2.6.2 Teaching and learning resources and professionalism

Chemistry is a practical subject that requires both practical and demonstration activities (Edomwonyi-Out & Abraham, 2011). Students are required to conduct scientific investigations in order to fully understand scientific concepts (Ituma et al., 2015). This is because students learn better when they are involved in practical experiences than from what is taught in transmissive ways by the teacher (Ituma et al.) Therefore, to achieve such an objective, secondary schools need operational chemistry laboratories (Ejidike & Oyelana, 2015).

A lack of, or limited laboratory facilities in Kenya have a negative impact on students' performance in chemistry. Inadequate staffing is also cited as one of the causes of consistently poor performance in science subjects in Kenya (Nui & Wahome, 2006). Supporting these assertions, Mobegi, Ondigi, and Oburu (2010) purport that the frequent use of teacher-centred approaches in many Kenyan secondary schools is due to inadequate teaching and learning resources, poor student ability, and a lack of frequent training on "methodology" (instruction). Few or no interactive forums for science and mathematics teachers was also cited by Nui and Wahome (2006) as one of the factors contributing to poor students' performance in these subjects in Kenya. Nui and Wahome suggest that introducing in-service training for teachers, could help to mitigate the problem.

The quality of teaching and learning of chemistry in many countries is affected by an insufficient number of qualified teachers and other supporting staff (e.g., Ali, 2012; Edomwonyi-Out & Abraham, 2011; Sifuna, 2010). Teacher-centred methods that limit student participation and encourage rote memorization are common in teachers' classrooms in these countries and some teachers have inadequate content knowledge (Ali, 2012). Although it is often assumed that qualified teachers are quality teachers (Rice, 2010), Kodero, Misigo, Owino, and Simiyu (2011) identified numerous ineffective teaching characteristics among trained teachers in Kenya. These authors and others (e.g., Sifuna & Kaime, 2007) recommend that practising teachers frequently attend in-service professional learning and encourage the Kenyan government to consider improving current professional learning programs such as SMASE (Gathumbi, Mungai, & Hintze, 2013).

2.7 Chapter conclusion

This chapter has provided an overview of literature regarding teacher learning individually and in collaboration with colleagues through reflective practice. The subject focus of the study is chemistry, thus, teaching and learning challenges encountered by teachers of science and chemistry specifically, were also reviewed. Three major issues emerged from this review:

a) The current state of chemistry (science) education and teachers' classroom practices is of relatively poor quality;
b) Ongoing and collaborative teacher professional learning, through reflection on teachers' personal teaching contexts and experiences, is important in any attempt to improve quality teaching; and
c) *Contextual problems*, considered as those problems unique to teaching and learning of chemistry *in a particular context*, such as inadequate books and laboratories, have an impact on what is possible for improving the quality of teaching and learning in science.

Chemistry is a conceptual subject, making it abstract and thus students often perceive it to be difficult to learn. This often leads to the development of negative attitudes and low interest towards the subject. The development of secondary school students' understanding and appreciation of chemistry (science) begins with the teacher, and in particular, their teaching methods. So, the teacher must have a comprehensive scientific knowledge, and sound understanding of how to teach students using student-centred approaches. These approaches can help students to think about scientific concepts based on inquiry, sharing ideas, and explanation based on evidence. However, in contrast to what research says and policy asks for, teaching in chemistry is largely dominated by teacher-centred approaches, and an over-reliance on textbooks, thus limiting students' development of scientific skills and knowledge.

Ongoing and collaborative professional learning embedded in teachers' daily classroom activities offers science teachers a platform to improve their professional knowledge and student achievement. Such an approach to professional learning involves teachers in sharing their teaching experiences, and engaging with one another to improve their professional knowledge (e.g., subject matter, instructional strategies, and how students learn). Learning embedded in teacher's daily activities, in which teachers are responsible for their learning, can be a life-long process. However, research investigating teachers' learning from everyday activities is limited.

Context-specific learning is important, as not all findings from research on teacher learning are applicable across all contexts and settings. Various contextual factors influence effective teaching and learning of secondary school chemistry. The literature reviewed cites the need for operational laboratories if students are expected to develop scientific skills and if teachers are to employ inquiry approaches in teaching. Adequate time is also required to carry out practical activities and demonstrations. The review further cited that there is a need to consider students' abilities when designing subject curriculum, and that teachers need to be involved in the development of curriculum. Other factors, such as students' and teachers' attitudes, contribute to effective learning and subsequently, students' performance in Chemistry.

The current study is an attempt to provide chemistry teachers with a model of professional learning that draws on their individual and collective teaching experiences using individual and collaborative reflective practice. As noted in this literature review, the use of teachers' classroom experiences as a source of professional knowledge can be life-long. Teachers can therefore use this knowledge, which they continuously acquire from practice, to improve their teaching methods and become more innovative in solving some of the contextual problems associated with teaching and learning of chemistry in Kenya. Improved teaching methods can encourage students to learn chemistry and improve their performance. In Chapter Three, the research design and methodology adopted in this study to explore teacher trainer participants' professional learning from reflection on their individual and collective teaching experiences are presented.

CHAPTER THREE
RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

Literature discussed in Chapter Two suggests that long-life learning for teachers is necessary due to changes and demands in the education sector. This chapter discusses the research design and methodology adopted to explore Kenyan teacher trainers' learning from reflection on their teaching experiences. The focus is on teachers' experiences of teaching from their teaching, which gives them an opportunity to be responsible for their own learning, individually, and in collaboration with other teachers. Each component of the methodology and reasons for the selection of participants, data collection methods, and analysis are discussed.

In Section 3.2, the research design is presented, with a time-line indicating when the different stages of the study occurred. The researcher adopted an interpretivist approach to research, and a constructivist view of learning. Section 3.3 demonstrates the reasons for this interpretivist approach and outlines the ways in which the basic instructional principles of a constructivist view of learning, central to cognitive and social perspectives, were used to provide participants with opportunities to be actively involved in their own learning. In Section 3.4, the researcher demonstrates the reasons for a qualitative case study approach to be adopted for the inquiry into the teacher trainers' teaching and learning experiences. Four experienced Kenyan County Chemistry teacher trainers were involved in the study. How they were selected is outlined in Section 3.5. Following this, in Section 3.6, there is a discussion of the choice of methods used in data collection, including the instruments, and data collected.

In Section 3.7, details of an orientation workshop that was conducted to induct participants into the study are outlined. Section 3.8 details the data analysis process, including the steps followed to identify theoretical initial themes and categories (codes) from literature and research questions, and the development of a coding scheme for data analysis. The processes of testing the coding scheme applicability and reliability, in which a sub-set of data were coded, are also presented. In the same section, steps followed to code and organise data, using the refined coding scheme, after testing its applicability and reliability into meaningful chunks, using Microsoft Excel, are outlined. Ethical issues are considered in Section 3.9 highlighting how research participants' rights and privacy were ensured during data collection and analysis.

Strategies employed to ensure trustworthiness in data collection and analysis are discussed. Finally, in Section 3.10, the main points developed in the chapter are summarised.

3.2 Research design

The aim of this study was to explore *how* and *what* Kenyan Chemistry County teacher trainers learn from their teaching experiences when they engage in individual and collaborative reflection on their teaching. The study seeks to answer the following overarching research question: *How and what do Kenyan County chemistry teacher trainers learn from participating in a study in which they reflect on their secondary school teaching experiences?*

To help articulate the response to this question, five sub-questions were investigated:

1. How do Kenyan County chemistry teacher trainers address pedagogical critical incidents arising from their lessons through reflection?
2. How does reflecting on pedagogical critical incidents facilitate Kenyan County chemistry teacher trainers' learning?
3. What are the common contextual problems Kenyan County chemistry teacher trainers face that prevent them from pursuing their pedagogical goals in their chemistry classrooms?
4. How do the Kenyan County chemistry teacher trainers say they intend to operationalize their reflection experience to improve teaching and learning in secondary school chemistry in the Kenyan context?
5. How do the Kenyan County chemistry teacher trainers say they intend to operationalize their learning from reflection in their roles as County chemistry teacher trainers?

To answer these questions, a research design involving three stages was employed, focusing on teaching experiences, knowledge development, and learning. At stage one, individual teacher trainers reflected individually on their practice after their usual scheduled teaching lessons. At stage two, learning experiences were examined through group reflection discussions on their practices with other participants in the study. At stage three, learning experiences were further examined through teacher trainers' individual interviews. Although formal activities such as structured group reflection discussions and interviews were organised by the researcher, the focus of the study was on how practising teachers learn *informally* from their teaching experiences through individual and group reflection. Teacher trainers were therefore assumed to learn through engagement in their day-to-day teaching and learning activities rather than

from a selection of professional development activities such as implementation of a new innovation in the context of an education reform (Hoekstra et al., 2009; Little, 2002). The group discussions and interviews enabled the researcher to gain more insights from the teacher trainers' classroom accounts, thus, facilitating deeper analysis of their professional learning experiences based on their teaching practices.

To assist teacher trainers in constructing knowledge for learning from their teaching experiences, and to assist their sharing of these learning experiences, a critical incident reflection approach was adopted. Using a critical incident questionnaire provided by the researcher, participants provided written descriptions of self-selected critical incidents from their classroom teaching and documented issues in terms of their meaning and what they learnt from them. Following self-reflection, participants shared their learning from their reflections in group reflection discussions, which were audio recorded. A group reflection discussion guide was provided by the researcher to aid participants' discussion of their written classroom accounts to the group. The group reflection discussions were designed to give the teacher trainers opportunities to explore their own and others' critical incidents more openly and deeply, reaching beyond their own interpretation of the issues and ideas for improvement.

The researcher took a participant role in the group reflection discussions. The researcher often used questions and her own experiences as a former chemistry teacher and as a current national chemistry trainer, to prompt and direct participants' attention to the aim and purpose of the study. The researcher also occasionally provided chemistry content and pedagogical knowledge when needed. In accordance with current practice in Kenya, it was assumed that teacher trainers would be more likely to discuss the managerial problems they faced in the classroom rather than pedagogical incidents. Thus, two additional national chemistry teacher trainers, neither of whom were classroom teachers, were also present to provide group moderation and to monitor the audio recording.

The following sequence of activities describes the timing of self-reflection and group reflection discussions that were conducted over the period of August 2015 to April 2016.

1. The study commenced with an orientation workshop to induct participants into the study. In the workshop, County teacher trainers agreed to meet monthly, during weekends, in one of the participant's schools. The County teacher trainers could not meet during weekdays

because there is no provision in the Kenyan education system for replacement of teachers. Also, being County teacher trainers, the participants could not engage in the study during school holidays as that is when they plan and conduct in-service training for other chemistry teachers.

2. In the periods between the monthly group meetings, participants documented self-reflections on selected incidents or situations from their weekly chemistry lessons from which they thought they could learn. Such incidents or situations in this study were referred to as critical incidents. Teacher trainers were asked to reflect on their actions, and those of their students, when such incidents occurred. They were requested to write what they thought they learnt from these reflections. The approach is considered appropriate in that it focuses on what teachers themselves found relevant for their learning (Henze, van Driel, & Verloop, 2009).
3. From the critical incidents identified across a one-month period, each participant selected and presented one during the monthly group reflection meeting. Individual participants described what happened in their classrooms and the other members offered comments that included alternative methods of addressing the "problem". Meetings were held monthly on weekends between September 2015 and March 2016. In November 2015, the group met twice to help compensate for time lost after a late commencement in the study period due to a delay in ethics clearance in Kenya. In the month of December, the group could not meet at all due to school holidays in Kenya. The February 2016 group meeting was also cancelled due to the researcher being unwell. Overall, the group met six times in the data collection period. The four teacher trainers also participated in individual interviews in the month of April 2016. Figure 4 provides an overview of these activities for the research period.

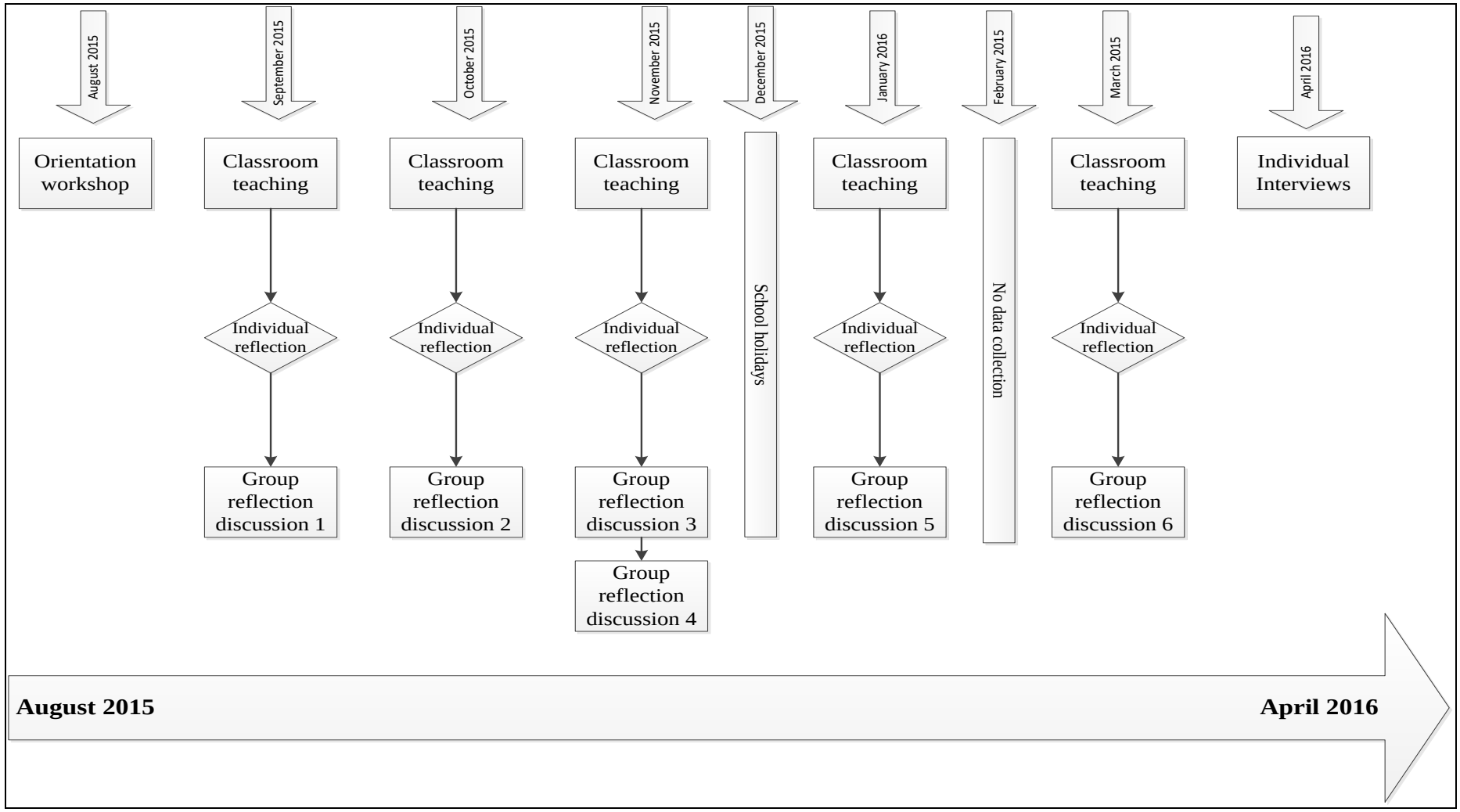


Figure 4. Sequence of activities conducted during the study

3.3 Philosophical orientation and theoretical perspective

This study is primarily concerned with chemistry teacher trainers' experiences of learning from their teaching in collaboration with other teacher trainer participants. It explores *how* the teacher trainer participants negotiated, constructed meanings, and made sense of their teaching experiences. These factors represent key elements of an interpretivist paradigm approach to research, which emphasizes understanding individuals and their interpretation of the world around them (Guba & Lincoln, 1985). Thus, this paradigm was adopted in this study to inform the research process. A paradigm, according to Lincoln and Guba (1985), comprises four elements, namely, epistemology, ontology, methodology and axiology. Interpretivist paradigm is oriented to a subjective epistemology, a realistic ontology, qualitative methodologies, and a balanced axiology (Kivunja & Kuyini, 2017; Lincoln & Guba,1985).

Ontology is concerned with the assumptions a researcher makes about the nature of reality or knowledge. Epistemology is concerned with evaluation the researcher makes about information that counts as acceptable and how it is acquired and interpreted (Denzin &Lincoln, 2005). The relativist ontology within an interpretivist paradigm approach assumes that multiple, but equally valid accounts of realities exist when individuals interact with the world around them (Stake, 1995, 2006). The assumption of a subjective epistemology is that knowledge is constructed rather than discovered (Lincoln & Guba, 1985). The knowledge constructed and evaluated is subjective because human beings construct their own meanings of the world in different ways; reality is our own making (Furlong, 2013; Guba, Lincoln, & Lynham, 2011). The role of the researcher is to study the multiple realities people construct based on their experiences and the implications of these constructions for their lives (Patton, 2002). The researcher interprets the meaning participants are making of context using their own thinking of data, informed by their interactions with participants (Kivunja & Kuyini, 2017). In this view, knowledge is mainly constructed by mutual negotiation and is context specific (Crotty, 1998; O'Donoghue, 2006), thus, social interactions are also the basis of constructing knowledge.

In this study, multiple realities and construction of knowledge were considered in terms of the implications for the participants as classroom teachers and County teacher trainers. Through interaction with participants and the research data, the researcher was trying to understand how the teacher trainers understood and *constructed knowledge* from reflection on their teaching experiences, individually, and in collaboration with other participants.

There are varied theoretical views on how knowledge is constructed, such as constructivism and constructionism (Crotty, 1988; Piaget, 1990). Although the two terms are often used interchangeably, they do actually differ at an epistemological level. In constructionism, the emphasis is on knowledge being constructed from a person's interaction with their world in a social context (Crotty 1988). The social context is at the centre of meaning making, and the knowledge is collectively constructed. In constructivism, knowledge is constructed through experiences, reflection on one's own ideas, and interactions among learners (Vavrus, Bartlett, & Salema, 2013). The individual is at the centre of meaning making and constructs his/her knowledge individually within the social context. Further, according to Crotty, in constructivism, each individual's way of making sense is unique, valid, and therefore worthy of respect and consideration. A constructivist view of learning was adopted in this study to provide a lens through which the teacher trainers' learning was explored. This is because, even though teacher trainer participants shared their critical incidents and reflected together, they still constructed their own personal meanings of what occurred in their classrooms and what they might change to address concerns/improvements in future.

Within constructivism, there are also varied views of learning depending on whether knowledge for learning is constructed through individual cognition or social co-construction processes (Patton, 2002). Many scholars in education encourage a synthesis of cognitive and social perspectives (e.g., Gilboy, Heinerich, & Pazzaglia, 2015; Kwan & Wong, 2014; Le Cornu & Peters, 2009). Hartle, Baviskar and Smith (2012) argue that social interaction can enhance cognitive constructivism. For the purpose of this study, the four basic instructional principles proposed by Kwan and Wong (2014) as central to constructivist learning through both cognitive and social perspectives, were adopted. These are: (1) learners are active participants in the learning process; (2) social interaction is necessary for better learning; (3) learners make sense of new information in terms of what they may already know; and (4) learners regulate their learning. Central to this view of learning is an assumption that teacher trainers can learn by constructing subjective meaning both from their teaching experiences: a *cognitive perspective;* and through interacting with their colleagues: a *social perspective* (Creswell, 2013; Patton & McMahon, 2014; Stake, 1995). Through both individual cognition and social co-construction processes, the researcher also anticipated that she would gain a deeper understanding of teacher trainers' learning experiences. The four basic instructional principles central to constructivist

learning are described below in the context of ontological, epistemological and methodological perspectives of this study.

3.3.1 Active participation in the learning process

Teachers can actively learn from their daily classroom activities (Little, 2002). To facilitate this kind of learning and understanding for adult learners, one has to provide an environment in which participants can actively construct their own knowledge based on their experiences. This could occur through interaction with other people, or individually during the activities they perform in their daily lives (Stein, 1998). For this reason, the researcher engaged participants in reflection activities to promote critical thinking (Vavrus, Bartlett, & Salema, 2013). Participants were asked to identify, describe, reflect and write on critical/puzzling incidents in their chemistry lessons from which they thought they could learn. Schön (1983) argues that when an individual is engaged in solving a puzzling situation, new knowledge is likely to be constructed and an individual's existing knowledge frameworks are likely to be altered. As such, this was the expectation for the participants of this study. Participants, who were chemistry classroom teachers as well as chemistry County teacher trainers, needed to understand that their students have to do something in order to learn; that learning does not occur just by receiving information delivered by teachers, but rather through active involvement. In other words, knowledge is constructed rather than discovered (Stake, 1995, 2006). Multiple, but equally valid accounts of realities exist when individuals interact with the world around them. This is because human beings construct their own meanings of the world in different ways (Guba, Lincoln, & Lynham, 2011). The role of the researcher is to study the multiple realities that people construct, and the implications of these constructions for their lives (Patton, 2002). In this study, such realities and construction of knowledge were considered in terms of the implications for the participants as classroom teachers and County teacher trainers.

3.3.2 Social interaction for better learning

Although people construct varied interpretations of the world around them, when they share and speak to each other, they may develop a common understanding of the world. Such common understandings held by large numbers of respected people, according to Stake (1995), are considered credible and even factual. In group reflection discussions, for example, teachers can present varied methods of teaching for the same topic depending on their understanding of the content and the perceived needs of their students. To facilitate social interaction in this study, participants were engaged in group reflections, where they discussed their individual

written incidents from their classroom teaching. As noted by Tobin, Briscoe, and Holman (1990), in social collaboration individuals speak about what they know about the phenomenon under investigation; they also compare their understandings of the phenomenon with those of others and negotiate a common understanding. The researcher anticipated that when participants shared their varied interpretations of their teaching experiences, they could develop a common understanding of teaching and learning of chemistry. This common understanding among science teachers, according to Loughran, Berry, and Mulhal (2012), is central to the learning and development of a sophisticated knowledge of practice.

3.3.3 Prior knowledge for better learning

The importance of prior knowledge is also recognized in a constructivist view of learning. Warford (2011) argues that it is not easy to promote the learning of teachers without awakening their previous knowledge and experiences during the learning process. It is not possible to construct new knowledge without referring to, and making connections with previous knowledge. Therefore, participants needed to reflect on their prior knowledge to learn. Reflection, therefore, can be considered as a key activity in the learning process (Postholm, 2012). In this study, participants used critical incidents to reflect on their classroom experiences, drawing on prior knowledge to try to understand them.

To comprehend how participants learnt from their prior knowledge and experiences, the researcher needed to gain an understanding of those experiences. As noted by Larkin and Thompson (2011), this could be done through a process of meaning making from the participants' accounts of their experiences. Participants' accounts of experiences were presented through group reflection discussion, and in the interview process. Transcripts of group discussions and interviews provided a further avenue through which the researcher could analyse and interpret data in order to understand participants' teaching experiences and subsequent learning within their own contexts. Context, together with prior knowledge, is considered important in constructivist views of learning (Patton, 2002).

3.4 Research methodology

Methodology is concerned with the approach a researcher follows to make an inquiry. The purpose of this study was to explore *how* and *what* chemistry teacher trainers learnt from the meanings they constructed through reflection on their teaching experiences, and how this learning might improve their practice. The exploration was about understanding learning

experiences, which called for a qualitative design (Merriam, 2009). A qualitative case study approach was adopted to guide data collection and analysis. This is because a qualitative design seeks socially constructed meanings from people's experiences rather than numerical data associated with a quantitative approach (Yin, 2009; Yin & Davies, 2007). In a qualitative case study, quotations and themes in participants' own words and their varied perspectives are required as evidence to understand the phenomenon under investigation (Creswell, 2013; Hancock & Algozzine, 2015). These forms of research align with professional teacher learning, from their points of view, which is a focus in this study.

The study is a *qualitative collective case* study involving four Kenyan County chemistry teacher trainers. A Stakian viewpoint of case study approach was adopted as a means to explore teacher trainers' learning. According to Stake (1995, 2006), constructivism should be the epistemology that orients and informs qualitative case study research. Qualitative researchers conceive that knowledge is constructed rather than discovered. In this study, construction of knowledge is the basis of the research. Stake also contends that there are multiple views of a case under investigation. He argues that qualitative case study researchers should be gatherers of interpretations and report the constructed reality or knowledge gathered from these interpretations. His views are linked to the subjective epistemological and relativist ontological orientation of this study. Teacher trainers constructed meaning of their teaching experiences individually and together with other teacher trainer participants. The teacher trainers' varied interpretations were explored, interpreted and reported in this study.

This study utilised an instrumental collective case study design. In an instrumental case study, the researcher gains insights into a particular phenomenon (Stake, 1995, 2006). Within-case, the unit of analysis in this study was the activities a single teacher trainer undertook while teaching and his/her learning from these activities. In collective case study, data is treated as a collective, and analysed as a whole rather than in distinct and separate sets (Goddard, 2010). The group discussion reflections enabled this wholistic analysis, allowing comparisons to be made between individual teacher trainers' experiences and the ideas emerging as they were shared in discussions. Each Kenyan County chemistry teacher trainer's learning experiences studied *collectively* provided insights into how and what these teacher trainers learnt and contributes to our understanding of teachers' experiences of learning from teaching. In this way, "generalizations from the entire collection to understand the phenomenon deeply from a variety of perspectives" (Goddard, 2010, p. 165) were able to be made. Such insights and

generalizations could be used by other teachers and also by people interested in organizing teacher professional learning and development programs.

One of the strengths of using case study is its foundation in real-life situations and experiences and its potential to explore a complex phenomenon, such as learning to teach, from multiple perspectives (Avalos, 2011; Loughran et al., 2012). Multiple data collection methods were used to gather qualitative data about activities teacher trainers undertook in their classrooms and their subsequent learning experiences. These methods included group reflection discussions on individual critical incidents, and individual interviews. Participants wrote down and interpreted critical incidents from their teaching which they used as prompts during group discussions. These methods also gave the researcher an opportunity to explore other variables that emerged in the data, such as the contextual problems that participants perceived to be affecting teaching and learning of chemistry in their learning contexts.

3.5 Participants

There are 47 Counties in Kenya; each considered as an educational district. Each County in Kenya has at least four County chemistry teacher trainers. As noted earlier in Chapter One, chemistry teacher trainers are also classroom chemistry teachers. They teach Chemistry in their respective schools. They conduct in-service training for all other classroom teachers in their respective Counties during school holidays following their training by national trainers during half-term break. Some trainers also hold administrative positions in their schools such as: school principal, deputy principal, head of department or head of subject.

A single County was selected for this study, and its existing group of four Chemistry County teacher trainers were invited to participate. An existing group such as this, potentially provides a well-structured group learning environment in which peers question, evaluate and constructively critique each other's practice, which can lead to restructuring of knowledge and understanding (Lamb, Kabes, & Engstrom, 2011). To select the County and case participants, the following procedure was followed:

1. Identification of Counties with chemistry teacher trainers who had taught chemistry for a minimum of five years in the classroom as a fully qualified teacher after teacher preparation and trained teachers for a minimum of five years and was accessible by the researcher for travelling convenience. To identify the eligible Counties, data were accessed from the

Centre for Mathematics, Science and Technology in Africa (CEMASTEA), where the researcher is affiliated in her capacity as a National trainer (See affiliation letter, Appendix A).

2. Counties not more than four hours' drive, except Nairobi, were considered. Nairobi, the capital city of Kenya, is over-researched, so it was excluded. Of the the three Counties that met the criteria, the first one contacted agreed to participate and was therefore used.
3. The County Education Director of the selected County was contacted to give consent for the study to be conducted in the County. Consent was provided on the condition that the research was approved by the National Council for Science and Technology and that the County chemistry teacher trainers were willing to participate (See certificate to conduct research in Kenya, Appendix B).
4. County trainers were asked to participate through an invitation letter (Appendix C) sent via the County Education Director. Participation was voluntary and all four teacher trainers from the selected County accepted the invitation to participate.

The reason a minimum experience of five years was chosen as a criterion was to help ensure that participants were not working at the novice level. In Kenya, public school teachers' probation period is five years of teaching and therefore, teachers who have taught for more than five years are considered to be experienced. The inclusion of the participants based on length of teaching experience was to include participants who had sufficient experience with students. In most cases, experienced teachers' classrooms are stable, and teachers are more concerned with ensuring that students are learning rather than dealing with the class management issues that are often associated with novice teachers (Gatbonton, 2008; Martin, Yin, & Mayall, 2006). Experienced teachers are therefore expected to be more likely to select pedagogical critical incidents over other types of classroom incidents, which would better address the purpose of this study.

County chemistry teacher trainers were selected over classroom chemistry teachers based on the presumed willingness they would have to participate and the potential to impact chemistry teaching more broadly through the in-service training the teacher trainers would go on to deliver. According to current practice in Kenya, the assumption was that the trainers were likely to be willing to participate in professional development activities, as these could be seen as an additional opportunity to their usual training. Also, as teacher trainers, they were likely to share their experiences with other chemistry teachers during in-service education training (INSET),

thus potentially widening the scope of impact the study might have. Two participants were male and two were female. Table 2 shows participants' characteristics

Table 2

Participants' characteristics

Teacher	Teaching subjects	Responsibility	Years of experience	
			Classroom teacher	Teacher trainer
Dott	Chemistry Mathematics	Deputy principal/County teacher trainer's representative	22	17
Rett	Chemistry Biology	Deputy principal	18	15
Ritt	Chemistry Biology	Chemistry subject head	15	5
Kytt	Chemistry Mathematics	School principal	25	15

3.6 Data collection methods

Data were generated through two methods, designed specifically for the purpose of gathering information regarding teacher trainers' perceptions related to learning activities, learning outcomes, and challenges they encountered when teaching chemistry. These were: 1) group reflection discussions on individuals' selected critical incidents, and (2) semi-structured, individual interviews. Participants prepared their own written protocols as prompts for use in the group reflection discussion meetings. Group reflection discussions and interviews were audio recorded.

As noted in the study design, prior to the group reflection meeting, teacher trainers were asked to write self-reports in which they described and reflected on a critical incident that occurred in one of their weekly chemistry lessons. It was assumed that participants were likely to learn more from learning activities that they themselves considered relevant and important for their learning (Meirink et al., 2009). In order to support teacher trainers in recalling their teaching and learning experiences, they were provided with a *critical incident reflection questionnaire* (Figure 5) to guide their reflections and writing.

Critical incident reflection questionnaire

This study seeks to explore whether Kenyan County chemistry teacher trainers can learn and develop their pedagogical skills from participating in a study in which they reflect on their secondary school teaching experiences. The questions listed in this critical incident questionnaire will assist you to isolate one critical incident that stood out in your chemistry lessons during the week. You will use the questions to describe, analyse, and interpret the critical incident during weekly individual reflection.

1. Describe a critical incident/situation involving pedagogy/instruction that stood out from your chemistry lessons this week. (A critical incident/situation may be something that excited you or bothered you that made you rethink about your teaching.)
2. What action(s) did you or your student(s) take to address the incident/situation?
3. What actions would you take (if any) if faced with a similar incident(s) in future chemistry lessons?
4. In what ways do you think the actions taken in question 3, if any, would improve your lesson delivery in future?
5. In what ways do you think these actions discussed in question 4 would improve your training for chemistry teachers in your County?

Thank you for your cooperation

Figure 5. Critical incident reflection questionnaire

The purpose of using protocol writing was to provide participants with opportunities to reflect back on their classroom practices (Van Manen, 1990). Reflecting on a critical incident initiates a process of self-reflection, a practice encouraged by Hillier (2005), in which teachers pause and reflect on prior personal experiences. This could facilitate their learning by revealing the knowledge and skills in their everyday practice (Bruster, & Peterson, 2013; Tripp, 2012). The process of identifying, reflecting and writing down critical incidents is also said to create a situation where teachers struggle with meaning-making, and this could help them to develop and understand new content and pedagogical knowledge (Berry, 2007). This process actively involved the teacher trainers in their own learning process, a key concept in the cognitive constructivist view of learning. They documented classroom activities, their learning experiences, and their intentions to remedy identified difficulties. Although the teacher trainers had freedom in their choice of critical incidents, the questions in the critical incident reflection questionnaire guided them to focus their attention on teaching practices and student learning. An example of a completed critical incident reflection questionnaire is shown in Appendix D.

3.6.1 Group reflection discussions (GRD)

Group reflection discussion meetings took place monthly between September 2015 and March 2016, except in the month of December 2015 and February 2016 where there were no meetings, and in November when two meetings were scheduled (see Figure 1). A total of six meetings were held over the course of the research study. Each group reflection session took approximately two hours and was audio recorded. Participants used their individual written reflection accounts of their selected critical incidents as prompts for discussion during the group reflection meetings. They were each given 15 to 20 minutes to describe their critical incident before it was open for discussion. One participant's critical incident was presented and discussed before moving to the next participant's incident. Each participant presented one reflection each meeting. This provided individual teacher trainers an opportunity to state their classroom teaching related problems or dilemmas, and other participants to ask for clarification, probe, and to give feedback and opinions.

Group reflection discussions focused on the improvement of individual teacher trainer's practice and student learning experiences through sharing knowledge among the teacher trainers. Group discussions were used in this way due to their likelihood to stimulate dialogue and debate among participants and thus elicit a rich range of views and perspectives (Gray, 2013). They served as vehicles through which participants shared and deliberated their classroom experiences. Discussions also promoted social negotiation of meanings, a key element in a social constructivist view of learning. Group reflection discussions also helped to generate rich data because sometimes, as Tomkins and Eatough (2010) say, "participants can be unware of what they think or feel or remember about an experience until a group discussion, with the stimulus of other people's sense-making efforts, bring[ing] these thoughts, feelings, and memories to light" (p. 248). In this way, group reflections acted as stimuli because they allow profound conversations where the ideas of others activated individual's own thinking and reasoning (Cox, Steegen, & De Cock, 2016). Group reflection sessions were guided by a group reflection discussion guide shown in Figure 6.

Group reflection discussion guide

The study seeks to explore whether Kenyan County chemistry teacher trainers can learn and develop their pedagogical skills from participating in a study in which they reflect on their secondary school teaching experience. The questions listed in this reflection guide will assist you to analyse and interpret one critical incident among the four weekly reflections in the last one month that stood out in your chemistry lessons. You will use the written account during the monthly group reflection meeting to present your experiences.

1. Describe the context of your critical incident; (a) level of the students; (b) topic; and (c) sub-topic.
2. Describe what happened and why.
3. What makes the incident you identified critical?
4. Discuss what you did and why. Was it effective or ineffective? Explain why?
5. Discuss what you would do if faced with a similar incident(s) in future chemistry lessons.
6. In what ways do you think these actions discussed in question 5 would improve your lesson delivery in future?
7. In what ways do you think these actions discussed in question 5 would improve your future training of secondary school teachers?

Thank you for your cooperation

Figure 6. Group reflection discussion guide

In total, 23 critical incidents were discussed in the group reflection meetings out of the expected 24. One of the participants was a school principal and did not present his critical incident on two occasions. On one occasion he had to leave early, before he presented his critical incident; and for another he was absent attending to administrative duties. In one of these absences (meeting 6), one of the other participants presented two incidents for discussion. Audio files of group discussion reflections were transcribed and a section of one of these transcripts is shown in appendix E.

3.6.2 Interviews

Interviews are commonly used as a method of collecting data in phenomenological research (Plunkett, Leipert, & Ray, 2013; Smith et al, 2009). In this study the interview was semi-structured to enable the interviewer to probe and expand meaning once the participant answered the major questions (Stake, 1995). Personal stories of learning experiences told by the participants using their own words during the interview portrayed the multiple views of learning

from teaching experiences. This contributed to a deeper understanding of the phenomenon under investigation and its associated meaning by the researcher (Smith et al., 2009).

Stake (1995) describes interview as the main road to reviewing multiple realities. In this study, interviews gave the researcher an opportunity to listen to teacher trainers describing their varied, individual learning experiences. In this way, they also helped to keep individual participant's learning experiences firmly in sight. Participants also critiqued their teaching methods, giving varied reasons, during the interviews thus contributing to learning advocated by the principles of constructivism underpinning this study, that acknowledges the existance of multiple realities constructed by individuals.

Individual interviews were conducted at the end of the study in April 2016. All four teacher trainers participated in an interview that was approximately 20 minutes in duration. The interviews were conducted over a mobile phone and audio recorded using *Another Caller Recorder* (ACR) recording application. The decision to interview over the telephone rather than in person was made by the researcher in the field because of time constraints. As noted in the study design, the study did not commence as anticipated, and schools in Kenya were on holiday in the month of April, when the interviews were conducted. Therefore, it was not possible to meet the participants at the school, because they had travelled to their rural homes. Further, participants were involved in teacher trainer in-service training sessions that are held in school holidays at a location far from the school, making access to them in person difficult. The researcher also had a deadline in which to return to Australia in early May, placing a time restriction on when interviews could reasonably be scheduled. For these reasons, it was decided that a telephone interview should be conducted. Interviews were guided by the interview guide shown in Figure 7.

I (the researcher) conducted the first interview with one participant and the other three interviews were conducted by one of the moderators. I decided to use the National trainer, who moderated the group reflection discussions to conduct the other three interviews to minimize any conflict of interest and to assist in ensuring participants felt safe to speak freely. The interview duration (of approximately 20 minutes each) was shorter than initially anticipated. In hindsight, I realised that some of the questions in the interview guide asked participants to give one example and this possibly made them feel restricted in providing additional examples, thus

affecting the duration. Audio recordings of interviews were transcribed and one of these transcripts is shown in appendix F.

Interview guide

This study seeks to explore whether Kenyan Chemistry County teacher trainers can learn and develop their pedagogical skills from participating in a study in which they reflect on their secondary school teaching experience. Before we start this interview, I want to highlight a few important points: firstly, I want to assure you that even if you and I share many experiences, your experiences are unique because you operate in two communities at the same time (that of a trainer and that of a classroom teacher) which personally I have not experienced. Therefore, your participation is of high importance in this investigation and you are welcomed. Secondly, your voluntary participation in this interview will be greatly appreciated and I want to assure that your responses will be COMPLETELY CONFIDENTIAL and thirdly, this interview is scheduled to take not more than ONE HOUR but you are free to withdraw before completion if you desire.

1. Have you learnt any pedagogical lessons from individual reflection on your practice? (Prompt: If yes, give me an example of one of these lessons that changed your thinking. If no, why do you think you were not able to?)
2. How did you learn these pedagogical lessons? (Prompt: Was it from the students' responses or from your own reflection or from sharing with colleagues in a group reflection).
3. How would you describe the group discussion sessions? (Prompt: What did you learn from this kind of collaboration?)
4. How will you apply lessons learnt in your future classes? (Prompt: [If there were lessons learnt]. Give me an example of how you might use one in your future classes).
5. Will you apply lessons learnt from this study in your future training for chemistry teachers in your County (Prompt: If yes, how will you apply this? If no, why would you not be able?

Thank you for your cooperation

Figure 7. Interview guide protocol

3.7 Orientation workshop

An orientation workshop was conducted prior to the commencement of the data collection period, in August 2015. During this workshop, the researcher discussed with participants, using examples, how they should use the critical incident approach to reflect on their teaching. Figure 8 shows a written record of an example of a critical incident used by the researcher during the orientation workshop. Following the examples provided, participants were asked to think of an incident from their previous lessons in chemistry and to reflect, describe and analyse it using the following key questions:

i) Why did it happen?
ii) What did you do?
iii) What would you do if faced by a similar situation?

Next, they were asked to present their responses for discussion in the group. Four incidents were discussed for approximately four hours.

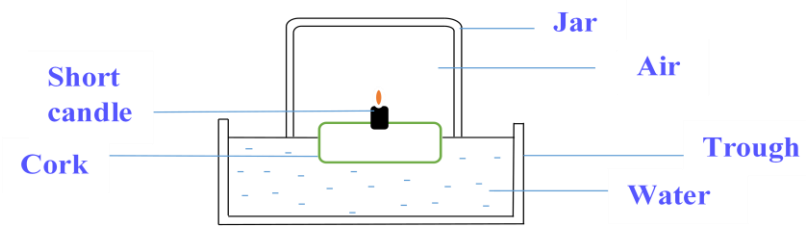
Following this activity, participants were introduced to the three instruments used for the collection of data that would take place in the study. Procedures for how they should use the critical incident reflection questionnaire to reflect on their normal teaching activities were outlined by the researcher. Participants were invited to comment and, as noted earlier, they agreed that they would meet on weekends at one of the participants' schools for the monthly group discussions. Various questions asked in the three instruments addressed several research sub-questions as shown in Table 3 (see research questions in Section 1.8)

Table 3
Research sub-questions and the source of data for each

Research sub-questions	Data source questionnaire		
	Critical incident reflection (prompts for group discussion)	Group reflection guide	Interview guide
1	1-3	2 – 4	2
2	3	5	1
3	3, 4	6	4
4	4	7	5
5	1-3	1 – 4	1, 3

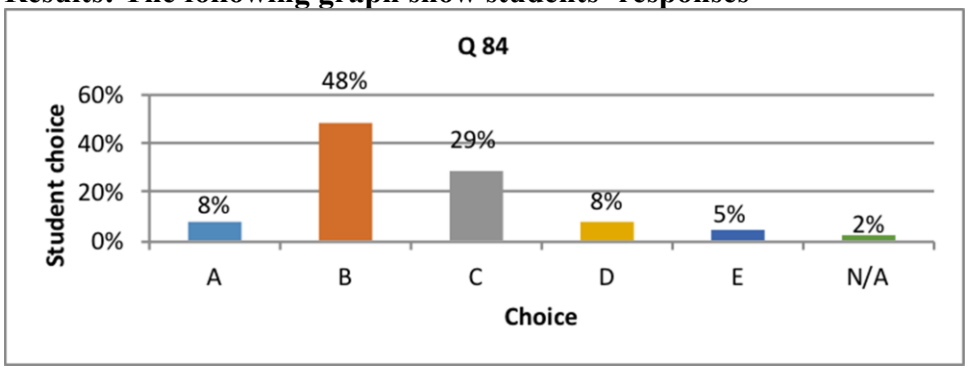
The question below was one out of the questions set to determine the impact of SMASE on student achievement in Chemistry. While piloting tools for this study, students' responses made Kenyan chemistry national trainers realise that the way the concept of oxygen supporting burning is demonstrated, using a burning candle, introduces a misconception to students.

Q84: Before revision: *When a candle is lit and covered with a bell–jar, as shown in the diagram below, it continues to burn for some time and then the flame goes [out]. Which one of the following explains clearly why the flame went [out]?*



A. *The air is used up*
B. *The oxygen is used up*
C. *The carbon (IV) Oxide produced extinguished it*
D. *The air inside the bell–jar contains moisture which extinguished it*
E. *The nitrogen in the air does not support burning*

Results: The following graph show students' responses



Although many students got the correct answer – B, a big proportion of students also gave C as the correct answer. Students thought that Carbon (IV) Oxide produced when a candle burns extinguished it because it does not support combustion. The reason why the burning candle flame went out is because all the oxygen enclosed in the bell-jar, that support burning, was used up by the burning candle. Following a discussion among chemistry national teacher trainers, it was suggested that when teachers perform this experiment, they should use sodium hydroxide (NaOH) instead of water. NaOH absorbs carbon (IV) Oxide produced making it clear to the students that the candle was extinguished as a result of absence of oxygen.

Figure 8. An example of a critical incident used by the researcher during induction workshop

Data collected, using instruments discussed in Section 3.6, included audio recordings from interviews and group reflection discussions, as shown in Table 4 To ensure that nothing was omitted during transcription of audio-recorded data, audio tapes were listened to whilst reading through completed group reflection and interview transcripts.

Table 4
Data collected from individual participants and group reflection

Name	**Critical incidents discussed**	**Interview**	**Duration in minutes of the interview**
Dott	7	1	16
Rett	6	1	21
Ritt	6	1	18
Kytt*	4	1	15

Note. *Kytt did not attend two group discussion sessions because of administrative duties.

3.8 Data analysis

Thematic analysis guided the qualitative data analysis for group reflection discussions and interviews (Boyatzis, 1998; Braun & Clarke, 2006, 2017). Similar to other methods of analysing qualitative data, thematic analysis method is used to identify, analyse, and interpret patterns of meaning (themes) within data. Braun and Clarke (2006) state that one of the benefits of thematic analysis is its flexibility. They argue that thematic analysis method can be used to report experiences, meanings and the reality of participants (essentialist or realist), or to examine ways in which experiences, events, and realities affect a range of discourses within a society (constructionist). In this study, thematic analysis was used to examine ways in which the teacher trainers learned from their teaching experiences.

In thematic analysis, themes can be identified in two ways: deductively (theoretically) or inductively (Boyatzis, 1998; Stuckey, 2015). In an inductive approach, themes identified are data driven rather than arising from the researcher's theoretical interest in the area being researched. In contrast, in deductive approach (theoretical), analysis is driven by the researcher's interest in the area being researched. In the current study, the researcher was interested in *how* and *what* teacher trainers learn from their teaching experiences (essentialist or realist), a quite specific research question (Braun & Clarke, 2006). Thus, a theoretical approach was adapted to identify themes from the research data.

Although there is a belief that inductive approach tends to provide rich description of data, this approach was not considered in this study. The researcher supports Braun and Clarke's (2006) argument that researchers cannot completely free themselves of their theoretical and epistemological comments, and that data cannot be coded in an epistemological vacuum. Also, according to Braun and Clarke, a theoretical approach enhances analysis by sensitizing the researcher to subtler features of the data. However, Braun and Clarke also acknowledge that this approach has been criticized (e.g., Boyatzis, 1998), in that it can narrow a researcher's analytic field of vision, leading to a limited focus on only some aspects of the data at the expense of other potentially crucial aspects.

Theoretical coding was undertaken initially by selection of *a priori* codes in the literature based on the researcher's theoretical sensitivity (Glaser, 1998) as a former chemistry teacher and national trainer. To guard against narrowing the field of analysis, coding in this study was kept open to the possibility that teacher trainers' comments might elicit the need for adding, removing, and/or modifying the initial theoretical codes. The process of data analysis and development and refinement of a coding scheme followed these steps:

a) Identification of focus areas from the research questions in which "initial themes" were developed. Three areas were identified (*potential professional learning activities, potential professional learning outcomes and contextual problems).* (section 3.8.1).
b) Identification of categories and sub-categories from related literature with indicators for the three focus areas (sections 3.8.1.1, 3.8.1.2, 3.8.1.3).
c) Development of theoretical coding scheme by constructing anchor items for the theoretical codes (sections 3.8.1.1, 3.8.1.2, 3.8.1.3)..
d) Development of theoretical coding scheme by identifying categories and sub-categories from related literature for the three focus areas (theoretical codes) and constructing anchor items for the theoretical codes (sections 3.8.1.1, 3.8.1.2 and 3.8.1.3).
e) Testing applicability of the theoretical coding scheme on a sub-set of transcripts to refine the theoretical codes; adoption of any emerging codes and production of a coding book with anchor items (refining the coding scheme) (3.8.2)
f) Testing reliability of the theoretical coding scheme on different sub-sets of transcripts (intra-rating), to ensure consistency of use of the coding scheme by the researcher (refining the coding scheme) (3.8.3).
g) Coding of all data using the refined coding scheme (3.8.4).

h) Clustering of coded units with similar meaning to search for themes.

i) Identification of emerging themes.

3.8.1 Identification of focus areas

Important features reflected in the research questions of this study were *how* teachers learn, *what* they learn and common *contextual problems* the teacher trainers face while teaching Chemistry in the Kenyan context. As noted by Henze et al. (2009), teacher learning from teaching experiences takes place as a result of participation in everyday activities in the workplace context. This learning is not only individual but can also be social in nature (Henze et al., 2009). *How* teachers learned was conceived of as the *learning activities* teachers undertook while teaching in class and out of class, with or without other teachers, which, in their own perception, resulted in the development of their professional knowledge and skills. *What* teachers learned was conceived of as the *learning outcomes* that resulted from undertaking the learning activities. As noted by Kwakman (2003), "teachers' learning is strongly connected to professional goals which demand teachers to strive for continuous improvement of their teaching practices. From this principle, teacher learning is rather referred to as professional learning" (p. 152). Following Kwakman's description of teacher learning, learning activities and outcomes were referred to as *professional learning activities* and *professional learning outcomes.*

Group reflection discussions, and interviews were used to collect data and therefore, the researcher had access only to "reported" professional learning activities and outcomes. Professional learning activities and learning outcomes were, therefore, treated as *"potential professional learning activities"* and *"potential professional learning outcomes"* because actual actions and outcomes could not be confirmed through direct observation. They were considered as preliminary focus areas or "initial shared themes" (Smith et al., 1999). The critical incident analysis adopted to facilitate self-reflection could not confirm actual actions, and outcomes. A critical incident, according to Farrell (2013), is an "unplanned and unanticipated event that occurs during class" (p. 81) that teachers can learn from through reflection and analysis. Therefore, it was not possible for the researcher to plan for learning activities, because it was only the teacher trainers themselves who could identify incidents from their classrooms that they found relevant for their learning (Henze et al., 2009). Focusing on learning activities that a teacher has concern for were considered. This is because, according to Hoekstra et al. (2007), they increase chances of finding examples of teacher learning outcomes than activities

that a teacher has no concern for. Further, they also suggest teachers' desired areas of focus for changed practice.

Research has shown that to a large extent, activities teachers undertake in class for effective teaching and learning of chemistry are influenced by contextual factors such as availability of learning resources (Ejidike & Oyelena, 2015; Ituoma, Twoli, & Khatete, 2015; Lohman & Woolf, 2001). As such, the third focus area (initial shared theme) identified in relation to the third research sub-question addressed *contextual problems* perceived by the teacher trainer participants specific to chemistry teaching in Kenya.

To facilitate deeper analysis, each focus area identified above, was further assigned categories and sub-categories. They were identified from literature relevant to this research and the research questions (Parkinson, Eatough, Holmes, Stapley, & Midgley, 2016). From this process, theoretical codes were formed. (Braun & Clarke, 2006; Stuckey, 2015).

3.8.1.1 Categories of potential professional learning activities from the literature

Six studies in the literature exploring experienced teacher learning in the work place based on teachers' reported learning activities were examined (Bakkenes, et al, 2012; Hoekstra et al., 2007; Kwakman, 2003; Loman & Woolf, 2001; Meirink, Meijer, Verloop, & Bergen, 2007; Van Eekelen, Boshuizen, & Vermunt, 2005). The present study is exploratory in nature, and thus hypotheses cannot be drawn, however, it was anticipated that some of the learning activities found in previous research on teacher learning from the work place might also be identified in the current study. The six studies examined presented several categorizations of learning activities as shown in Table 5.

Some of the eighteen categories of professional learning activities from the six studies examined were not considered appropriate for this study, as some of them focused on a specific education innovation (e.g., *struggling not to revert to old ways* in Bakkenes et al., 2010). Bakkenes et al. studied teacher learning in the context of educational innovation regarding active and self-regulated active student learning and process-oriented teaching. Teachers, who tried to change their teaching methods but continued to use old methods in this study, were considered to be *"struggling not to revert to old ways".* Some teachers were also found to engage in activities that enabled them to avoid learning about new educational innovations, and the researchers agreed that such teachers were*" avoiding learning"*. These two categories were

excluded in the theoretical coding scheme for this study as there were no data to suggest that they were relevant.

Table 5
Categories of potential teacher professional learning activities

Potential professional learning activities	Studies					
	Lohman & Woolf (2001)	Kwakman[a] (2003)	Van Eekelen et al. (2005)	Meirink et al. (2007)	Hoekstra et al.(2007)	Bakkenes et al.(2010)
Experimenting[a]	x	x[a]		x	x	x
Learning by doing[a]		x[a]	x			
Reflecting		x		x		
Considering own practice						x
Learning by thinking			x			
Orienting					x	
Experiencing friction						x
Collaborating		x				
Getting ideas from others						x
Knowledge exchanging	x					
Learning in an informal, unplanned interaction with colleague			x			
Learning in formal/planned meeting with colleagues/external expert			x			
Seeking explicit student feedback					x	
Learning in interaction with students			x			
Learning from others without interaction				x		
Learning from others in interaction			x	x		
Reading		x	x			
Environmental scanning	x					
Struggling not to revert to old ways[b]						x
Avoiding learning[b]						x

Note: x - Indicates a learning activity reported in corresponding study.
[a]Kwakman (2003) combined the categories of doing and experimenting
[b]Excluded from theoretical coding scheme as deemed irrelevant

Six general categories of potential learning activities were formed from the remaining sixteen categories identified. These six categories emerged after combining some of the identified categories except for *'experiencing friction'* for reasons explained below. These are: experimenting, reflecting, experiencing friction, learning from others in interaction, learning from interacting with students, and environmental scanning. The coloured wording shows how the categories are combined to produce the potential professional learning activities in Table 6.

Experimenting, for example, was a learning activity identified by researchers across all the studies except Van Eekelen et al. (2005). However, Kwakman (2003) did not consider "experimenting" and "doing" as separate activities. She argued that teachers were likely to learn more by "experimenting" in that experimenting is a deliberate effort by teachers to try something new in the classroom, unlike "doing", which she claims is a part of teachers' routine work. Meirink et al. (2007) separated the categories of experimenting and doing because they thought "doing, in contrast to experimenting, often does not imply an intention to learn" (p. 149). I did not believe the "doing" category was relevant for coding data generated in the present study, thus, following the researchers of five of the six other studies examined; only "experimenting" was adopted.

Four learning activities: reflecting, considering own practice, learning by thinking and orienting, were combined and termed *reflecting* in the present study. Bakkenes et al. (2010) used the "*considering own practice"* learning activity to refer to teachers reflecting on their own practice and/or student learning. According to Van Eekelen et al. (2005), "*learning by thinking"* takes place when a teacher takes time to reflect and think about school matters" (p. 457). *Orienting* is a term used by Hoekstra et al. (2007) to refer to an activity involving forethought by teachers on how to proceed with teaching. According to Bakkenes et al. (2010) and Van Eekelen et al. (2005), teachers can learn by reflecting on practice, something also inferred from Hoekstra et al.'s (2007) description of orienting as forethought. Thus, based on these considerations, "*reflecting*", as used by Kwakman (2003) and Meirink et al. (2007), was adopted for this study to represent these four learning activities.

Learning from others in interaction, identified in the study of Meirink et al. (2007), was adopted in the present study after combining five categories from other studies: learning in an informal, unplanned interaction with a colleague; learning by participating in formal/planned meeting with several colleagues or an external expert; collaborating; knowledge exchanging; and getting

ideas from others. To define this activity, Meirink et al. (2007) used activities such as talking, discussing, and brainstorming with others, characterizing it by the presence of interaction between people. Additional activities identified by the other researchers that suggest the notion of *"learning from others in interaction*" include: collaborating (storytelling, talking, asking for help, sharing materials and ideas about innovations and instructional issues (Kwakman, 2003); Learning in an informal, unplanned interaction with a colleague (asking colleagues for opinions or explanations, and "having a chat") and learning in formal/ planned meeting with colleagues /external expert (Van Eekelen et al., 2005); knowledge exchanging (talking, observing, and sharing resources with others) (Lohman & Woolf, 2001), and getting ideas from others (e.g., discussing student behaviour with a colleague) (Bakkenes et al., 2010).

Learning in interacting with students (Van Eekelen et al., 2005) was adopted as a category, after combining it with other activities found in the studies examined that suggest that teachers can learn through interaction with their students. Such activities include seeking explicit student feedback about teaching (Hoekstra et al., 2007), and knowledge exchanging (Lohman & Woolf, 2001) where teachers gain ideas from students through conversations, asking questions or from their written work and behaviour.

The activities of reading, environmental scanning, learning from others without interaction, and getting ideas from others, were all combined and termed *"environmental scanning",* the category identified in the study of Lohman and Woolf (2001). Lohman and Woolf used the term "environmental scanning" when teachers reported that they browsed the internet, scanned journals and read educational publications in everyday activities. Meirink et al. (2007) described the category of "learning without interaction" as observation, listening, and reading articles. These descriptors are all in line with Lohman and Woolf's description of "environmental scanning". Also reflected in this description, were Kwakman's (2003) "reading"' (including studying content matter literature teaching manuals, and reading journals and newspapers), and Bakkenes et al.'s (2010) "getting ideas from others" by individually reading a book, attending a lecture, or by observing a colleague doing something. A theoretical coding scheme for potential professional learning activities was developed on the basis of the categories described above which were informed by the six studies examined. Table 6 shows the six themes that emerged from the literature with indicators of potential learning activities.

Table 6
Potential professional learning activities with indicators related to pedagogical practice

Potential professional learning activities	Indicators of the professional learning activity
Reflecting	Considering/thinking about own teaching practices and students' learning, individually or in collaboration; forethought on how to proceed with teaching/or implement a teaching method within or after a lesson, based on a past experience; comparing own teaching method with theory or colleagues' teaching methods (Bakkenes et al., 2010; Hoekstra et al., 2007: Meirink et al., 2007; Van Eekelen et al., 2005)
Experimenting	Deliberate/intentional/purposeful effort to trial a self-invented, borrowed (e.g., from a colleague), or developed (e.g., in a group meeting) teaching method/material or lesson format, individually, with students, with colleagues in class, or recorded in future plans (Bakkenes etal., 2010; Hoekstra et al., 2007; Kwakman, 2003; Lohman & Woolf, 2001; Meirink et al., 2007).
Learning from others in interaction	Discussing, telling, recounting, sharing, and exchanging knowledge of one's and others' teaching methods, experience, and ideas about students' learning and education in informal or formal meetings (Kwakman, 2003; Lohman & Woolf, 2001; Van Eekelen et al., 2005); asking for help, giving help, getting tips and ideas, asking for opinions or explanation about teaching, student learning, and subject content/education matters from a colleague (Bakkenes et al., 2010; Van Eekelen et al., 2005).
Learning in interaction with students	Gaining an insight/idea through conversations with students, seeking feedback about teaching, asking questions, or from considering students' written work and behaviour (Bakkenes et al., 2010; Hoekstra et al., 2007; Lohman & Woolf, 2001; Van Eekelen et al., 2005).
Environmental scanning	Looking over resources from reading a book, written texts by others, journals and educational publications, browsing the internet to acquire professional knowledge/information about education issues; observing colleagues' teaching methods, listening to presentations of experts (Kwakman, 2003; Lohman & Woolf, 2001; Meirink et al., 2007; Van Eekelen et al., 2005).
Experiencing friction	A discrepancy between what is expected and what actually happens in class. For example when an unexpected event happens or when a teacher's teaching method does not work as expected (Bakkenes et., 2010).

3.8.1.2 Categories of potential professional learning outcomes from the literature

In the six studies examined for learning activities, the three studies of Bakkenes et al. (2010), Hoekstra et al. (2007), and Van Eekelen et al. (2005) distinguished categories of *potential learning outcomes* related to changes in teachers' behaviour, cognition, beliefs, and emotions. These three studies presented several categories of learning outcomes as shown in Table 7.

Table 7
Categories of potential teacher professional learning outcomes

Studies	Potential professional learning outcomes	
	Categories	Sub-categories
Bakkens et al. (2010)	Changes in knowledge, attitudes and beliefs	Awareness Confirmed ideas New ideas[a]
	Changes in practices[a]	New practices[a] Back to old practices[a]
	Intentions [to] practice	Intention to continue new practices Intention to try new practices Intention to continue current/ old practices
	Changes in emotion	Positive emotions Negative emotions Surprises
Hoekstra et al. (2007)	Becoming consciously aware as such Becoming consciously aware and adjusting course of action Becoming consciously aware and reframing	
Van Eekelen et al. (2005)	Changing a social behavior Performing a new technical skill[a] Making a resolution for next time Collecting professional knowledge	

Note. [a]Excluded from theoretical coding scheme as deemed irrelevant

Four general categories of teachers' learning outcomes were formed by following and adding to the categorizations of Bakkenes et al. (2010). These are: (1) changes in knowledge, attitudes and beliefs; (2) changes in practices; (3) intentions to practice; and (4) changes in emotions. Sub-categories from Bakkenes et al. (2010), and categories from Hoekstra et al. (2007), and Van Eekelen et al. (2005) were placed under the four categories, depending on how they were defined by the researchers who were involved in those studies.

Changes in knowledge, attitudes and beliefs was adopted in the present study after combining five categories from other studies. To define this activity, Bakkenes et al. (2010) used activities such as awareness, confirming ideas and new ideas. They described "awareness" as a situation in which teachers notice something in class that is important to them that they were not aware of before the innovation. Additional activities identified by Hoekstra et al. (2007) that suggested the notion of *awareness* include becoming consciously aware as such; becoming consciously aware and adjusting course of action; and becoming consciously aware and reframing. They described these as teachers noticing something of importance in class while teaching and adjusting their course of action or reframing.

Bakkenes et al. (2010) coded a learning outcome as ''confirmed ideas'' when teachers indicated that they felt more strongly about an existing idea or that the idea became more deeply rooted "New ideas" were coded as a learning outcome in the same study when teachers indicated that they gained new insights and ideas after the learning activity had taken place. Teachers in Van Eekelen et al.'s (2005) study expressed that they gained theoretical or practical insight after "collecting professional knowledge" or that they consciously tried a new type of "social behaviour" as a result of a prior experience. These teacher claims suggest gain of *'new ideas'* and as such, these two categories were also subsumed under the umbrella category of *"Changes in knowledge, attitudes, and beliefs*".

Bakkenes et al. (2010) categorized "new practices" and "back to old practices" under the learning outcome *"changes in practice".* These two sub-categories, together with the category *"*performing a new technical skill" identified by Van Eelekelen et al. (2005), were not included in the present study codes for potential learning outcomes. The reason for their omission lies in their relevance to the implementation of new innovations specific to their associated studies. As noted earlier, teacher learning following a specific educational innovation was not being

explored, yielding these categories irrelevant to the focus of the present study. Also, as noted earlier, changes in practice were not confirmed in this study.

The *Intentions to practice* category in Bakkenes et al.'s (2010) study produced three sub-categories: to continue new practices; to try new practices; and to continue current/old practices. In these sub-categories, teachers expressed intentions to continue with new teaching practices, to make adjustments and do things differently in future, or to continue with their "old" teaching methods. "Making a resolution for next time" was described by Van Eekelen et al. (2005), as a situation in which teachers decided to repeat certain behaviour in future lessons, depending on whether or not it appeared to be effective. Such inferences in the present study were categorized as "intentions to practice".

The *changes in emotions category* (see Table 7) was further sub-divided by Bakkenes et al.'s (2010) into positive emotions, negative emotions and surprises. Positive emotions were coded as a learning outcome when teachers reported feelings of pride or satisfaction. Reported outcomes were coded as negative emotions when teachers reported feelings of irritation, anger, concern or doubt. They referred surprise to indications of unexpected revelation or disclosure by the teachers.

The three general categories (changes in knowledge, attitudes, and beliefs; intentions to practice; and changes in emotions) were considered for development of a theoretical coding scheme under the theme "potential professional learning outcomes", and a set of indicators for these is given in Table 8.

Table 8

Potential professional learning outcomes with indicators related to pedagogical practice

Potential professional learning outcomes		Indicators of learning outcomes
Categories	Sub-categories	
Changes in knowledge, attitudes, and beliefs	Awareness	Noticing something important in class (Bakkenes et al., 2010; Hoekstra et al., 2007). Noticing something important in class and subsequently adjusting/reframing course of action (Hoekstra et al, 2007).
	Confirming ideas	Gaining more insights and ideas from own initiatives or from colleagues (Van Eekelen et al., 2005).
	New ideas	Statements made by the teacher trainers stating that they have learnt something (Bakkenes et al., 2010).
Intentions [to] practice	Intention to continue new practice	Statements made by the teacher trainers stating that they intend to continue with new practice (Bakkenes et al., 2010).
	Intentions to try new practices	Statements made by the teacher trainers stating that they intend to try a new skill/with adjustment. (Bakkenes et al., 2010; Van Eekelen et al., 2005).
	Intention to continue current/ old practices	Statements made by the teacher trainers stating that they intend continue current/ old practices. (Bakkenes et al., 2010; Van Eekelen et al., 2005).
Changes in emotions	Positive emotions	Utterances regarding satisfaction (positive emotions) as a result of students' understanding of concepts taught, students enjoying and participating in the lesson; or a teaching approach that worked for the teacher as planned practice (Bakkenes et al., 2010).
	Negative emotions	Utterances regarding disappointments or discouragements (negative emotions) as a result of students' not understanding concepts taught; or students not enjoying or participating in the lesson; or a teaching approach not working as the teacher expected (Bakkenes et al., 2010).
	Surprises	Utterances indicating surprise due to disclosure of unexpected results (Bakkenes et al., 2010).

3.8.1.3 Categories of contextual problems affecting teaching and learning of chemistry

Contextual problems were those perceived by the teacher trainers, specific to the context of chemistry teaching in Kenya. Three studies that explored factors affecting teaching and learning of chemistry (Chen & Wei, 2015; Edomwonyi-Out & Abraham, 2011; Ejidike & Oyelena, 2015) were used as a starting point to assign potential categories (theoretical codes) to the contextual problems affecting teaching and learning of chemistry in the Kenyan context. Two of the studies examined were conducted in African "developing countries". These are: Nigeria (Edomwonyi-Out & Abraham, 2011) and South Africa (Ejidike & Oyelena, 2015), where teachers are likely to face similar challenges to those of the Kenyan teacher trainers who participated in this study. Although learning is influenced by context, the third study (Chen & Wei, 2015), which was conducted in the "rising developing country" of China, was included to minimize narrowing the analytic field of vision to only one context (developing countries). The three studies identified 13 factors that affect teaching and learning of Chemistry as shown in Table 9.

Table 9
Categories of contextual problems affecting teaching and learning of chemistry

Categories of contextual problems	Studies		
	Chen & Wei (2015)	Edomwonyi-Out & Abraham (2011)	Ejidike & Oyelena (2015)
Pedagogical content knowledge	X		
External examinations	X		
Time adequacy/enough science practical periods	X	x	X
Teaching resources/laboratory adequacy/ enough and recommended textbooks	X	x	X
Class size	X	x	
Belief / attitudes about science	X	x	X
Peer coaching[a]	X		
Non-professionalism		x	X
Teachers' academic and professional qualifications		x	X
Chemistry workshop/in-service training		x	
Conditions of service/remuneration		x	
Examination malpractice		x	
Choice of career		x	

Note. x indicates that factor was identified in the corresponding study.
[a]Excluded excluded this aspect of theoretical coding as it is captured elsewhere.

Professional learning and development of teachers in the present study were grounded in teachers' teaching experiences. According to Van Eekelen, Vermunt, and Boshuizen (2006), the outcome of teacher professional learning is influenced by work context. The professional learning and development of teachers is mostly situated within classrooms and schools, and is partially influenced by other professional learning activities that occur outside the classroom and school. Although not completely discrete, these contexts informed the identification of the three categories of contextual factors thought to affect the teaching and learning of chemistry. The three categories are informed by the thirteen factors identified in the three studies examined and summarised in Table 9. The categories are presented with their sub-categories with related indicators to pedagogical practice in Table 10. All categories and sub-categories were treated as "theoretical codes" except for *peer coaching* as will now be explained.

Chen and Wei (2015) referred to *peer coaching* as a process in which two or more teachers exchange ideas through reflection on practice, and together, attempt to implement those ideas in their teaching. Teachers' exchange of ideas as an activity was included in the potential professional learning activities category *"learning from others in interaction"* and thus, was excluded here. However, the idea of giving teachers opportunities to learn together was included in the *"chemistry workshops/in-service training"* category.

Ejidike and Oyelena (2015) in their Nigerian study found that *examination malpractice* influences teaching and learning negatively. Passing chemistry is highly regarded in Nigeria, and therefore teachers who fail to teach well, possibly due to time constraints, engage in examination malpractice to please the school and parents. Many students do not take their learning of chemistry seriously, as they are aware that they will be assisted to pass the end of course examination either by their parents or teachers. External examinations also affect teaching and learning of chemistry in many countries. Chen and Wei (2015) found that since external examinations determine university entry in China, teachers focus on only what is included in those examinations (examination-oriented teaching). The two categories of "examination malpractice" and "external examinations" were combined to form the over-arching category of "external examinations". This category is presented with several indicators for the coding scheme in Table 10, as are indicators for other categories associated with *contextual problems affecting teaching and learning of chemistry*.

Table 10

Contextual problems with related indicators to pedagogical practice

Contextual problems		Indicators of contextual problems
Categories	Sub-categories	
Classroom factors	Pedagogical content knowledge	Indication from TTs' teaching accounts, suggesting limitation in knowledge about: teaching at particular grade level/concepts; instructional strategy; students' prior knowledge; and students' learning abilities (Chen & Wei, 2015).
	Teaching time	Statements made by TTs indicating: a lack of adequate teaching hours and practical periods; and heavy workloads (Chen & Wei, 2015; Edomwonyi-Out & Abraham, 2011; Ejidike & Oyelena, 2015).
	Class size	Utterances by TTs regarding the high number of students in classes, limiting effective teaching and learning of chemistry (Chen & Wei, 2015; Edomwonyi-Out & Abraham, 2011).
	Belief and attitudes	Utterances by TTs regarding teachers' and students' beliefs and attitudes about chemistry that affect teaching and learning (Chen & Wei, 2015; Ejidike & Oyelena, 2015).
School factors	Teaching resources	Statements made by TTs suggesting a lack of equipped laboratories and textbooks (Chen & Wei, 2015; Edomwonyi-Out & Abraham, 2011; Ejidike & Oyelena, 2015).
	Choice of career	Utterances made by TTs regarding students' career choices relating to science subjects, that affects teaching and learning of chemistry (Edomwonyi-Out & Abraham, 2011).
External factors	External examinations	Statements made by TTs suggesting that focus, administration, and relevance of examinations influence teaching and learning of chemistry (Chen & Wei, 2015; Ejidike & Oyelena, 2015).
	Teachers' academic and professional qualifications	Statements made by TTs indicating that levels of teachers' academic and professional qualification affect teaching and learning (Edomwonyi-Out & Abraham, 2011; Ejidike & Oyelena, 2015).
	Non-Professionalism	Indication in TTs' accounts of non-professional characteristics affecting teaching and learning of chemistry (Edomwonyi-Out & Abraham, 2011; Ejidike & Oyelena, 2015).
	Chemistry in-service training	Indication in TTs' accounts that limited opportunities for teachers to attend in-service training affects teaching and learning of chemistry (Edomwonyi-Out & Abraham, 2011).
	Conditions of service/ remuneration	Indication in TTs' accounts suggesting that conditions of service/remuneration influence teachers' motivation and commitment to work (Edomwonyi-Out & Abraham, 2011).

Note. TT indicates Teacher Trainers

Tables 6, 8, and 10 illustrate indicators of categories and sub-categories that were used as codes in developing a theoretical coding scheme for data analysis. However, these were used as *initial* theoretical codes to help the researcher focus on the research questions and purpose of the study (Braun & Clarke, 2006; DeCuir-Gunby, Marshall, & McCulloch, 2011). To minimize narrowing the analytic field of vision associated with the theoretical approach of developing a coding scheme, data analysis was not restricted to these initial theoretical codes. Analysis was kept open to add/reduce/refine categories and sub-categories if needed, to capture the nature of learning as highly contextualized, and ensure it reflected the specific Kenyan context of this study. This refining of categories occurred during testing applicability and reliability of the theoretical codes.

3.8.2 Testing applicability of the theoretical coding scheme

To determine whether the theoretical coding scheme addressed all the variations in the teacher trainers' contributions, its applicability was tested on a selection of data. For practical reasons, group reflection data were defined by the meeting number in which they were collected. Since six group reflection discussion (GRD) meetings were held, they were labelled GRD1 through GRD6. Group reflection discussion and interview transcripts were first recorded in a Microsoft Word document and converted into a table format. This was then transferred into a Microsoft Excel file for coding. Rows (r) were used to locate the source of coded units in the Microsoft Excel file during and after coding (e.g., GRD1, r. 20).

A sub-set of group reflection discussion transcripts was coded for the purpose of testing the applicability of the theoretical coding scheme. Coding was kept open to the possibility that teacher trainer's comments might suggest the need for addition, removal or modification of the initial theoretical codes. The theoretical coding scheme was revised since some of the teacher trainers' comments in data did not fit in the initial theoretical codes, and there were no matching data for others. Revision included removal, creation, and modification of some categories and sub-categories (initial theoretical codes) for reasons to be explained below.

3.8.2 .1 Refined coding scheme for potential professional learning activities

Theoretical codes for potential professional learning activities were developed based on six categories formed from the literature (see section 3.8.1.1). These categories were: experiencing friction; experimenting; reflecting; learning from others with interaction; learning from interacting with students; and environmental scanning (see Table 6). From the teacher trainers'

comments in the sub-set of data used to test applicability of the theoretical coding scheme, it was realised that the category "experiencing friction" identified by Bakkenes et al. (2010) was often an incentive for other potential professional activities such as reflecting and experimenting. For example, when Ritt *"realised that there was a problem with the workability of the experiment: The experiment was not working in most of the groups"* (GRD1, r. 217), he decided to try the same experiment to find out whether the reagents used by the students were correctly prepared. Similarly, Dott, after she experienced some "friction" in class, as a result of her Form Four students' inability to provide the correct response for a question around strong acids; a topic they had covered in Form One. To *"[her] disappointment [she] wondered where was this coming from"* (GRD1, r. 4). Due to these experiences of "friction" experienced in the classroom, Rett decided to carry out an experiment, whilst Dott reflected on the teaching methods previously used to teach the specific content. Therefore, the category "*experiencing friction"* led to activities for learning, but was not considered relevant as a distinct category of learning in and of itself. As such, "experiencing friction" was removed from the refined coding scheme (see Appendix I).

The other five categories formed for potential professional learning activities (experimenting, reflecting, learning from others with interaction, learning from interacting with students, and environmental scanning) were sub-divided for clarity. It was realised from data that teacher trainers were undertaking a particular learning activity in different ways and for different reasons. For example, in the category "*reflecting*", teacher trainers' comments suggested that they were reflecting before, during and after action, three distinct forms of reflection according to some authors (e.g., Eraut, 1995; Ghaye, 2011; Schön, 1983). Further, these different types of reflections focused on different aspects of teaching and learning, such as teaching methods, teaching and learning materials, or student learning. Therefore, the reflection category was divided into four sub-categories: "*reflecting on practice", "reflecting on practice-for action", "reflecting on practice-in-action",* and *"reflecting on practice-with-action"*. This sub-division was not revealed in the literature reviewed when the initial theoretical codes for professional teacher learning activities were established, although, to some extent there was similarity between these and the sub-categories identified by Kyndt et al. (2016).

In a similar way to "reflection", *"experimenting"* was also sub-divided. Sub-categories identified here were "experimenting with a teaching method" and "experimenting with teaching materials". It was also found that participants, apart from trying out alternative teaching

methods and materials, carried out experiments to confirm ideas and concepts. The ideas or concepts tested in this way stemmed from their own initiatives, requests from their students, or due to an unexpected situation that occurred in the classrooms, such as a student's response. Teachers tended to trial experiments when they failed to obtain expected results from practical tasks; and used experimentation to explore the reasons for failure. These data led to the addition of a sub-category termed *"confirming ideas/concepts*" and was attached to the broader category of "*experimenting"*.

In relation to the category "*learning from others in interaction",* discussing and exchanging knowledge was separated from sharing/telling/recounting insights. This distinction led to the formation of two sub-categories. A further sub-category was also identified and termed *"consulting"* to acknowledge teacher trainers' reports of approaching their colleagues to ask for help, get tips and ideas, ask for opinions or explanations about teaching, student learning, subject content and other education matters. For example, RettGDR1 asked, "*which one is bigger -1 or -2? Forgive me; I am a Biology Chemistry teacher"* (*r*. 117). Missing from the theoretical coding scheme were indictors to cover teacher trainers' comments when "critiquing" their own and their colleagues' practices (e.g., RittGDR1; "*yes, you did but even the issue of balloons is still emphasizing on reactivity and strength not the numbers"* (r. 53). Therefore, within the category of "*learning from others in interaction"* a fourth a sub-category *"critiquing practice"* was established.

The category *"learning in interaction with students"* was sub-divided into three sub-categories: oral conversations, written work, and student behaviour. "Observing behaviour" is often overlooked as a valuable learning opportunity to assess student learning. Dott, for example, realised that the experiment she gave her students was not effective due to the way they behaved; she stated: *"However, they did not seem to agree because this contradicted what they had given me"* (GRD1, r. 7). In the same vein, Rett concluded that her students were ready to learn because of the excitement they showed, she recounted: *"When they saw the set up, they were excited and ready to do the practical"* (GRD1, r. 132).

Examination of a sub-set of data enabled the refining of the theoretical coding scheme for *potential professional learning activities.* The final five categories identified in this refining process were: reflecting; experimenting; learning from others in interaction; learning in interaction with students; and environment scanning. A total of 15 sub-categories were

identified within these broader categories, and it was these sub-categories that were used as codes in the final analysis of data. A section of the revised coding scheme for professional learning activity, "*reflecting",* is presented with examples from the data in Table 11. (See the other categories in Appendix I.)

Table 11
Refined coding scheme for potential professional learning activity "Reflection" with anchor items

Codes	Anchor items
Reflecting-on practice	TT considers/thinks/wonders about their own and those of their colleagues' past teaching practices and students' learning, individually or in collaboration. *I think according to me, the problem is the way we are introducing acids and bases and the pH values in Form One* (DottGDR1, r.18)
Reflection on practice-in-action	TT considers/thinks/wonders about current practice to decide on how to proceed, triggered by unexpected incident in class about teaching methods/student learning/teaching and learning material/subject matter while teaching. *I thought very fast how I would engage the learners in a discussion with the same experiment. I asked them to come up with possible causes as to why it might be that the experiment did not work* (RittGDR1, r. 212).
Reflecting on practice-for-action	TT considers/thinks/wonders about past teaching practices/content to link new content, evaluate students' understanding of previous content taught, or to try different teaching methods/ materials. *In the past, I have been teaching this particular preparation of this gas theoretically. I looked at the conventional way of preparing the gas represented diagrammatically in our text books and I thought of trying it practically* (RettGDR1, r. 121-122).
Reflecting on practice-with-action	TT considers/thinks/wonders about teaching methods/student learning/teaching and learning material/subject matter to plan for future teaching. *I think in the future… because we were doing it last week, I look for a good cork, we heat gently, we give it time to decompose and see if we will be able to collect enough gas. I could also have done the experiment to completion before trying it with the students* (RettGDR1, r. 138).

Note. TT indicates Teacher Trainer. Texts in italics are examples from group reflection discussion data.

3.8.2.2 Refined coding scheme for potential professional learning outcomes

Codes for potential professional learning outcomes were developed based on the three categories formed from the literature (see Section 3.8.2.2). These are: (1) changes in knowledge, beliefs, and attitudes, (2) intention to practice, and (3) changes in emotions (Table 8). The category of "changes in emotions" identified by Bakkenes et al. (2010), was excluded from the refined coding scheme, however it was realised from the teachers' comments that change in emotions often resulted from other potential professional learning outcomes. Dott, for example, was disappointed in her class when she became aware that students had formed a misconception. The students *"were thinking that the higher the pH value the stronger is the acid or the stronger is the base"* (GRD1, r. 8). Further, when she realised that the "*students did not seem to agree because* [what resulted from what she had given them to do] *contradicted what they had given* [her]*"* (GRD1, r. 11). As a result of this experience, Dott adjusted her teaching actions. She decided to try another experiment which she thought might resolve the misconception. In a similar vein, when Kytt realised that he had marked an examination incorrectly to some of his students because he had assumed that they had not followed instructions, he was embarrassed. That experience also resulted in another potential professional learning outcome, 'intention to practice new skill.' He stated, "*I think following this discussion, I will not mark them wrongly. It was a long process and a very tedious one before I re-marked the papers. We had to test the solids again"* (GRD1, r. 322).

In the two examples above, Dott became aware of a problem with her students and adjusted the course of action accordingly, while Kytt expressed an intention to change his future practice based on what he had learnt from his experience. These and other similar examples led to the modification of the single sub-category *"awareness"* to form two sub-categories. The two sub-categories were: *"awareness with no immediate action*", which reflects the case of Kytt for situations in which no immediate action is taken and also those that the teacher trainers notice and were not required to act; and *"awareness and adjusting practice*" to accommodate the case of Dott, where either immediate action is taken to adjust intended directions or to address a situation that arises in class.

The final, refined coding scheme for *potential professional learning outcomes* has two categories "*changes in knowledge, beliefs, and attitudes*" and "*intentions to practice"*. Within these, a total of six sub-categories were identified for use as codes. Table 12 shows a section of

the revised coding scheme for professional learning outcomes for the category "changes in knowledge, beliefs, and attitudes". The other category, "intention to practice" is included in the codebook presented in Appendix I.

Table 12
Refined coding scheme for potential professional learning outcomes "changes in knowledge, beliefs, and attitudes" with anchor items

Sub-categories	Anchor items
Awareness with no immediate action	TT noticed something important in class about student learning/teaching methods/teaching materials but did not alter practice immediately. *The students were thinking that the higher the pH value the stronger is the acid or the stronger is the base. They think the six is for strong acids* (DottGDR1, r. 8).
Awareness and adjusting practice	TT noticed something important in class about student learning/teaching methods/teaching materials and adjusted/reframed course of action/sought ways to address the situation in class *However, they did not seem to agree because this contradicted what they had given me. I thought of a better way of doing it later alone* (DottGDR1, r. 11).
New ideas	Statements made by the TTs stating that they have learnt something from their own or another's practice. *I have also learnt that, in small scale experiments, everything must be scaled out. She scaled all the apparatus but heating was not scaled down* (KyttGDR1, r. 310).

Note. TT indicates teacher trainer. Texts in italics are examples from group reflection discussion data

3.8.2.3 Refined coding scheme for contextual problems affecting teaching and learning of chemistry in Kenya

The coding scheme for *contextual problems affecting teaching and learning of chemistry in Kenya* was based on three categories with several sub-categories identified in the literature (see Section 3.8.2.3). The three categories identified were "classroom factors", which encompassed sub-categories of pedagogical content knowledge, teaching time, class size, beliefs and attitudes; "school factors" with sub-categories of teaching resources, and choice of career; and "external factors" with sub-categories external examinations, teacher qualifications, non-professionalism, in-service training, and conditions of service/remuneration (see Table 10). In

the sub-set of data used to test applicability of the theoretical coding scheme, matching data were not found for some of the sub-categories identified in the initial theoretical coding scheme. These sub-categories: *"class size"* in the "classroom factors" category, *"choice of career"* in the "school factors" category, and "*conditions of service/remuneration"* in the external factors category, were subsequently excluded from the refined coding scheme.

Chen and Wei (2015) considered *"pedagogical content knowledge"* as teachers' knowledge about "instructional strategy, teaching objective, about students' prior knowledge, and requirements for learning new knowledge" (p. 203). In the refined coding scheme, the phrase "teachers' professional knowledge" was used to include teachers' knowledge of subject matter and pedagogical content knowledge that was found in data, even though these are distinct forms of teachers' professional knowledge.

It was also found that teacher trainers made a number of assumptions in their classrooms which hindered effective teaching of chemistry, and consequently student learning. Ritt, for example, assumed that solutions prepared by his colleague were ready for use, and therefore he did not test them before use. He stated,

> In future, I should not assume solutions prepared by another person are okay; rather I would go through the experiment myself before doing it with the learners. I should also take the details of the experiment beforehand… so that, in case it does not work, I should use the same details to prepare another solution. This is because it took longer to prepare another solution since I had to work out (GRD1, r. 225-226).

Contributions like this one from Rett, led to the creation of the sub-category *"assumptions"* in the "classroom factors" category.

The sub-category *"syllabus"* was also added to the category "external factors" as teacher trainers' comments suggested that some topics in the Kenyan chemistry syllabus were not aligned with students' abilities, leaving them with no choice but to learn by memorization. Kytt, in the discussion about Dott's students and the misconception regarding pH values, commented,

> now we can do this, because it is not our last meeting, is it possible to take it as an assignment and we try and see if we can come up with something that correlates the decreasing of this pH value? Something that now can make the students relate and solve this misconception that Dott is coming up with, which is very common, it is universal, it actually happens, especially for lower classes where they have not been taught a lot of things. Now, when we now move to the upper classes, Form Four, and introduce the hydrogen ion and concentration, it becomes clear there but for the Form Ones, Form Twos, it is a bit hard" (GRD1, r. 81).

Kytt's comment suggests that content taught is abstract and probably beyond abilities of students in Form One because for students to understand about pH values, knowledge of ionization and concentration of H^+ ions in a solution is required which is taught at Form Four.

The refined coding scheme for *contextual problems affecting teaching and learning of chemistry in Kenya* included the three categories: "classroom factors", "school factors", and "external factors" with eight identified sub-categories which were used as codes. Table 13 shows a section of the revised coding scheme for this theme with examples from data for the category "classroom". The other two categories are included in the codebook presented in Appendix J.

Table 13
Refined coding scheme for contextual problems affecting teaching and learning of chemistry in Kenya "Classroom factors" with anchor items

Sub-categories	Anchor items
Teachers' professional knowledge	TTs' knowledge about objectives of teaching chemistry at particular grade level, instructional strategy, students' prior knowledge, subject content and pedagogical content knowledge. *Which means as they were doing this practical you never paid attention to the kind of skills, that is, manipulative, observation and recording skills they were supposed to get from this experiment? The results can tell those areas were avoided* (Moderator 1GDR1, r. 267).
Teaching time	Adequacy of teaching hours, enough science practical periods. *However, many of us because of lack of enough time to cover the syllabus, we just use reagents available to us and carry out the tests without considering their concentrations* (RittGDR1, r. 240).
Beliefs and attitudes	TTs' and students' beliefs and attitudes about chemistry *Also there was another idea which was with my students that the topic of the mole was difficult* (RittGDR1, r. 217).
Assumptions	Statements made by TTs suggesting that teaching and learning was affected because something important in class about student learning/teaching methods/teaching materials was not taken into consideration. *In future, I should not assume solutions prepared by another person are okay* (RittGDR1, r. 155).

Note. TT indicates Teacher Trainer. Texts *in italics are* examples from group reflection discussion data

3.8.3 Testing reliability of the refined coding scheme

The refined coding scheme was applied to a second sub-set of data to test its reliability. As a result of this application, one additional code (a sub-category) was added to the category of

"classroom factors" under the focus area of *contextual problems affecting teaching and learning of chemistry in Kenya*. Noted in these data were students' difficulties in understanding the very basic scientific concepts. Chemistry requires significant prerequisite knowledge and understanding of basic concepts at lower grade levels if students are to understand the more complex concepts introduced at the higher grade levels. An example of this that emerged in the data is provided below from Ritt, who recounted the following transcript in group reflection discussion meeting three:

> As I was going around checking on what they were doing, I did not like what I saw. Most of them could not proceed, they were just there stuck. … At the end of the day, the lesson ended when we had not achieved the objective of writing ionic equation because there was some knowledge students did not have. What I discovered is that, for this topic, the students are required to have understood very well prior knowledge on how to write correct formulae, how to write oxidation states of some ions, for them to be able to handle this content. (r. 70)

Comments such as this one from Ritt led to the additional sub-category "*student learning abilities"* within the broader category of *"classroom factors"* (see Table 14). It was noted that students' difficulties in understanding basic scientific concepts challenged teachers in how to provide effective teaching and learning experiences. Teachers reported having to spend a lot of time revisiting the course work from lower levels, and as Ritt stated, they sometimes did not achieve lesson objectives, which subsequently inhibited their ability to cover the prescribed syllabus.

A refined coding scheme consisting of 30 codes within ten categories and three focus areas (*potential learning activities, potential learning outcomes, and contextual problems)* is shown in Appendix I. This coding scheme was used to code all group reflection discussion and interview transcripts. Coding was kept open until the last transcript was coded.

3.8.4 Data coding (data reduction)

The next step in the data analysis involved an interactive coding process through which the remaining transcripts were coded. As noted, coding was kept open to the possibility that teacher trainer's comments might suggest the need for additional, removal or modification of the revised codes until the last transcript was coded. Emergent issues that did fall under the refined coding scheme were placed in a separate code labeled "other".

To facilitate coding, Microsoft Excel was used (Ose, 2016). An Excel file was created with five columns: (1) row number (2) participant's name, (3) textual transcripts data, (4) focus areas,

categories, sub-categories (codes), and (5) interpretive notes made by the researcher. To facilitate the coding process, the codes were labelled alphabetically as follows: capital letters were used to represent focus areas, LA for potential professional learning activities; LO for potential professional learning outcomes, and CP for contextual problem. Categories assigned to each focus area were assigned numerical numbers and lower-case letters of the alphabet were attached to sub-categories. Since the group reflection discussion and interview transcript data were completed in Microsoft Word, they were first converted to a table format and then transferred to a Microsoft Excel file for coding. After coding, data were filtered by labels and transferred back to Microsoft Word in the form of matrices. Table 14 shows labels that were assigned to the codes.

Teacher trainers' comments (coding units) from the transcripts were coded with appropriate labels and researcher's interpretative notes placed on the right-hand column of each label. There was no restriction on the number of codes that could be applied to a particular coding unit from group reflection discussion and interview transcripts. Generally, one cell contained information corresponding to one label, but if a coding unit corresponded to more than one label (i.e., had more than one meaning), they were assigned as many labels as required and an explanation was provided in the right-hand column labelled "researcher's notes". For example, when Dott's students gave an incorrect answer for the pH value of strong acids (pH 6), she realised that these students had developed a misconception about the pH scale because they *"were thinking that the higher the pH value the stronger is the acid or the stronger is the base*" (GRD1, r. 9). This coding unit was assigned two codes, "learning in interaction with students" and "awareness and adjusting practice" because she followed up this situation with an experiment to help resolve the students' misconception. Appropriate notes (interpretative) were written in the right-hand column for each label assigned to assist in differentiating them from one another. A different excel sheet was used for each of the six group reflection discussions and each of the four interviews. The matrix shown in Table 15 illustrates a section of Dott's GRD1 critical incident in Microsoft Word upon completion of coding.

Following the coding process, data were filtered using labels for all the transcripts and grouped together and transferred to Microsoft Word. Table 16 shows potential professional learning outcomes filtered from the coded section of Dott's GRD1 critical incident.

Table 14
Labels for categories and sub-categories used to code data

Focus area	Category	Sub-category	Label
Potential professional learning activities	Reflecting	Reflecting-on practice	LA1a
		Reflection on practice-in-action	LA1b
		Reflecting on practice-for-action	LA1c
		Reflecting on practice-with-action	LA1d
	Experimenting	Experimenting with a teaching method	LA2a
		Experimenting with teaching materials	LA2b
		Confirming an idea/concept	LA2c
	Learning from others in interaction	Discussing and exchanging knowledge	LA3a
		Sharing/ telling/ recounting	LA3b
		Consulting	LA3c
		Critiquing practice	LA3d
	Learning in interacting with students	Oral conversations	LA4a
		Written work	LA4b
		Student behavior	LA4c
	Environmental scanning		LA5
Potential professional learning outcomes	Change in knowledge, attitudes, and beliefs	Awareness with no immediate action	LO1a
		Awareness and adjusting practice	LO1b
		New ideas	LO1c
	Intentions to practice	Intention to practice new skill	LO2a
		Intention to practice new skill with adjustment	LO2b
		Intention to try new practice	LO2c
Contextual problems	Classroom factors	Teachers' professional knowledge	CP3a
		Teaching time	CP3b
		Beliefs and attitudes	CP3c
		Assumptions	CP3d
		Student learning abilities	CP3e
	School factors	Teaching resources	CP4
	External factors	Examinations	CP5a
		Syllabus	CP5b
		Teachers' academic and professional qualifications	CP5c
		Chemistry workshops	CP5d
			Other

Table 15
A coded section of Dott's GRD1 critical incident

1	**Participant**	**Textual data**	**Labels**	**Notes**
5	Dott	We wanted to investigate strengths of acids and bases, and because this was something that was learnt in Form One with the introduction of the pH chart and pH values,	LA1a, LA1c	TT ***reflecting on*** what students had covered in Form One about bases, acids and the pH values to link with current content she wanted to teach in Form Four ***(reflection for action).***
6	Dott	I posed a question to my students to give me the pH value of a strong base.	LA4a	Questioning students to test understanding of content taught in lower level about pH values of bases. Questioning students to test whether they were remembering what was covered in Form One about pH values and strength of acids. ***(Interacting with students).***
7	Dott	One of the students answered that it is 14, which is correct.	LO1a LA4a	Response suggests that students understood about the pH values of bases. ***(Interacting with students).***
8	Dott	Then I posed another question: What is the pH value of a strong acid?	LA4a	Questioning students to test understanding of content taught in lower level about pH values of acids. ***(Interacting with students).***
9	Dott	Bearing in mind that in Form One we drew a pH chart with pH values, I thought in Form Four, this could be remembered easily.	LA1a LA1b	TT anticipated that students would answer question asked because the content being tested was covered when those students were in Form One. (***Reflecting on practice and reflecting in practice).***
10	Dott	However, they told me the pH of a strong acid is 6.	LO1a,	Response suggest that students had not understood about the pH values of acid; they gave a wrong answer, misconception ***(awareness, students learning difficulties***)
11	Dott	Wao... to my disappointment. I wondered, where was this coming from?	LA1b	Because TT had anticipated that students would answer question the question correctly, she was disappointed and this prompted her to think ***(reflection-in-action)*** about the source of the problem or how she could do to solve the problem.

12	Dott	The students were thinking that the higher the pH value the stronger is the acid or the stronger is the base.	LO1a	TT realise that students had a misconception about pH values of acids and bases.***(awareness).***
13	Participants	(chorous) Misconception.	LO1a	Participants confirm that Dott's students had a misconception about pH values of acids and bases. ***(awareness).***
14	Dott	Yes, misconception. So I thought what could I do, and eeh, with students in Form Four. One of the conventional methods of testing strength of an acid is using, for example by using ethanoic acid, hydrochloric acid, universal indicator paper and the pH chart. I gave them those materials to carry out the tests. The pH chart dipped in hydrochloric acid gave a pH value of 2, and that one in ethanoic acid 6.	LO1b, LA1b, CP3a	After realizing that her students were having a misconception about pH values of acids ***(awareness)*** she thought of solving the problem, and decided to use conventional materials ***(reflection-in-action).*** However she did not inquire from the students their thinking ***(limitation in formative assessment skills).***
15	Dott	However, they did not seem to agree because this contradicted what they had given me.	LO1a	TT realised that the experiment did not iron out the misconception ***(awarenes).*** Actually, the experiment theTT set was not for the content to teach. She wanted students to deduce from the experiment the pH value of a strong acid. A 2 for a strong acid, does not make sense for the students, because in reality they probably expected a big value for a strong acid ***(PCK)***. Student misconceptions are not easily eliminated especially when they challenge their previous thinking.
16	Dott	I thought of a better way of doing it later alone. I took two conical flasks and 50ml HCl and 50ml of ethanoic acid, and went to the class because I wanted to iron out that misconception that the pH of a strong acid is 6.	LO1b	When TT realised that the approach she used did not help in eliminating students' misconception, she thought of a different approach ***(reflecting-in-practice) for action.***

Table 16
A filtered coded section of Dott's GRD1 critical incident (learning outcomes)

Row	Participant	Textual data	Labels	Notes
7	Dott	One of the students answered that it is 14, which is correct.	LO1a	Response suggests that students understood about the pH values of bases. ***(Interacting with students).***
10	Dott	However, they told me the pH of a strong acid is 6.	LO1a, CP3a	Response suggest that students had not understood about the pH values of acid; they gave a wrong answer, ***(awareness, students learning difficulties;*** misconception).
12	Dott	The students were thinking that the higher the pH value the stronger is the acid or the stronger is the base.	LO1a	TT realise that students had a misconception about pH values of acids and bases.
13	Participants	(chorous) Misconception.	LO1a	Participants confirm that Dott's students had a misconception about pH values of acids and bases.
14	Dott	Yes, misconception. So I thought what could I do, and eeh, with students in Form Four. One of the conventional methods of testing strength of an acid is using, for example by using ethanoic acid, hydrochloric acid, universal indicator paper and the pH chart. I gave them those materials to carry out the tests. The pH chart dipped in hydrochloric acid gave a pH value of 2, and that one in ethanoic acid 6.	LO1b, LA1b, CP3a	After realizing that her students were having a misconception about pH values of acids ***(awareness)***she thought of solving the problem, and decided to use conventional materials ***(reflection-in-action).*** However she did not iquire from the students their thinking ***(limitation in formative assessment skills).***

15	Dott	However, they did not seem to agree because this contradicted what they had given me.	LO1a, CP3a	TT realised that the experiment did not iron out the misconception ***(awareness).*** Actually, the experiment the TT set was not for the content to teach. She wanted students to deduce from the experiment the pH value of a strong acid. A 2 for a strong acid, does not make sense for the students, because in reality they probably expected a big value for a strong acid ***(PCK)***. Student misconceptions are not easily eliminated especially when they challenge their previous thinking.
16	Dott	I thought of a better way of doing it later alone. I took two conical flasks and 50ml HCl and 50ml of ethanoic acid, and went to the class because I wanted to iron out that misconception that the pH of a strong acid is 6.	LO1b	When TT realised that the approach she used did not help in eliminating students' misconception, she thought of a different approach ***(reflecting-in-practice) for action.***
17	Dott	I asked the students to come and put the two solutions into the two conical flasks, and in each of these put a piece of magnesium ribbon 3cm long. I asked another two students to hold the magnesium ribbons so that they could drop them and cork the flasks at the same time with balloons. We allowed the reactions to go for at least 10minutes after the two flasks were corked with the balloons. After the 10 minutes, the balloon with the flask with HCl acid inflated very fast and it looked bigger, than the one with ethanoic acid.	LA3b, LO1a	carrying out an alternative experiment with students to confirm pH values of different acids .Teacher trying to iron out the misconception

Patterns were then examined in the ideas expressed by participants about teaching and learning processes within each focus area. To trace connections for potential new themes within these ideas, interpretative notes made by the researcher were utilised. Interpretation was guided by both the purpose of the study and the research questions. Similarities and differences were noted in the way participants expressed ideas about teaching and learning processes reflected in the researcher's interpretative notes. The process of generating new themes involved abstraction and subsumption, which according to Smith et al. (2009), are basic forms of looking for connections between emergent themes, depending on how the researcher perceives the way in which themes fit together. Some of the categories and sub-categories in initial themes (focus areas) were clustered to form a "super-ordinate theme" (abstractions), whilst other initial themes acquired "super-ordinate" status (subsumption). Examining the learning outcomes represented in Table 16, for example, it can be concluded from the notes made by the researcher, that participants' knowledge about students' learning was realised, particularly in regard to misconceptions. Results of the data analysis process discussed in this chapter are detailed in Chapter Four.

3.9 Ethical consideration

Permission to conduct this research was granted by the Australian Catholic University Human Research Ethics Committee on 29/02/2016 (Ethics Register Number: 2015-45E; Appendix G) and the National Council for Science and Technology, Ministry of Education, Kenya on 3rd July 2015 (Serial No. 5622, Appendix B). Following approval to conduct research, researchers have an obligation to preserve research subjects' rights and privacy while interacting with them in the data collection process (Bryman, 2012). In this regard, informed written consent was obtained from the four participants in the study (see Appendix H, participant information letter and informed consent form). To protect confidentiality, identifiable details were excluded from the research data and pseudonyms were used in data analysis. The Ethics committee was notified of changes to the initial procedures of data collection, such as inclusion of a group reflection discussion moderator and a recorder. Extension of the data collection period was also sought and granted from the Ethics committee for reasons given in Section 3.2.

3.9.1 Provisions for trustworthiness

Trustworthiness, or rigor of a study, is referred to as the degree of confidence in methods used to collect and interpret data (Amankwaa, 2016; Connelly, 2016; Cope, 2014; Polit & Beck, 2014). Methods used to collect and analyse data for this study followed a qualitative case study To ensure trustworthiness in qualitative research, four quality criteria outlined by many qualitative researchers were selected (e.g., Amankwaa, 2016; Cope, 2014; Connelly, 2016; Lincoln & Guba, 1985). These include: credibility, dependability, transferability, and confirmability. Each of these is outlined in the Sections following.

3.9.2 Strategies to ensure credibility

Credibility in qualitative research ensures that the raw data and findings of the research are free from bias and are therefore believable and trustworthy. Two strategies described by Houghton, Casey, Shaw, and Murphy (2013) to enhance credibility in qualitative research were used. These strategies were triangulation and prolonged engagement with the participants. Regarding triangulation, data were generated through two methods: group reflection discussions (group reflection), and individual interview. Multiple methods of data collection strengthened the methodological design of the study, not only by the different data collecting methods for cross-validating data, but also, by offering opportunities for deeper insight into the phenomenon under inquiry (Guion, Diehl, & McDonald, 2011; Patton, 2002). In this way, a better understanding of the research problem can be realised (Thurmond, 2001). With respect to length of engagement in the field, the researcher constantly communicated with participants during the research period spanning August 2015 to April 2016. Communication was mostly administered through phone calls, as participants were not always able to respond to emails in a timely fashion due to challenges with internet connectivity in Kenya. A lack of any new emerging data during the sixth group reflection meeting also serves as evidence that saturation had been reached (Houghton et al., 2013) and there would be no benefit from prolonged data collection.

Other methods such as member checking and peer debriefing can also enhance credibility in qualitative research. These methods are used to check agreement with the coding process, researcher's interpretations of data and findings. Use of these methods proved to be impossible once the researcher travelled back to Australia, because as noted, participants were not able to respond to emails sent by the researcher due to challenges with internet connectivity. Other

methods of communication, such as phone and post are expensive and unreliable in Kenya, and hence were not viable alternatives for undertaking a member checking process.

3.9.3 Strategies to ensure dependability

Houghton et al. (2013) describes dependability as the consistency of the research process over time. Concerns regarding dependability can be addressed through techniques such as audit trails (Ryan-Nicholls, Kimberley, & Will, 2009), which are achieved by clearly outlining and documenting the research process. In the present study, the researcher maintained an audit trail in all aspects of the study. A detailed initial and refined coding scheme was used to code transcribed qualitative data. Comprehensive descriptions are provided, including elucidating steps taken in the development of the initial coding identified in this chapter, refinement of the coding scheme, and the coding procedures. These detail trails help to ensure that coding decisions are transparent (Baralt, 2012) and enhance dependability of the research findings.

3.9.4 Strategies to ensure transferability

Cope (2014) describes transferability as the degree to which the research findings can be transferred to other contexts. Transferability decisions are made by the readers of the research. According to Houghton et al. (2013), it is the responsibility of the researcher to provide detailed descriptions of the research in order for the reader to be able to make an informed decision about its relevance to other settings. In the current study, accounts of the study context and the research methods have been described in detail. This will assist readers to consider interpretations as they are relevant to their own contexts.

3.9.5 Strategies to ensure confirmability

Confirmability in qualitative research, according to Polite and Beck (2014), is demonstrated when the researcher proves that the research data and interpretation represents participants' voices rather than those of the researcher's viewpoints. This can be done by the researcher explaining how interpretations and conclusions were established and derived directly from the data. Rich quotes from the participants' data, that support emerging themes are used in qualitative research (Cope, 2014). As a collective case study, with such a qualitative approach, many rich examples from the voices of the participants that informed analytical conclusions are provided in this thesis.

3.10 Chapter conclusion

This chapter has presented the research design and methodology adopted in the study. It has outlined the sequence of activities carried out during the study and the points of data collection and contacts in the field. The research questions that guided the research and how they align to the data collection instruments are stated. The process of data analysis, using a coding scheme developed from research questions and literature related to the study, was discussed. The steps followed to revise the initial the coding scheme using research data were also outlined. The revised codes were assigned labels, making it easier to code, filter, and group data during the analysis process. Finally, strategies adopted to establish trustworthiness of the research findings, and ethical issues to ensure that participants' rights were protected during data collection and analysis were also presented. In Chapter Four, findings resulting from data analysis process described in this chapter are presented.

CHAPTER FOUR

RESULTS AND INTERPRETATIONS

4.1 Introduction

In Chapter Three, the research design, methodology, and data analysis method adopted in this study were discussed. From the analysis, several potential professional learning activities and outcomes, which can provide insights into how and what teachers learn from their teaching experiences, were discerned. Several contextual problems influencing teaching and learning of chemistry in Kenyan secondary schools were also identified. In this chapter, these findings are presented. The presentation of findings is organized into three sections (how teachers learn, what they learn, and contextual problems), which are linked to the research questions, and illustrated in Figure 12. The dotted line is to indicate that contextual problems were not researched directly but were reviewed in the process of learning and learning activities investigated.

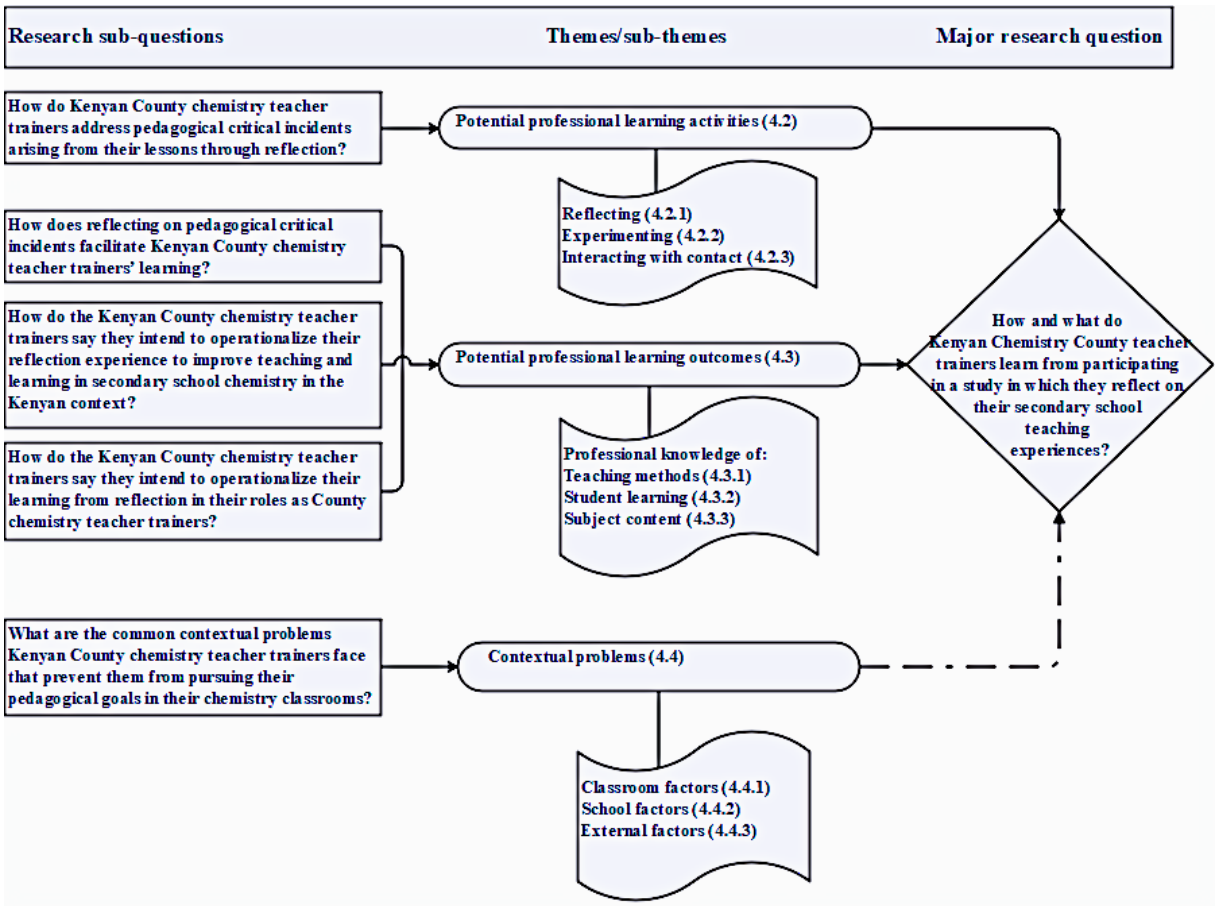


Figure 12*:* Research findings in relation to the research questions

As a qualitative study, a considerable number of verbatim extracts from the group reflection discussions and interviews transcripts are reported to support the findings. In this regard, teacher trainers are given a voice in the findings. These are presented in the three sections after this introduction as follows: In section 4.2, findings regarding professional learning activities that the teacher trainers participated in, that helped them learn, are discussed in detail. These include reflection, experimenting and interaction with contact. Following this is section 4.3 detailing findings of what the teacher trainers learnt. Three professional learning outcomes were identified: increased knowledge of teaching methods, of how student learn, and of subject content. In section 4.4, contextual problems reported by the teacher trainers that impede effective teaching and learning of Chemistry are reported. These include classroom (related to teachers and students), the school, and external factors such as external examinations. The chapter is concluded in section 4.5 by highlighting the main study findings.

4.2 Potential professional learning activities—how teacher trainers might learnt

The study explored professional learning and development of Kenyan practising County chemistry teacher trainers. As noted in Chapter Two (literature review), teachers undertake many professional learning activities, alone or with others in collaboration, that can lead to learning and improvement of their teaching. To establish learning activities that Kenyan chemistry teacher trainers can undertake to provide learning and development, the major research question consisted of two parts: (1) How teacher trainers learn; and (2) what they learn. To answer this question, the first sub-research question centered on understanding *how* teacher trainers learn from their teaching experiences: *How do Kenyan County chemistry teacher trainers address pedagogical critical incidents arising from their lessons through reflection?*

To determine how teacher trainers learn from their teaching experiences, actual professional learning activities in which they engage in the classroom were explored. These activities were identified from the group reflection discussion and interview transcripts. In group discussions, teacher trainers discussed written protocols, which they produced after reflecting on critical incidents that occurred in their chemistry lessons and from which they thought they could learn. Data analysis revealed that teacher trainers predominantly used three different types of professional learning activities.

The first professional learning activity was *reflecting,* in which teachers reflected on their practice before, during, and after class, and in group reflection discussions with their colleagues. The second professional learning activity was e*xperimenting,* in which teacher trainers experimented with teaching methods and learning materials in the classroom and expressed intentions *to try* new ideas, teaching methods, and learning materials both in their classroom teaching and in the training they provide for other chemistry teachers during in-service training (INSET). The third professional learning activity was *interacting with contact*, in which teacher trainers *interacted with students* in the process of teaching and learning. In addition, they *interacted* freely *with their colleagues* in group reflection discussions held on weekends.

Data analysis revealed that teacher trainers rarely scanned professional information and they also rarely consulted or exchanged ideas with other teachers in their school. The three commonly used potential professional learning activities (*reflecting, experimenting* and *interacting with contact)* are presented separately in this chapter. However, they are not discrete categories, as teacher trainers potentially learned from the interplay between the three activities.

4.2.1 Reflecting

Group reflection discussion and interview data showed that teacher trainers reflected on their practice using incidents they considered critical in their classrooms. They reflected on those incidents after conducting their normal classroom teaching and when sharing the incidents with other teacher trainers during group reflection discussions. Schon (1983) referred to this type of reflection that takes place after action as *reflection-on-action.* In the process of analysing teacher trainers' descriptions of what happened in their classrooms, three further types of reflection were also evident in data. These were *reflection-in-action, reflection-for-action,* and *reflection-with-action.*

Reflecting, as demonstrated in each of the four types of reflection, acted as a catalyst through which teacher trainers questioned themselves about their actions in the classroom, thought about improvement, and considered their students' learning. Teacher trainers' contributions did, however, only provide indirect evidence of the actions described, as they were not directly observed. The findings of this study are therefore based on reported actions and learning by the teacher trainers through reflection before, during and after teaching, to improve their teaching and learning in chemistry. Figure 13 illustrates the types of reflection teacher trainers used that contributed to their learning from their teaching experiences.

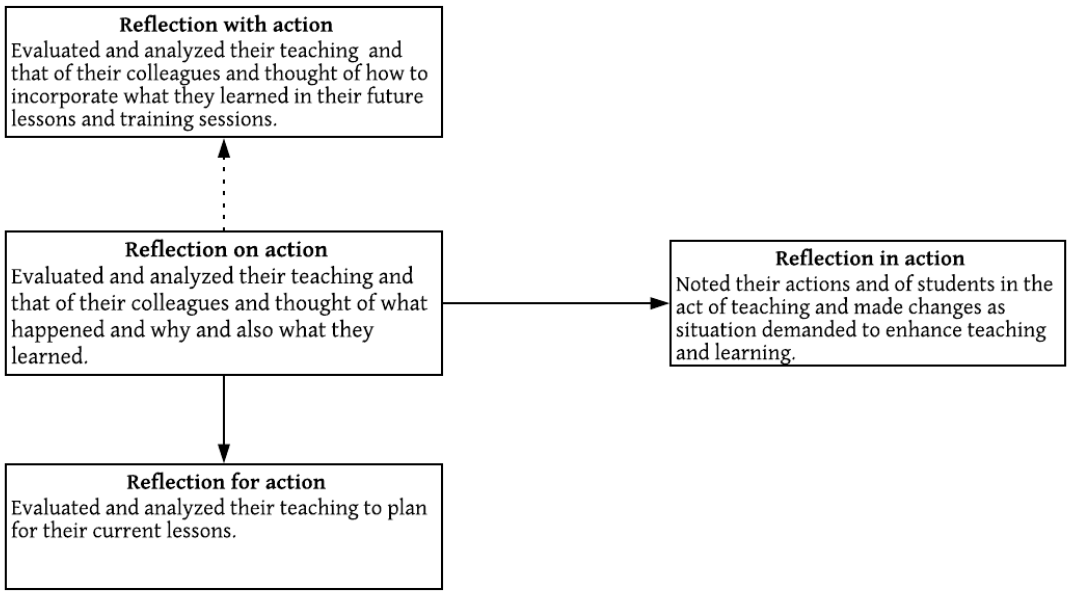


Figure 13*:* Using reflection *for, in, on,* and *with* action to improve teaching and learning

Data supporting the identification of these types of reflection in the teacher trainers' reports are discussed in the following sections.

4.2.1.1 Reflection on action by teacher trainers

The design of the study required of the teacher trainers *to reflect on* their teaching individually after their lessons, and collaboratively in monthly group reflection discussions. Reflection-on-action was considered as a spring board for the other types of reflection as illustrated in Figure 13, with arrows leading from it to the other three types of reflection (*reflection for, in and with action*). The solid-line arrows represent current action, and the broken-line arrows, future action. Reflection-on- action was considered as a spring board for the other types of reflection because when teachers plan what they are going to do, how they act on the spot to solve immediate problems, or when they plan for the future, they often use knowledge acquired from past experiences. In reality, as Eraut, (1995) noted, it is difficult to separate the other three types of reflection from reflection-on-action especially reflection-in-action.

Reflection on action was evident in data generated from all four teacher trainers through expressions such as: "I asked myself what could have been the problem. I remembered that when I was doing the same experiment with these students back in Form One…" (DottGRD4, r. 8); "When I reflected on this incident, I thought 'the boiling tube is not the best' because the

heating requires a large surface area" (RettGRD1, r. 145); "When I thought about the students who were not courageous enough to handle the weighing balance, I wondered if they understood what I was teaching" (KyttGRD3, r. 94); and "What I came to reflect…try to rethink later on, why could these students not fix the clamp on the stand? I thought the way we have been doing these experiments, I thought in many lessons I just do a demonstration without a class practical" (RittGRD6, r. 58).

In group reflection discussions, teacher trainers reflected on their own practice, and that of their colleagues. For example, others contributed to reflective discussion on Rett's critical incident in GRD6, when she sought their opinion as to whether, in future, she should "[teach] endothermic [reactions] theoretically, and then do the experiments and calculate a few examples before [she] move to exothermic reactions" (r. 45). She sought this opinion after reflecting individually on how she taught endothermic and the exothermic reactions. She wondered whether teaching the two concepts in the same lesson, and before students were engaged in any experimental work might possibly confuse students and lead to the development of misconceptions.

4.2.1.2 Reflection on action-for-action by teacher trainers

Reflection-on-practice-for-action was the second type of reflection identified in the data. Reflection for action, according to Eraut (1995), refers to doing something for a purpose. It was coded as a potential learning activity when teacher trainers' reports suggested that they thought of what to do for a particular purpose. Data revealed that teacher trainers' reflected-for-action by looking back upon their teaching strategies and content covered in their previous lessons for the following reasons: (a) to link up with the new content they intended to teach; (b) to evaluate their students' understanding of previous content taught; (c) to try different teaching methods; and (d) to try new teaching materials.

Reflection-for-action was, for example, identified in Dott's GRD1 critical incident. She described an incident from a lesson where she wanted to teach acids and bases in a Form Four class. The first part of this topic in the Kenyan chemistry syllabus is introduced to students in their first year of secondary school and revisited in the second part of their fourth year. *To link what she wanted to cover with what had been covered earlier*, Dott thought of asking students questions related to what they had covered in Form One. She recounted:

> We wanted to investigate strengths of acids and bases, and because this was something that was learnt in Form One with the introduction of the pH chart and pH values, I posed a question to my students to give me the pH value of a strong base. One of the students answered that it is 14, which is correct. Then I posed another question: What is the pH value of a strong acid? (r. 5-8).

Connections among unit concepts are critical, as Ritt learnt from one of his lessons and reported in a follow up group reflection discussion meeting (GRD3). In this incident, Ritt noted that for some chemistry topics, such as writing ionic equations, students are required to have a good understanding of the pre-requisite knowledge about ion formation, oxidation states, and valences. Therefore, it could be important for teachers to reflect on how they can link content from previous lessons with new content they intend to teach. The common method used to link the two is through questioning and answers, which Dott used in her critical incident above.

Reflecting-for-action to *evaluate students' understanding of previous content taught* is closely related to reflecting-for-action to link previous and new content. It would not be worthwhile for a teacher to introduce new content when students have not understood previous content, especially if the two are closely related. Students are not likely to understand new content if they have not understood previous content, as reflected in Ritt's (GRD3) class.

There were several incidents where teacher trainers reflected-on-practice-for-action to evaluate students' understanding of previous content taught (e.g., DottGRD1; DottGRD6). Several incidents were also evident where teacher trainers could not proceed with their lessons after becoming aware that students had not understood previous content (e.g., RittGRD3). An example of this occurred in Dott's GRD1critical incident where she could not proceed with the Form Four content when she realised students had not understood the Form One concepts regarding acids and bases. She explained in the following abbreviated excerpt what she did:

> Bearing in mind that in Form One we drew a pH chart with pH values, I thought in Form Four, this could be remembered easily. However, they told me the pH of a strong acid is 6. Wao... to my disappointment. I wondered, where was this coming from?... So I thought what could I do, and eeh, with students in Form Four. One of the conventional methods of testing strength of an acid is using, for example by using ethanoic acid, hydrochloric acid, universal indicator paper and the pH chart. I gave them those materials to carry out the tests (GRD1, r. 9-14).

This incident, which also demonstrated *reflection on action-in-action*, and similar to others that were reported, provided no evidence that Dott probed her students' thinking to determine how this misconception arose in order to inform her *plan for action*. Possibly, if she had, she could

have used the information garnered to inform her subsequent teaching actions. The experiment she recalled giving students to do, although produced the expected results, did not convince the students that a strong acid has a lower pH value. She commented: “However, they did not seem to agree because this contradicted what they had given me (GRD1, r. 15). Dott’s students’ reactions demonstrate the importance of effectively reflecting for action to evaluate students’ understanding of previous content taught.

Reflecting on practice-for-action helped teacher trainers to evaluate students’ understanding of previous content taught. They revisited the content they thought students had not understood. Lack of it, or ineffective reflection-for-action, as evidenced in Dott’s pH example, can result in the implementation of learning activities that do not lead to students understanding and learning.

Teacher trainers’ reports also suggested that they reflected-for-action when they wanted to *try* alternative *teaching methods*, when they realised previous teaching methods were not effective and they wanted to improve. This kind of reflection is important for planning to avoid repeated mistakes and to garner improvement. Rett (GRD1), for example, recalled “In the past I have been teaching this particular preparation of this gas theoretically. I looked at the conventional way of preparing the gas represented diagrammatically in our text books and I thought of trying it practically” (r. 129-130). In this incident, Rett was referring to the preparation of Nitrogen (IV) Oxide gas. She noted that her students enjoyed practical lessons and therefore decided to prepare this gas practically. She further stated: “When [the students] saw the set up, they were exited and ready [to do] the practical” (r. 136). It can be argued from Rett’s comment, that her students’ behavior motivated her reflection-for-action (learning from interacting with students).

These findings suggest that teachers should consider reflection-for-action as an important professional learning activity when planning lessons. Illustrating this further, as Rett prepared the Nitrogen (IV) Oxide gas, she noted, “all of a sudden there was an explosion the… boiling tube broke and the Nitrogen (IV) Oxide gas was in the air and you know, Nitrogen(IV) Oxide is poisonous” (r. 140). This suggests that Rett had not reflected-for-action comprehensively, although her report indicated that she looked at the conventional way of preparing the gas in the textbooks. She omitted critical aspects that caused the explosion when she was preparing this gas with her students. Some of the things she could have considered in her planning, apart from the cork and the heating which she subsequently thought of considering in future lessons,

were suggested by other teacher trainers during the group reflection discussion. These included: use of ice cold water (Dott), making sure that a lot of pressure does not accumulate while heating (Kytt), and checking the distance between the burner and the condensation point (Ritt). Rett's action was possibly influenced by the current view of "good practice" in teaching; she allowed students to use two burners in an effort to increase the level of students' interest, and to achieve student-centred learning.

4.2.1.3 Reflection on action-in-action by teacher trainers

The third type of reflection identified in data was reflection-on-practice-in-action which, according to Schön (1983), occurs during action, "*in situ"* or *on-the-spot experimentation".* The action was coded as a potential learning activity when teacher trainers' reports showed that they thought of what happened, and what to do in the act of teaching. Eraut (1995) noted that since many things happen simultaneously during a lesson, it is impossible for a teacher to be consciously aware of all that happens in the classroom. This was evident in data (KyttDGR1) when Kytt described his GRDI critical incident, stating that he only realised that there was a problem with group two experiment "when the students complained" (r. 273).

Analysis of teacher trainers' reports suggested that they reflected-in-action to solve puzzling problems (critical incidents) that occurred in the classroom during teaching. The problems were triggered by unexpected actions from students, or by unexpected outcomes from experiments. Teacher trainers, for example, reflected-in-action when they: (a) realised students had not understood what they were teaching from: the questions they asked; the responses they gave verbally or in written form; or by just reading their behavior; (b) failed to achieve what they were expecting in a lesson. As a result of reflection-in-action, teacher trainers stopped in the midst of teaching and made necessary adjustments to better ensure that students understood what they were teaching. Such examples of reframing, not only assist students' understanding, but also help to ensure that the lesson can continue.

Reflection-in-action can be found in Rett's GRD4 critical incident. In this incident, a student asked Rett why she drew three rather than two energy levels for sodium metal (2.8.1). From this question, Rett "realised that the students had not fully understood the maximum number of electrons that are supposed to be in every energy level" (r. 38). Rett reported having to stop, think, and act to attend to this problem. She acted in two different ways. Firstly, she "reviewed

again" (r. 39) and secondly, she "took time, and [she] thought how [she] could make it better. She explained, "in those rings, instead of placing buttons [dots or crosses], [they] used plasticine—modelling clay" (r. 41). The first action was immediate and teacher-centered and it is possibly why her students were not convinced, making Rett to think further on how to improve her teaching action (reviewing).

Similar to Rett, Dott (GRD5) also noted that her students had not understood the maximum number of electrons that are associated with each energy level. However, in this situation, Dott realised the lack of understanding when she reviewed students' notebooks after asking them to write the electronic arrangement for sodium and magnesium atoms. She recalled:

> To my surprise, what they wrote for Sodium was 2.9 and Magnesium 2.10. Then I thought what I could do for students to understand that the second energy level should have a maximum of eight electrons. I made balls using plasticine, two small size for the first energy level, eight bigger size for the second energy level, in that order (r. 7-9).

Here, Dott also demonstrated reflection-in-action (on the spot), when she noticed a problem with her students. This situation compelled her to reframe the problem by thinking of another way of approaching the topic for her students to understand.

Kytt had earlier acknowledged the importance of reflection-in-action, although he did not say this directly. This happened when exchanging ideas in GRD3. He was reflecting on Ritt's GRD3 experience of the experiment that failed to give expected results when he was standing in for a colleague. He suggested that if teachers are keen when monitoring students as they carry out practical activities, they are likely to notice when

> something [is] wrong and now as a teacher you can go back and…, you know, do some quick test to find out where the problem might have been. So in about five to ten minutes you can actually go back and maybe discover that there must be something wrong with …particular situation…immediately and prepare a fresh one and…sometimes the students may not even know… You actually correct on the spot and the students go on with the practical… All the stages can be undertaken in the same lesson, assuming it is a double lesson you can actually correct depending on the availability of time and the resources which are there. (r. 258)

Reflection-in-action, although having its own limitations, such as teachers not having enough time to think through their actions, is important, as demonstrated by the reported incidents. It provides teachers options for immediate improvement in their practice. This feature of immediate action, distinguishes reflection-in-action from the other types of reflection that occur before or after an action has taken place.

4.2.1.4 Reflection on action-with-action teacher trainers

The fourth type of reflection was reflection-on-practice-with-action. This type of reflection is concerned with future action, and in this study, was closely connected to teacher trainers' intentions to practice or try new skills. They reflected-with-action when responding to questions they were asked on how they intended to improve their future lessons and in-service teacher training from what they had learnt from their reflection experiences. Teacher trainers were expected to reflect on their learning experiences with the intention of suggesting how to improve future actions in their classrooms. Teacher trainers complained of time constraints in their classrooms, especially in areas where students lacked basic scientific concepts and skills. They reported spending a lot of time trying to attain student understanding. In some incidents reported, teacher trainers were not in a position to respond to all the problems they noticed in the classrooms (*on-the-spot adjustment)*, but expressed an intention to address them in their future lessons with various improvements to their teaching. For example, when Kytt (GRD3) was faced with such a problem, he commented:

> When I thought about the students who were not courageous enough to handle the weighing balance, I wondered if they understood what I was teaching. Did I do the correct thing by ignoring them? How could I have balanced the two: revisiting the skill of handling the weighing balance and achieving the lesson objectives? I decided that in future lessons; I would mix students whom I think can handle apparatus with those who cannot, I would tell the students to make sure that everybody handles all the apparatus. I would go around the class making sure this is being done and also assisting them. By doing this, I think all students will be happy and will be eager for the next step of comparing their masses. (r. 94)

From this contribution, we can see Kytt expressing concern in relation to his teaching; he is questioning his actions after the lesson (did I do the correct thing by ignoring them?), illustrating reflection-on-action. He started by evaluating and examining his actions in class. He also thought of a way to improve this action in future (I would mix students whom I think can handle apparatus with those who cannot). This example of reflection-with-action provides an indication that Kytt learnt from this experience. He was improving his teaching because he was building on his past experience to plan for future lessons. In this way, he would accommodate those students who were not able to handle the weighing balance. He considered students' learning abilities and thought of alternative ways to assist their learning using a peer-teaching approach. He was optimistic that in this way, his students would be motivated to learn.

Through reflection on his practice, Kytt, as illustrated by this quote, was able to identify and interpret his weakness and thinks of a way to improve his practice. The experience afforded him an opportunity to articulate his reasoning for his own teaching and learning priorities (revisiting the skill of handling the weighing balance and achieving the lesson objectives) and the potential change in teaching practices when he said that in future lessons he would consider those students and mix them with other more-able students. The expansion of learning opportunities for the weak students mirrored the teacher trainer's own expansion of knowledge on how student learning could be enhanced.

From findings presented in Section 4.2.1, about *reflecting*, it can be concluded that reflecting, as a potential professional learning activity, helped teacher trainers to advance their professional knowledge. Dott confirmed this in her response during her interview:

> As an individual, I have learnt a lot out of the critical incidents that we had. One I realised as a teacher, there are many things I have been assuming in my teaching and out of the discussion I realised that I don't do a reflection of what I have taught. Probably students have had misunderstanding of my concepts and maybe that is why they do not do well in the examinations. And again, in the group discussions, I have also realised other teachers have been faced with [the] same challenges I have, we teach and we do not do a reflection. We seriously affect the learning of the students because we assume much. (Interview, r.7)

In the interview, Dott said that she does not reflect on her teaching, which has probably resulted in students performing poorly in examination. The professional learning aspect of this study has enabled her to consider the reflective process because she said that she realised:

> For example, when I am teaching chemistry in Form One about separation, I dwell much with teacher demonstrations. When we teach in Form One, we should not leave the work there; we should bring it on board even to the upper classes. (Interview, r. 9)

She also noted that she learnt from her students

> Because [she] can give a particular concept and [she] give it to be done this way, and then the students give [her] a different suggestion. (Interview, r. 11)

And also from reflecting with her colleagues:

> I realised that involving other teachers in what we were doing, you will learn doing a particular concept in a different way and the end result is the same. (Interview, r. 15)

In conclusion, two main positions can be expressed about reflecting from the teacher trainers' reports. Firstly, it was clear that for teachers to learn about teaching, and when trying to do something different or better for various reasons to improve their teaching and student learning,

they have to use more than one kind of reflection. Reflecting, in each of the four types of reflection, acted as a catalyst through which teacher trainers questioned themselves about their actions in the classroom, thought about improvement, and considered their students' learning.

Secondly, through reflecting, teacher trainers expressed an intention to change their practice (e.g., DottGRD2; RettGRD6, RittGRD5). They expressed this intention in relation to trying to understand specific situations in their classrooms and to take effective and applicable actions. They thought such actions would likely strengthen and improve their practices, and subsequently, enhance their students' learning.

4.2.2 Experimenting

Experimentation in the context of teaching and learning involves teachers trying out new teaching approaches and assessing students' learning (Bakkenes et al., 2010). Data in group reflection discussions revealed that teacher trainers purposefully experiment in their classrooms to: (a) try out teaching methods; (b) try out learning materials; (c) test students' understanding of content; (d) enhance student learning; and (e) increase their own understanding of content.

Teacher trainers also stated that they could try what they had learnt from their classroom experiences in future lessons and with other teachers during in-service teacher training to improve their practice and gain more experience. Following group reflection discussions, teacher trainers expressed intentions to also trial the teaching methods of their colleagues to assess whether they could be applicable in their own classrooms.

4.2.2.1 Experimentation: Trying out teaching methods

Teacher trainers' data confirmed that the topic *"Mole"* in chemistry is as perceived difficult by Kenyan secondary students (e.g., DottGRD5; RettGRD3; RittGRD2). Likewise, teacher trainers said that, similar to many other teachers, they experience difficulties while teaching this topic. Reasons for these difficulties were given as: students' negative attitudes (RettGRD3; RittGRD3); students' limited understanding of basic scientific concepts (RittGRD3; DottGRD3); and the abstractness of concepts associated with the topic (DottGRD5). One way that teachers have reported trying to address these challenges is by trialling a variety of teaching methods and materials to explain abstract concepts and to motivate students. In this study, the following examples of such trialling were reported.

Ritt discussed his critical incident (GRD2) where he tried an alternative method for teaching the mole. He recounted having taught this topic "theoretically" in the past, and that he decided to try a practical approach on this occasion, to help his students' understand the concept better:

> I had really prepared for this lesson about the mole concept how I am going to introduce it. From what I know in the past, I have been introducing this topic theoretically but this time I wanted to introduce it with a practical so that I can go deeper for my students could understand better. I wanted to use different fruits to bring the concept of mole. We were to weigh the same number of fruits and by getting different weight I could bring out the idea of a mole…So I decided to use this practical approach. I was optimistic it would work. (r. 166-168)

Ritt's trialling of a different teaching approach to enhance his students' understanding incorporated practical work using concrete materials (fruits), items that are familiar to students. Experimentation does not always lead to expected results; however, there is always something to learn. In this particular incident, Ritt did not achieve his lesson objectives, but he confirmed his students' negative attitude towards the subject. He could not proceed with the lesson the way he had planned, but later reported that he decided to try another approach. "I had to look for extra time. But this time I wanted to involve another teacher. There is this [teacher from] neighboring school which has been performing so well in chemistry" (r. 174-175). In the discussion regarding Ritt's experience that followed, teacher trainers suggested additional teaching strategies Ritt could try with his students to address both the difficulties students seem to have and their negative attitude towards the topic. For example, Rett suggested that Ritt should not write the topic "mole" on the chalkboard, but give the students the activities to perform first. Kytt, although generally supportive of Rett's suggestion, was skeptical about its effectiveness. He argued:

> I also support the others when they say that we should not introduce the topic by mentioning its name *"mole"*. I do not know whether it will work or not. This is a topic we all do at Form Three; the first topic. The students know that the first topic is the mole. (r. 196)

He further stated that students are aware that teachers follow the topics the way they are sequenced in the books and also the syllabus when teaching. He suggested that it is sometimes good for teachers to change the order of teaching, except the first topic on introduction to chemistry which must come first. He said that he does not sequentially follow the topics the way they are outlined in the text books. When the teacher trainers reflected and discussed how Ritt's experience could be used during INSET, Kytt suggested that Ritt should create a story and *try* to use it as a case for training. He reminded them that teachers "have a problem of

changing student's attitudes in Chemistry. So by creating a story, it can bring out many learning lessons during INSET" (r. 209). Dott was impressed by Ritt's idea of inviting the teacher from the neighboring school and suggested that they could *try* this idea with the teachers during INSET, who also happened to have negative attitudes towards the training. She thought that if they brought external speakers to talk to teachers, they are likely to change their attitude about INSET as a waste of time.

Teacher trainers in follow up group reflection discussions, expressed intentions to *try* their colleagues' teaching methods to assess whether they could work with their own students (e.g., Rett, GRD3; RittGRD5). In GRD3, Rett was encouraged by Kytt to try his method of teaching. She had recounted an incident where her students were reluctant to participant in an experiment of heating metals in air:

> **Rett:** I will try all that with my next Form One class and see whether it works.
> **Kytt:** It will work. I have done it with my Form One classes always. Form Ones have to be treated with a lot of care. If you are not careful, that is when you lose your students and even if you try other tricks later on you will not get them. (r. 66-67)

Trying out different teaching methods, as demonstrated by Ritt, can result in teachers understanding their students better: their learning needs and difficulties, motivating them to seek alternative teaching methods.

4.2.2.2 Experimentation: Trying out learning materials

Teacher trainers frequently stated that they lacked basic laboratory materials (e.g., KyttGRD1; RettGRD1). The Kenyan secondary school chemistry syllabus (K.I.E, 2002), encourages teachers to improvise and use local materials when a school does not have conventional learning materials (e.g., RettGRD1), so this often occurs in teachers' practice. Dott (GRD2), for example, following a successful experiment with her students in which she was testing whether local materials could be used as electrolytes, commented:

> I think this demonstrated a lot of improvisation in addition to the conventional method in our text books. I think it is important if we encourage our teachers to *find* out what we have in our environment; there is a lot of chemistry out there that could be used to raise the curiosity of the learners. They could also tell students to go and *find* out other substances in their homesteads that could be used as electrolytes. (r.18-19)

The Kenyan secondary school chemistry syllabus also requires teachers to help students link the physical and chemical processes they learn about with the physical environment around them. This kind of link, as demonstrated in Dott's GRD2 critical incident, make students aware

of the presence of science in everyday life and also motivates them to learn. Such awareness potentially increases students' understanding of abstract chemistry concepts. Dott said that when she connected electric current to a lemon on students' request, and "the bulb glittered … it was a joyous moment in the class" (r. 9).

In discussing this critical incident in GRD2, Dott reported that she considered the activity to be effective, suggesting that she had learnt something about enhancing her students' learning. In the group discussion, Rett suggested other local materials that could also be used as electrolytes, but when she was asked by the moderator whether she had tried them out, she replied, "I have not tried… but what I know is that Momosa Pudica's extract is an electrolyte. There are a number of them. I can try outside this" (r. 31). This is an indication that teacher trainers were motivated by the group reflection discussions to think about and try new teaching and learning materials.

Kytt (GRD3) decided to try local materials for a different reason. In an experiment where he was using metal balls to introduce the concept of relative atomic mass of elements, he realised that a lot of time was lost because students were not familiar with the metal balls found in the laboratory. He observed that students spent a lot of time admiring the metal balls "rather than doing the actual weighing of the masses" (r. 96). He decided that in future lessons, he could *try* to use balls prepared from other local materials, such as beads and grains instead of always using metal masses which the students were not familiar with.

It can be concluded from the teacher trainers' reports that experimentation with learning materials, particularly those that students were familiar with, can help teachers improve their teaching practices. Experimenting with such material can result in teachers gaining new ideas and insights, and helps to motivate students, as Dott's incident showed. Experimenting with local materials can also help teachers enhance students' understanding and retention of scientific concepts. For example, Dott reported "The activity I created with different balls of plasticine was to increase the students' retention of the knowledge that electrons follow the $2n^2$ rule when occupying the various energy levels from the nucleus" (DottGRD5, r. 10). However, according to Kytt (KyttGRD1), teachers should be careful when improvising with learning materials. He said that he learnt from Rett's GDR1 critical incident that in small scale experiments, everything must be scaled proportionally. He recalled that Rett scaled all the

apparatus in which she was preparing Nitrogen (IV) Oxide, but did not scale down the heating. Her allowing of students to use two burners then caused excessive heating which contributed to the reasons why the experiment exploded.

4.2.2.3 Experimentation: Testing students' understanding of content

Teacher trainers planned experiments to test their students' understanding of scientific concepts and procedures (e.g., KyttGRD1; RittGRD4). Ritt's GRD4 critical incident indicates that he had planned for an experiment to test his students' understanding about complex ions. He "provided them with inadequate sodium hydroxide solution, which was insufficient to clear the precipitate; [he] wanted to test whether they could observe and record correct observations" (r. 68). Although in this experiment students were expected to *observe changes* in the precipitate *as* it dissolved, they concentrated only on the final product. Rather than describing what they saw throughout the process, they indicated that the precipitate did not dissolve (the usual product) since there was precipitate remaining, and this is what they were expecting.

Dott recounted a similar experience to Ritt's in her classroom when testing students' understanding about how cations are identified using sodium hydroxide. She found that because students expected to obtain results immediately when they added sodium hydroxide in excess and did not obtain the expected result, they normally asked why the precipitate is not being formed or why the precipitate is not dissolving instead of recording. She stated that she normally asks them to record what they are seeing, and then from there they normally discuss, and that is when she explains to them the reasons for the variation. Both Ritt's and Dott's experiences serve as evidence that experimentation can be used to test students' understanding of content.

4.2.2.4 Experimentation: To confirm ideas and increase understanding

Teacher trainers carried out experiments to confirm ideas they had, or when students made requests, or when sudden, unexpected situations arose in the classroom. In chemistry, when teachers fail to get expected results, particularly in laboratory experiments, they carry out "on the spot" experiments to explore the reasons for the failure. Rett for instance (GRD2), suspected that someone had exchanged the labels of the containers for the solutions she was using to demonstrate the rate of diffusion of gases, and this quite likely caused the experiment to fail. To "confirm [her] suspicion, [she] tested the two solutions with litmus paper and this confirmed that actually the lab assistant did not follow [her] instructions" (r. 103). An incident in which

an experiment was carried out on request by the students is found in Kytt's GRD1 critical incident where

> students requested [him] whether [they] could go back and repeat the experiment; because they were sure they followed the procedure and did what was expected. And, because they were candidates, preparing for the final examination, [he] thought it was important that [they] re-do the experiment. (GRD1, r. 268)

In these two incidents, teacher trainers reported to have learnt when they confirmed ideas and concepts through experimenting. Rett, for example, reported that she learnt several lessons such as: (a) laboratory assistants in their laboratories might not give the correct information as they are not usually careful when preparing the solutions and labels; (b) it is important to check the work of others (e.g., laboratory technician) to ensure that chemicals are labelled correctly; and (c) it is important that teachers test reagents before conducting experiments in the classroom.

Similarly, Kytt (GRD1) stated he learnt that teachers should not assume that all that is done for them is actually correct. He assumed that students had followed instructions when replacing solid chemicals. He also stated that he assumed he was always correct. In this regard, he noted that it is important for teachers to recognize that the students also know a lot, because when they challenged his marking of some of the students' scripts, he realised that proper instructions were not followed when replacing solid chemicals for the second group of students' practical examination. From this experience, he noted that if the students had not realised and alerted him, he would not have realised there was a problem with the chemicals.

From findings presented in Section 4.2.2, it can be concluded that teacher trainers potentially developed some competence in teaching methods through experimenting. This competence was demonstrated for areas such as: content related ideas, learning materials (DottGRD2), and knowledge of how students learn (RittGRD4). They acknowledged the importance of experimenting, particularly in relation to trialling experiments before conducting them in class. RettGRD1, for example, said that teachers might notice variables they need to change, and probably get better results within a shorter time if they tried experiments in advance. Participants reported a willingness to implement what they learnt through experimentation in their future lessons and to also share their learning with other teachers they train during INSET. This suggests that they considered their learning to be important. They also reported plans to expand their knowledge by inviting other teachers' contributions of experiences in INSET

training. Expansion of this knowledge is likely to make teaching of these particular concepts even better.

4.2.3 Interacting with contact

A third learning activity emerged from the varied ways teacher trainer participants interpreted classroom events and thought of possible alternative teaching methods following individual and group reflection. These interpretations and possibilities of learning came about through participants' interaction with one another and their students in the classrooms. As such, data from these conversations and interactions led to the identification of the professional learning activity termed "interacting with contact".

An example of interaction with contact occurred in the discussion ensuing from Dott's critical incident discussion in GRD1 (detailed in 4.2.1). In this incident, Dott noted her disappointment when her Form Four students could not accurately describe pH values for strong acids, an item of assumed knowledge (from Form One coursework) at this stage of the syllabus. Her students had developed a misconception that stronger acids had larger pH values. When the moderator asked Dott what might have caused such a misconception, Dott was prompted to reflect on the problem. In her response, she noted that "the problem is the way [they] are introducing acids and bases and the pH values in Form One. The concept is still very new to the students" (r. 22). She explained:

> The problem is that in Form One, teaching is done theoretically. I think such a simple experiment could have been done in Form One where we show inflation of balloons. If it was done in Form One so that they see HCl producing gas faster, and then the balloon becoming bigger, they would definitely remember that HCl is a stronger acid (GRD1, r. 26-27).

In this incident, Dott identified an issue with traditional approaches to teaching ("theoretically") as not being effective for student learning. The alternative approach of using balloons to capture hydrogen gas, she thought of using to eliminate the students' misconception, was challenged in the group reflection discussion. The following abbreviated exchange illustrates this interaction:

> **Rett:** How can you eliminate that misconception of the numbers, maybe somebody has a trick.
> **Dott:** Which numbers?
> **Rett:** pH chart values. You know if you tell me that this is a strong acid I will always think of the value six.
> **Dott:** Which I did.
> **Ritt:** Yes, you did but even the issue of balloons is still emphasizing on reactivity and strength not the numbers (r. 48-53).

A further issue was revealed in this exchange when Dott did not appear to understand the issue when she asked Ritt "*which numbers?"* This also suggests a limited knowledge of practical examples for teaching pH values of acids among the participants, as Ritt, was also unable to offer a practical-based resolution to teaching the concept. However, Ritt was able to recognize and explain why Dott's experiment idea did not address the content she was trying to teach.

Further discussion of this critical incident, revealed a possible gap between expectations inferred through the Kenyan chemistry syllabus and Form One students' cognitive abilities:

> **Kytt:** Maybe let's look at what is required in Form One. The emphasis is on the colour more than the numbers. They are required to know that red indicates a strong acid and as we to move towards the blue colour it becomes weak; not relating the numbers now with the colours
> **Rett:** Now you have to think beyond the colours, it is not solving the problem. Check here (drawing), I have a number row 1 to 7. Let's think of how to convince the students without those colours that a strong acid has a value of 1 and a weak acid a value of 6.
> **Kytt:** I was trying to borrow the idea of how we calculate the pH using logarithms.
> **Rett:** Is this done in primary or secondary school?
> **Kytt:** The number line is taught at all levels, but the issue of logarithm is at secondary school level.

From this discussion, we can see that by reflecting on the incident together, teacher trainers were able to consider why Form One students found it difficult to understand the pH values of acids. Moreover, in the same discussion, teacher trainers tried to develop a common understanding of how they could help students understand the concept. It was from the discussion that they realised that the syllabus content regarding pH values was at a cognitive level higher than that of the typical Form One student. Therefore, students are left with no other choice but to memorize pH values. This was noted by Kytt in his comment: "no matter how we try to argue, the issue rests on memorization" (r. 70).

Students at the Form One level have limited chemical and mathematical knowledge and the concept underpinning pH values is abstract, and demands mastery of a large number of related concepts that are taught at higher levels. Therefore, as evidenced by Dott's experience in this critical incident, students were unable to understand the concept of the strength of acids in relation to pH value; and this is probably why they developed the misconception. When Dott was asked by the researcher what she learnt from this critical incident, she said "that [she] need

to differentiate a strong acid and weak acid with simple experiments" (GRD1, r. 43). Her response suggested a realization that she needed to change her teaching practice.

The examples discussed in this Section indicate how interacting with contact through group reflection discussions helped teacher trainers to develop their professional knowledge. By engaging in reflective conversations, teacher trainers realised that some of their teaching methods were not effective. These conversations also led to the sharing of possible alternative methods for them to try with their students. Furthermore, by reflecting on their interactions with their students in the classroom, they became cognizant of students' learning difficulties, and misconceptions. Although they did not always generate working solutions for some of these challenges, they were in a better position to understand the sources of the problems.

During their discussions, participants were not always in agreement about the best teaching approaches to address student learning. For example, Kytt disagreed with his colleagues about students' behavior about one of the suggested teaching approaches (KyttGRD3 Section 4.2.2.1 & 4.3.2.1). Professional debate in these instances guided the teacher trainers' discussion and led to greater clarity about teaching experiences and possible methods. As a result of this sharing, they experienced professional learning. An example of this occurred in GRD6 when Rett admitted that it had not occurred to her that she was not doing the right thing when teaching exothermic and endothermic reactions. As a result of the learning she garnered from the discussion and sharing, she attested to approach the topic differently in future. Likewise, Kytt (GDR1) expressed his appreciation for the group discussion in shaping his ideas regarding changes in practice (Section 4.2.2).

In conclusion, teacher trainers engaged in professional learning activities by *reflecting, experimenting, and interacting with contact* (Section 4.2). The four teacher trainers' reports indicated that these three learning activities were important ways in which teachers developed professional knowledge and skills. In regard to reflecting, the four types of reflection identified (reflection-on-action, reflection-in-action, reflection-for-action, and reflection-with-action), enabled the teacher trainers to firstly, plan *for action* as a result of *reflecting on* their teaching, and then using those reflections to plan future lessons. Secondly, although not planned for, data revealed that teacher trainers *reflected-in-action* and used those reflections to reframe and modify their teaching in the moment. This occurred when they realised students were not

understanding content taught or when experimental activities were unsuccessful. In these situations, they organized on-the-spot experiments to resolve misconceptions, revisited content taught in previous lessons, and held discussions with students to elicit their ideas and learning difficulties. Following individual and group reflection, teacher trainers were able to identify strengths and weaknesses in their teaching methods of which they were not previously aware. They expressed their intentions to use these reflections to modify *their future lessons*. For example, they expressed intentions to involve students more in practical experiences.

Findings from data analysis showed that *experimenting* enabled the four teacher trainers to develop their professional knowledge. They developed this knowledge by trialling different teaching methods, utilizing different learning materials, and confirming ideas and concepts. They took immediate actions to alter their teaching and experimented with alternative teaching methods and learning materials. This happened when they realised students were experiencing learning difficulties as they were teaching and/or when they observed students encountering challenges with particular learning materials, for example solid chemicals and solutions. Teacher trainers also reported their intentions to try their colleagues' teaching methods, learning materials, showing that they learned from participation in group reflection.

Teacher trainers interacted with students in the classroom and with their colleagues in the group reflection discussions. In the classroom, they recalled that through interaction with students they were able to identify specific learning difficulties by: reviewing students' written work; engaging in conversations with students; and observing student behaviours. In group reflection discussions, teacher trainers exchanged ideas about teaching methods and experiences to enhance student learning and experience of subject content. They also shared and critiqued their own and one another's practices. Through these interactions, they potentially acquired knowledge which they could use to address instructional problems, and to explore innovative teaching methods and learning materials.

4.3 Potential professional learning outcomes— what teacher trainers learnt

The study seeks to understand teacher professional learning through reflective practice. As noted in the literature review (Section 2.3.3), practising science teachers have a wide range of learning opportunities. To explore what Kenyan chemistry teachers learnt from their

experiences of critical incident reflection and subsequent group reflection discussion, the second, fourth and fifth research sub-questions were considered. These questions asked:

2. In what ways does pedagogical critical incident reflection facilitate Kenyan County chemistry teacher trainers' learning?

4. How do the Kenyan County chemistry teacher trainers say they intend to operationalize their reflection experience to improve teaching and learning in secondary school chemistry in the Kenyan context?

5. How do the Kenyan County chemistry teacher trainers say they intend to operationalize their learning from reflection in their roles as County chemistry teacher trainers?

Intentions to practice were considered as potential professional leaning outcomes because as Bakkenes et al. (2010) posit, they are precursors of change in actual practices.

To determine what teacher trainers learnt, their responses to questions asked in the critical incident reflection questionnaire (Section 3.6.1) and the interview (3.6.3) were examined. In those questions, teacher trainers were asked to state what they learnt, what they would do if faced with similar situations, and how they would use what they had learnt to improve chemistry lesson delivery and training for chemistry teachers in future. From the analysis of these responses, three *potential professional learning outcomes* were identified in relation to teachers' professional knowledge of practice. These were: *knowledge of teaching methods, knowledge of how student learn, and subject content knowledge*. The analysis also indicated that forms of knowledge used by teacher trainers to learn included *knowledge-in-practice, knowledge-of-practice, and knowledge-for-practice*

Teacher trainers reported personal gains in professional expertise following reflection on practice, and from their participation in group reflection discussions. They tempered most of these claims with an intention to adopt new ideas emerging from their reflection experience in future classroom teaching and in the in-service training they provided as County chemistry teacher trainers. The three potential professional learning outcomes (*knowledge of teaching methods, knowledge of how students learn, and subject content knowledge*) identified in data are presented here separately, however, similar to the potential professional learning activities reported in Section 4.2, they are not necessarily discrete categories.

4.3.1 Development of knowledge of teaching methods

Potential change in teacher trainers' teaching methods was identified as a professional learning outcome. "Change" in this study was reflected by evidence of participants' intentions to modify their practice as a result of their learning through participation in the study. Data in the group reflection discussion and interview transcripts indicated that the four teacher trainers developed their professional knowledge regarding teaching methods, including a shift towards more student-centred approaches.

To "change" *their teaching methods*, findings suggested that teacher trainers used knowledge-in-practice, knowledge-of-practice and knowledge-for-practice which was acquired from individual and group reflection on their teaching. Dott (GRD3), for example, considered a possible weakness in her teaching when conducting demonstrations. She became aware of this weakness from the way her students behaved during a demonstration on testing chloride ions. She recounted: "What surprised me is that, as I was doing all this, my students were just looking at me, some were not even interested with what I was doing" (r. 10). When she reflected on this incident after class, she realised that she rarely involved students in class demonstrations and sometimes she assumed they were following what she was doing, when they may not have been. The other teacher trainers proposed strategies for involving students in the learning process such as informing them "prior to the lesson the content area [to be covered] for them to familiarize themselves with prerequisite knowledge" (RittGRD3, r. 37). Dott, also conveyed that teachers should "also involve them" (r. 38).

Another incident that demonstrated that teacher trainers used knowledge they acquired *in practice* to learn about teaching methods was found when Ritt realised that he did most of the work (teacher-centred) on the chalkboard when teaching ionic equations (GRD3). He recounted,

> The first one, that is preparation of Barium Sulphate I did it on the chalkboard; I was writing on the board but I could ask students as I did that, and some of them could answer; but *I did most of the work*. Maybe I was not very keen of what the students were telling me about the ions, maybe I was writing the oxidation states myself without realizing that some of the students had challenges. I only came to discover when I gave them their own example to work on (r. 80).

From this experience, Ritt reported the following: (a) for this topic, he discovered that the students required to have understood very well prior knowledge on how to write correct

formulae, how to write oxidation states of some ions, for them to be able to handle this content, (b) In future lessons, he would consider the topic on structure of the atom and the periodic table to be very significant in the Chemistry course work, even in other classes, (c) He proposed that this topic should be allocated more teaching hours and that teachers should try to make connections of every topic taught, and (d) that one way of making those connections is by involving students in developing concept maps, which probably would help them to link up topics.

The other teacher trainers acknowledged that writing ionic formulae/equations is a challenging topic and emphasized the following: teachers should revisit the pre-requisite knowledge before commencing on writing stoichiometric equations (Dott); giving few items at a time for students to practice (Rett); and being patient with the students as they practice the skill of writing ionic equations (Kytt).

RittGRD3 shared another incident in which his students surprised him in an experiment in which they were testing chloride ions and the expected precipitate was not formed. He was surprised when students quickly informed him that there was a problem. When he thought about his students' actions, he suspected that they had read in advance what they were going to cover in the lesson. He said that *he learnt* several lessons from this incident, including that: "[teachers] should always inform the students the content [they] are going to handle prior to the lesson and advise them to read ahead, [and that] some topics also require the students to revise the pre-requisite knowledge (GRD3, r. 28). From this experience, he thought if Dott, in her GRD3 critical incident had given students an assignment on the preparation of salts, or solubility of salts, a topic they had covered in Form Two, the students might have had a better idea of what was expected in the experiment she was conducting on testing chloride ions. Ritt purported that had Dott's students revisited the context of salts, they may have noticed that there was a problem with the experiment which they did not. Ritt believed that students should be responsible for their learning; and one way of facilitating such responsibility is for teachers to give them information on what they are to learn *prior* to the actual teaching. He argued that, in general, their students are not serious about their work, especially in science and mathematics; and that teachers have to keep reminding them to revise and read ahead of the teacher.

Ritt's and Dott's critical incidents, illustrate that teacher trainers learnt about teaching methods from their reflections on their teaching experiences. This learning offered them a basis for thinking about and planning their teaching methods in terms of student learning. Rett, similar to the other teacher trainers, reported in her interview that:

> I learnt that it is good sometimes us as teachers we involve our students in one way or the other to assist the rest, what we have as peer teaching. So that we do not spoon feed [but] we also allow them to be actively involved. (Rett interview, r. 10)

Findings from data analysis also showed that teacher trainers learnt about teaching methods through *knowledge-for-practice,* which they acquired during group reflection discussions. Ritt said that he learnt a new way to teach electronic configuration from the discussion of Dott's GRD5 critical incident. He stated:

> I have been giving a theory approach… I did not have any other way of teaching and I think that is why I have been having the same problem my colleagues have been having, but today *I have gotten a new idea*. From what [Dott] has described, the way she has been doing it. *I think I will adopt her method*, and see whether it can change my students. (r. 16)

Dott's response in the GRD2 discussion, illustrated in the excerpt below, also suggested that she learnt from her colleagues.

> **Moderator:** The point you missed is that part where you could have explained about the reactions taking place at the electrodes.
> **Ritt:** Maybe the opportunity did not arise because of the setup of the experiment the students proposed. However, you could have done that with the juice.
> **Dott:** I agree it is a point I missed, I have taken note (r. 81-83).

This interaction helped Dott to realise that the approach her student suggested, to find out whether local materials such as lemon juice could be used as electrolytes, was not as effective as she thought. The lemon fruit suggested by the students could not explain the reactions taking place at the electrodes, a learning outcome prescribed in the Form Two Kenyan syllabus. By stating that she had *"taken note"* suggested that she learnt and would likely try what she learnt in future lessons, when handling the same content.

Interview data corroborated group reflection discussion data, revealing that teacher trainers acknowledged having learnt about teaching methods from their colleagues. Kytt, for example, explained:

> In the group reflection, I experienced a lot of learning. This is where I realised that we have different approaches of teaching the same content. The same content can be approached using different methods depending on the students one is handling. I also

> learnt others have the same challenges I have with my students but they approach the problem differently from the way I approach. I thought it is the way I have been teaching certain concepts but I realised there other ways of doing it. (Kytt interview, r. 27)

Teacher trainers also reported having learned alternative teaching methods from knowledge they constructed from their own classrooms *(Knowledge-of-practice).* Ritt, in GRD5, decided to try a different teaching method because he was having a back-log of Form Two work that had not been taught in the stipulated time frame. He set up an activity and gave groups of students some guiding questions to research. He asked them to present their research to other group members through the method of micro-teaching; before presenting in the actual lesson. In his account of this critical incident, he "learnt that students can learn on their own if they are organised and are given direction and necessary resources" (r. 77). He thought his students would not cooperate, but to his surprise, he said the lesson was interesting. Following this learning experience, Ritt stated:

> What I would do in future lessons, when I have a topic that I want to cover in a short time, rather than going step by step the way we have been doing. I will be dividing the work among students and give them some time to go and do some research and present their findings to the class. (r. 76)

Similarly, in GRD6, Dott conveyed her realization that few students answered questions on empirical formulae correctly in an exam she had administered, suggesting they had not understood this concept. Consequently, she decided to use one of the students, who scored well on these items, to peer teach the others. From the way this student explained the concept to the other students, Dott learnt "that probably if students among themselves may copy and imitate [her] teaching, and they do it among themselves, they like it more and they understand" (r. 8). Rett and Ritt supported Dott's teaching method, but Rett was worried that students could "lose confidence with [her] and trust their fellow friends" (r. 13). There is also a risk in peer teaching that incorrect information is conveyed, as it happened in her lesson about the concept of ions and electrons. Ritt shared an incident that occured in his school with one of his colleagues to support Rett's concern, he recalled that:

> one of [his] colleague teachers used to tell students to peer teach every time he felt he was not fully prepared, but after some time the students realised his weakness and embarrassed him in class when they demanded to be taught by one of his students. (r. 14)

Critical incidents reported in Section 4.3.1 demonstrate that teacher trainers developed knowledge of teaching methods acquired in, for, and of practice. The three forms of knowledge,

therefore, have potential to help teachers improve teaching methods and student learning. In GRD3, Dott realised a weakness in the way she carried out demonstrations, whilst, Ritt learnt that students' negative attitude towards the "mole concept" could be solved by varying the teaching methods. According to Ritt, when another teacher was invited to introduce the topic for him, students' performance improved, and they appeared to have hope to pursue the subject.

Ritt (RittGRD5) said he was happy with the peer teaching method he used because he spent only a few minutes clarifying a small number of misconceptions and omissions. He said that he covered a whole topic within a very short time. In DottGRD6, Dott reported that peer teaching enhanced her students' understanding of empirical formulae. Ritt (RittGRD5) also learnt a new way of teaching electronic configuration from Dott's critical incident discussion; and Dott (DottGRD2) noted areas that needed improvement in her teaching practice.

When teachers developed knowledge of teaching methods that enhanced quality of teaching and learning, students' learning was also enhanced, as demonstrated by Dott's GRD5 and Ritt's GRD2 critical incident discussions.

4.3.2 Development of knowledge of student learning

Knowledge of student learning refers to the knowledge teachers are expected to have to help students learn. This includes pedagogical content knowledge, that of knowing how students learn specific subject content, and of knowing how to identify and address misconceptions that students might develop. Additionally, knowledge of student learning incorporates general pedagogical knowledge. General pedagogical content knowledge refers to the range of learning theories and teaching and assessment strategies that enables teachers to accommodate all students' needs and learning abilities, and how to elicit and respond to students' prior conceptions that influence learning.

Data revealed that teacher trainers built knowledge of student learning and how to provide it from knowledge of, in and for practice acquired from their individual and collaborative reflection on their teaching experiences. Aspects of this learning included an increased awareness that students can learn better when teachers (a) involve them in practical experiences; (b) use students' ideas, (c) use guided practice, (d) address misconceptions (e) use students' prior-knowledge, and (f) attend to the language used in providing explanations. Data supporting the identification of these areas of teacher learning are discussed in the following sections.

4.3.2.1 Practical experiences

Participants realised that they were not involving their students fully in practical experiences, which is a critical component in learning both knowledge and skills in Chemistry (e.g., DottGRD3; RettGRD2; RittGRD6). Chemistry is a practical subject consisting of many concepts, some of which can be explored experimentally (DottGR1). As demonstrated in data, practical experiences were used to model some of the abstract concepts of chemistry and stimulate students' interest in aspects of the subject that they often find difficult and/or boring (Ritt GRD2). Increased engagement of students through practical experiences enhances student learning and retention (DottGRD5).

Rett, in GRD1, reported that "when [her students saw an experiment] set up, they [were] excited and ready to do [a] practical" (r. 136). Further, she said that students were so excited when they heard the cracking sound of the Nitrogen (IV) Oxide gas being released. Kytt *noted his learning* from the discussion of from Dott's GRD3 critical incident regarding students' behaviour when not involved in practical experiences. Dott blamed students' behavior on a lack of interest and a negative attitude towards chemistry. Kytt, however, suggested it was partly because she did not involve them in the experiment she was conducting. He stated, regarding his reflective thinking:

> When I come to think about it, and *also learning from the way your students behaved*, I can now approach it differently. I would ask my students to predict the expected results before doing the experiment. I will ask them to try and remember what we learnt when we prepared salts in Form Two. By doing this, I will expect the students to be curious at the outcome of the experiment. Those who will have predicted formation of a precipitate maybe will engage me, and as we argue we will come to realise where the problem is. (GRD3, r. 20)

In GRD4, Dott realised that her Form Four students had not developed skills required to fold a cone from filter paper for filtration. She said that when she reflected on this incident, she remembered that when she "was doing the same experiment with these students back in Form One, [she] did a class demonstration; and therefore, maybe [she] did not actively involve the students in the actual folding of the filter paper" (r. 8). Thus, Dott learnt that denying students opportunities to actively engage in practicals, likely contributes to the challenge they experienced in folding the filter paper.

RittGRD6 also discussed the potential impact of teachers' tendency to perform demonstrations rather than running practical classes when considering why his students could not fix a clamp

on a retort stand. He noted that the over-reliance on demonstrations meant that students were not gaining frequent experiences of handling apparatus. He said:

> "in many lessons [he] just do a demonstration without a class practical. And [he] usually do not involve the students in those small things like connecting apparatus in front of the class…, [and that] in most cases [they] usually give [students] a stand which is complete where the clamp has been fixed and they use it the way it is. (r. 58)

Ritt said that in *his future lessons he would increase* the frequency in which students assemble and handle apparatus, and ensure that when doing demonstrations, he would provide students opportunities to manipulate apparatus. He also noted that he would take apparatus mentioned in the teaching to show students, even in lessons not requiring demonstrations or class experiments. In addition, he noted his intention to "disabl[e] some apparatus and allow students to assemble, just for them to practice, so that they could also come to know these things" (r. 59).

In regard to students' challenges in developing manipulative skills, DottGRD6 said that when she gives her students an unassembled retort-stand and clamp, they normally tell her it is faulty. From the group reflection discussion on this issue, she stated: "I *think I am getting it clear* that I need to show them as early as lower classes, how to set a stand and a clamp" (r. 62), suggesting that Dott was learning from engagement in discussion with her colleagues.

Rett supported Dott's notion of the need for early exposure to apparatus, conveying that students are not introduced to laboratory apparatus until Form One, and then, they are only shown the apparatus and details of use and any assembly required is not demonstrated. She suggested that in future, teachers should show students how these apparatuses are assembled and allow them then to handle them directly. She also said that teachers should allow students to assemble their own equipment in Form Three titration, for example, where students interact with apparatus such as burettes, retort stands, and clamps, so that they can practice and further develop manipulative skills. Rett reiterated the sentiment in her interview. She said that *she learnt* that it is important to allow students to interact freely with chemicals and apparatus such as clamps and burettes, so that they can carry out experiments without problems.

Teacher trainers also appeared to have learned from involving students in practical activities (e.g., DottGRD1; DottGRD5; RittGRDI). Ritt in GRD1 recounted a critical incident that occurred when he was standing in for a colleague, and the redox reactions experiment students

were conducting was unsuccessful. He decided to involve students in a group discussion and to prepare additional solutions to try the experiment a second time. He recalled that, to his astonishment, the students engaged in a "meaningful" discussion and came up with reasons for the experiment's failure. When they repeated the experiment, he observed that

> As the experiment progressed successfully, [he] could see the enthusiasm of the students, they were eager to see whether the solutions they had assisted [him] prepare would work, or it would behave like the other one that did not work. [He] saw their commitment that last minute of the lesson and they really worked hard and when the colour changed [he] could see them happy, talking to each other, "Have you seen it?. Have you seen it?'' such kind of a thing. (r. 228)

From the way these students reacted following this practical experience, Ritt said that he learnt that if the experiment worked as planned, it could have boosted the confidence of the learners. He also realised that involving students in practical experiences motivated them and enhanced their learning. A similar conclusion was reached by Dott in GRD1. She reported that her students were able to understand that HCl was a strong acid through the practical experience she engaged them in an experiment with balloons. She said that previously, she taught this concept "theoretically", and that this is probably why her students could not answer the question she asked about the strength of acids. When she involved the students with the experiment involving balloons:

> After 10 minutes, the balloon with the flask with HCl acid inflated very fast and it looked bigger, than the one with ethanoic acid. [she] posed the question again, and they said, oh, so, it means HCl acid is strong acid now that there is more production of gas in the HCl than in the ethanoic acid. (r. 18)

From the discussion on these experiences, teacher trainers learnt that there is a need to involve their students in practical experiences for various reasons, such as: for students to develop manipulative skills (DottGRD4; RittGRD6); to enhance students' understanding (RittGRD2; RettGRD2); and to expose students to laboratory apparatus (RittGRD3). Ritt noted that they should expose students to laboratory equipment because some students in Kenya come from a very poor background and they are seeing basic laboratory apparatus, such as gas burners, for the first time in secondary school.

4.3.2.2 Student ideas

Teacher trainers' reflection discussions suggested that they learnt about the importance of using students' ideas as another way to involve them in the learning process. For instance, Kytt (GRD1) said that he learnt that "many a time, [they] assume the teacher is always right. [He

said that] it is also important that [they] recognise that the students also know a lot" (r. 329). Teacher trainers noted that student learning was more successful when they used students' ideas in the classroom. There was no evidence in data showing that they had planned to use these ideas. They were compelled to do so by situations that arose in the classroom. This was an important realisation, and the teacher trainers began to think of specific tasks they could use to increase their use of student ideas.

An example of this occurred for Dott (GRD 2) when running an experiment on the use of local materials as electrolytes (Section 4.3.1). In this experiment, she used lemon juice but when she responded to her students' request to try the experiment using the whole lemon fruit, she noted from the outcome that:

> the students are likely to have better ideas than [herself], and they put a lot of weight on them… So, [she] think[s] this was very effective and [she] found out that [she] could use the students' ideas, give them room to explain how we can do a particular experiment that [she] present[s]. (r. 11-14)

She reported to have "learnt that students can be creative and innovative and improve teachers' ideas; [she noted] this is quite interesting and [she] learnt [she] should provoke students to think more innovatively" (r. 22). She further explained that ''the students became interested and they were very happy with [that] particular lesson" (r. 13). Dott demonstrated her intention to increase the use of students' ideas when she said that in her future lessons, she would borrow students' ideas and incorporate them in her lesson preparation. However, she did not explain how she intended to elicit these ideas from the students prior to planning her lessons. She did also state that she could even ask students to demonstrate their ideas.

Ritt and Kytt's comments during GRD1 supported Dott's idea that students' curiosity is aroused and that they are more motivated when their ideas are acknowledged by teachers. Ritt's discussion of his critical incident reported in Section 4.3.2.1 regarding redox reactions, shows that he learnt that students' curiosity was aroused, when their ideas were considered in the prepararation of the chemical reagents needed to repeat the experiment. In a similar way, Kytt observed his students' excitement:

> The students requested me whether we could go back and repeat the experiment… some students said, "Teacher, I shall repeat what I did". As the experiment progressed I could hear them say, "Now this is what we observed and this is what I have written, you see". (GRD1, r. 269)

Despite the generally positive discussion around using students' ideas, Ritt (GRD2) cautioned his colleagues to be careful, because sometimes this might hinder them from explaining important points. Such an incident was reported in Dott's GRD2 critical incident discussion, reported in Section 4.3.1. When Dott used the whole lemon fruit on students' request, instead of just the lemon juice, she was denied the opportunity to explain that electrolytes are decomposed by electric current. With the whole fruit, the reaction at the electrodes was not visible as the site of the reaction was on the part of the electrode embedded in the lemon. Dott noted this, saying "with the lemon, they could not see the reaction" (DottGRD1, r. 80). Likewise, in Rett's critical incident, discussed in GRD1 (see Section 4.2.1.2), the experiment exploded because on request of the students, she allowed them to heat using two burners. Situations such as these led to Ritt's caution that teachers need to consider students' ideas before using them and *guide* students where necessary, so that the ideas are geared towards in-depth understanding of scientific concepts, and that they are safe to include.

The experiences reported here suggest that teachers became aware that they should not assume their students are "blank slates" with no prior knowledge or ideas (KyttGR1). Emphasising this, in his interview, Ritt said that he learnt from his reflections that:

> students know and have lot information, if only they are given time to work together and to do some things on their own—do research. Instead of the way I go to class, present information to them and it ends there. I learnt that when student are given some information to work on—do some research, they can even go out of their way and more than I could have done.

4.3.2.3 Guided practice

In several instances, teacher trainers realised that guided practice in their classrooms was either ineffective or was totally lacking. Such a situation arose in the discussion of Dott's critical incident in GRD4 (Section 4.3.2.1). She realised that guided practice was necessary for students to gain skills in folding filter paper to make a cone, and that teachers need to recognise the steps in the folding process with which students experience difficulties. She resolved that

> in future lessons; instead of giving students the whole procedure, [she] will be doing it step by step until [she is] sure they are able to do the right thing; for example, folding filter papers to make cones. (r. 9)

She said that teachers should not assume that students follow what they are shown when they are not actively involved in the learning process.

In the same group reflection discussion (GRD4), Ritt also reported that he learnt the importance of student step-by-step guidance. He became aware of the importance of guided practice when his students failed to make correct observations in precipitation reactions of an experiment (Section 4.2.2.3). He related his emerging thinking, that if teachers demonstrated the experiment before students carried it out, it would be a good way to guide the students and equip them with appropriate expectations of the activities to be performed. He said that this should apply even where a manual has been provided. There was no evidence in data how he was going to carry the demonstration without doing the actual experiment. If a teacher conducts the experiment before students carried it out, there is a possibility of diminishing their interest and denying them an opportunity to develop scientific iquiry skills.

4.3.2.4 Student misconceptions

Research suggests that students' chemistry misconceptions stem from many factors, such as difficulties in understanding scientific concepts, inappropriate teaching methods, and the abstractness of the subject. Such findings were no exception in this study. Kytt proposed in one of the group reflection discussions "I think the way we are teaching our students, they do not seem to understand" (GRD3, r. 34). If his sentiment is correct, it is likely that students are developing many misconceptions. Several critical incidents demonstrated teacher trainers coming to the realisation that their students held misconceptions of which they had not been previously aware (e.g., RettGRD6; DottGRD1). They also attributed the way they sometimes taught, at least in part, to the formation of these misconceptions (DottGRD4, r. 58).

An example of teacher trainers intimating teacher responsibility for misconceptions is seen in GRD5, when Dott discussed typical approaches to teaching about electron configuration. She said teachers "sometimes bring misconceptions and also [they] do not give [their] students opportunities to internalize those concepts" (r. 31). This prompted the group participants to recognise a need for a change in instructional strategies. The discussion led to Ritt's description of the typical approach to teaching electronic configuration, whereby a circle is drawn to represent the nucleus. Although teachers normally explain that the inner circle represents the nucleus, students often view this part of the image as another energy level. In response to Rett's GRD4 critical incident discussion, Rett proposed the use of something else other than a circle to differentiate the nucleus and hence, to avoid this common misconception from arising.

In contributing to this discussion, Dott noted that student misconceptions are likely to happen when teachers use text books verbatim. She noted that the discussion around the way this topic is generally taught reflects the way it is represented in text books. This is probably why her students did not understand this concept. She thought "maybe if [Rett] had made her own models and changed the way the nucleus is represented, so that it does not look like a circle" (r. 58), students may have understood why she did not place "electrons" on the circle forming the nucleus.

In another example, Rett reported that her students held a misconception about endothermic and exothermic reactions. She described in GRD6 how her students, "instead of drawing an energy level diagram showing endothermic reactions they were showing an exothermic reaction" (r. 22). She said that she was disappointed because the temperature readings taken in the experiment registered a decrease and therefore, she expected them to represent their findings in relation to an endothermic reaction. From this critical incident, she came to believe that students had not understood the difference between exothermic and endothermic reactions (although it may have been that they did not know which diagram represented which reaction type). During the reflection discussion session, teacher trainers wondered about the source of the error. If students did actually take the correct readings from that experiment, Ritt thought "the issue could be the way the teachers are approaching that concept of endothermic and exothermic reactions" (r. 28). He said that "what most teachers usually do, they do not take time to explain to the students the endothermic process before energy level diagrams." [He said that teachers] only tell students that if it is an endothermic reaction the products are at a higher energy than the reactants" (r. 34). He said that teachers often fail to explain that the reaction is drawing heat from the surrounding environment, and so, for an endothermic reaction, the temperature of the thermometer will record a drop in temperature; but the reactants gain heat energy, and thus the products are at a higher energy level. According to Ritt, if this concept is not explained clearly, students are likely to become confused, and associate a drop in temperature with a drop in the products' energy. He purported that if Rett had not taken time to explain the concept to the students clearly, this would definitely result in misconceptions.

When teacher trainers reflected ways to better approach the teaching of energy level diagrams for exothermic and endothermic reactions, Rett realised that she needed to change her methods. She commented: "It had not occurred to me that I was not doing the right thing; I thought they

understood because they did not ask questions at the end of the lesson. Now I will approach the topic differently" (r. 37). Dott said students' difficulties in drawing energy level diagrams for these types of reactions are common among chemistry teachers. From their reflection discussion, she thought it could be of importance that "they took time to [explain to] students what happens to the system when a reaction occurs so that when [they] give an activity and [students observe] a temperature change, they will be able to relate the [two concepts]" (r. 33).

Further reporting of students' misconceptions arose in Dott's critical incident description concerning acids and their pH values (GRD1, Section 4.2.1.1). Dott intimated a realisation that her students had a misconception after she questioned them at the commencement of the lesson "The students were thinking that the higher the pH value the stronger is the acid" (r.12). According to the four teacher trainers, this misconception was influenced by the chemistry syllabus, which required students in Form One to know only the pH values of acids and bases using the pH scale chart. In the Kenyan chemistry syllabus, the topic of how these values are calculated is covered in Form Four.

In conclusion, teacher trainers' reports indicated that they were not aware of their students' misconceptions in the topics they described in their critical incidents. DottGRD1 and RettGRD4 for example said they were disappointed because they did not expect such misconceptions with students in Form Four. Learning about these misconceptions through reflection on their practice could be influential in their planning of future lessons. This potential influence was demonstrated in Rett's comment where she said that she will approach the topic differently (GRD4). Dott (in GRD1) also noted that if teachers used simple experiments, students would probably understand and remember that a strong acid has a lower pH value.

4.3.2.5 Prior-knowledge and pre-requisite knowledge

Teachers' knowledge of students' prior conceptions makes it possible for them to sequence instruction appropriate to learners' needs (KyttGRDR3). This is an important area of concern given that students require substantial pre-requisite knowledge to understand subsequent and interrelated topics in chemistry (RittGRD3). Data showed that individual and group reflection helped teacher trainers realise the importance of understanding students' prior knowledge before planning their lessons. Such an understanding, KyttGRD3 attested, would provide teachers with information that could help them plan lessons that could result in students'

learning. For example, in GRD3, Ritt described a critical incident in which he did not achieve his lesson objectives because his students had limited knowledge of what he intended to teach. He acknowledged that his lesson outcomes were compromised because students did not know how to write ionic equations, an area of pre-requisite knowledge. He commented:

> At the end of the day, the lesson ended when we had not achieved the objective of writing ionic equation because there was some knowledge students did not have. Wh\] at *I discovered* is that, for this topic, the students required to have understood very well *prior knowledge* on how to write correct formulae, how to write oxidation states of some ions, for them to able to handle this content (r. 74).

Kytt conveyed his thoughts in GRD3, that teachers should use students' prior knowledge instead of always giving them instructions on how to do experiments. They should allow students to test their preconceptions in the laboratory, come up with their own methods of confirming these preconceptions, and share their outcomes, regardless of whether they get positive or negative results.

Teacher trainers' reflective discussion demonstrated an increased understanding of the importance of knowing their students' prior knowledge in order to inform their planning. Such an understanding was evident in the example from Ritt above and was echoed by others in their discussion. In a related way, Kytt also noted how learning materials that are familiar to students could enhance learning as he reflected on the time wasted when his students were distracted by the metal balls used in the modelling task discussed in GRD3. Lack of students' prior and pre-requisite knowledge resulted in Kytt and Ritt spending a lot of their class time engaged in tasks that detracted them from the time they needed to explore the intended outcomes.

4.3.2.6 Language use

Finally, teacher trainers also recognised the importance of considering the language they used when communicating chemical terms with students. Language used by teachers and in textbooks can act as a barrier to student learning (Rett GRD3). Most of the language that limits student learning is associated with words that have alternative, "common-language" meanings that differ from their science-specific meaning. This was reported to lead to confusion for some students. Rett reported an example of this language confusion in GRD3 when she used the word "reactive' when giving precautions about sodium metal. From the way her students behaved, she *realised* that they had interpreted the word as something explosive and dangerous. She came to this realisation because most of the students declined to move close to the demonstration

table to observe the reaction. She also described how she asked them work in groups to heat the metal, but most declined, and only a few were courageous enough to heat the sodium metal. Comments made by the other teacher trainers during this group reflection discussion, illustrated in the excerpt below, show that the word "reactive" acted as a barrier to student participation and could have been avoided if more considered language were used.

> **Moderator:** Did you say that it is reactive and dangerous? because there are words we use and they scare students?
> **Rett:** Personally, I assumed it is part of the precautions that I should give before we heat Sodium.
> **Moderator:** It is, but I am concerned by the words you used and also the timing. Or what is the feeling of the other members?
> **Dott:** For me, so that I can make more students to participate in this lesson, I would have avoided telling them that heating sodium is very dangerous and I give them a sodium metal piece equivalent to the size of a match stick, and tell them to heat when the burner is at a distance. So that if the metal sparks, it will not do any harm to the students. Then, when they do that, probably at the end of the lesson, I will now explain to them that the sparking of the sodium they saw is due to its reactive nature and that's why we heated only a small piece. I could have approached that way. So that many do it, I first hold my sentiments that burning sodium can be dangerous.
> **Ritt:** I share the same sentiments as my colleague here. Sometimes there is a way you can handle instructions with the students and you make them get afraid to participate (r. 50-54).

Rett confirmed that the issue resulted in a lot of the lesson's time being wasted: "A lot of time was spent in encouraging the other students… [she] did not have time to heat the other metals, [she] had to postpone the heating of the other metals to the next lesson" (r. 48). This discussion helped teacher trainers to think more critically about the language they use when giving precautions for carrying out experiments. After listening to her colleagues' alternative ways of giving precautions, and their alternative methods of teaching about heating metals in air involving reactive metals such as sodium, Rett expressed *intentions to change her practice.* She claimed that **"[**she] will try all that with [her] next Form One class and see whether it works" (r. 66).

Dott acknowleded that according to the syllabus, they are not supposed to heat metals like sodium when the moderator asked them whether students are allowed to heat reactive metals on their own. However, she also noted that there was no issue in teachers going beyond the syllabus at times, as teachers are encouraged to be innovative. She conceded, however, that a class demonstration rather than small group work would be more appropriate for a task like that described by Rett. Some experiments are more dangerous than others, and where there is

increased risk, such as in heating sodium metal where some students may not be careful enough and may end up being burned, a demonstration would be best.

Overall, reflection on this critical incident demonstrated learning about language use in chemistry teaching. The outcome of this particular example showed Rett's intention to try her colleagues' alternative methods of teaching after experiencing the adverse effect of her choice of language in introducing an experiment.

Findings discussed in this section show that teacher trainers became more aware of student learning difficulties and, through reflective discussion of their practice, developed knowledge of alternative teaching and learning strategies. Teacher trainers came to realise that their classrooms were characterized by teacher-centred methods that left little room for them to appropriately consider student learning. Kytt and Dott, in GRD3, noted that their teaching was sometimes not translating to student learning, and that this occasionally led to the development of misconceptions. They acknowledged the importance of involving students in practical experiences. Rett observed her students' excitement when conducting laboratory experiments; and Kytt learnt that when students are not involved in practical experiences, they are less likely to show interest in learning. Dott, in GRD1, also realised that students' misconceptions about the strength of acids and pH values could be minimized by involving them in practical experiences. She used the rate and extent of balloon inflation to show that a strong acid produces more hydrogen gas than a weak acid when reacted with magnesium. Furthermore, Dott, Rett, and Ritt all discussed their learning of the importance of early practical experiences and of handling apparatus to develop students' manipulative skills.

Teacher trainers also came to realise that students were motivated when their ideas were used in the process of learning. This was observed with Ritt and Kytt when they recalled conducting laboratory experiments using reagents students had prepared. Dott also reported her students' excitement in class when a bulb lit in an experiment after the student suggested they use a lemon fruit as a possible electrolyte.

Dott and Ritt stated that they needed to guide students step-by-step, instead of giving them the whole procedure in the form of a manual. They reported that this would better enable them to identify areas in which students experienced difficulties, especially in laboratory activities. Ritt and Kytt learnt that prior knowledge and pre-requisite knowledge shaped students'

development of new knowledge. Kytt thought he could help student learn by using materials they are more familiar with, for example, using beads before introducing metals balls when teaching relative atomic mass. Ritt learnt that he needed to build on students' prior knowledge, and that he needed to begin his lessons by reviewing materials from the previous lesson to assess students' understanding before introducing new content. Teacher trainers were also concerned with language they used, especially when giving precautions in the laboratory. They realised that some terms can discourage students and sometimes scare them from conducting laboratory experiments.

From their own reflections and those of the group, teacher trainers proposed alternative teaching methods that they thought would lead to improved student learning. These include: involving student in practical experiences; conducting guided practice, using student ideas; and considering prior knowledge before teaching. In this regard, it can be argued that teacher trainers developed knowledge of how students might learn better through their individual and collaborative relfection practice.

4.3.3 Development of content knowledge

Findings suggest that critical incident reflection contributed to the development of the teacher trainers' understanding of some *concepts and procedures* in chemistry. Some of the critical incidents reported suggested that teacher trainers gained content knowledge (e.g., DottGRD1; DottGRD3; RettGRD6).

For example, Dott (GRD3) said that she learnt that she "should follow the right procedures when preparing reagents so as to get the expected results and avoid disappointments before learners, as [she] did when doing this simple experiment" (r. 12). In the experiment she was testing chloride ions, she realised that "some experiments are concentration sensitive" (r. 14). She used prior prepared solutions of dilute hydrochloric acid to test chloride ions, but the precipitate was not formed as expected. The precipitate, which was formed in a repeat of the experiment with sodium chloride as an alternative, then did not dissolve with heating as expected. She stated, "Actually we are supposed to warm but since it was not dissolving I boiled and boiled but the white precipitate was not dissolving. I was a little bit disappointed and I was also sweating before the learners" (r. 6). After reflecting on this incident, she said that she

> realised that in the first incident, the chloride ions from the hydrochloride acid were too few, they could not precipitate the lead ions from the lead nitrate which [she] had used

too much of it. Then, in the second incident, [she] had used too much sodium chloride and that is why the white precipitate that was formed even after boiling and boiling was not dissolving (r. 8-9).

During the DottGRD1 group reflection discussion, basic concepts of mathematics were explained to Rett, who was not very sure about them, as illustrated in the abbreviated excerpt below. This helped her to deepen understanding of mathematical concepts related to some chemistry concepts such as pH values.

Dott: Will it work mathematically?

Kytt: It might. By comparing chemistry and mathematics and the number line; you know mathematics is compulsory for all students and also because they have gone through the number line and the good thing with the number row is, it's done in every class right from Form 1.
Rett: Are you saying the number line starts with 7?
Moderator: No, he is talking about 7 being neutral, so that, as you move towards the positive it becomes basic.
Rett: Which one is bigger -1 or -2? Forgive me; I am a Biology Chemistry teacher.
Kytt: -1 is bigger than -2.
Rett: And which acid is stronger, when it has a value of -1 or that with -2?
Moderator: -1
Rett: You see, the misconception is still there, the number is still small.
Kytt: No, in mathematics we say that -1 is more positive than -2.
Rett: Not easy but if it can work in mathematically; it is Okay (r. 106-123)

Through group reflection discussion, teacher trainers engaged in reasoning and problem solving that deepened their understanding of this particular topic of acids, bases and pH values. They explored possible causes of the common misconceptions in this topic. They realised that content taught in some sub-topics, such as pH values, had related content that was beyond the level of students in Form One.

In conclusion, teacher trainers' reports presented in Section 4.3, illustrate that they developed their professional *knowledge of teaching methods, how students learn, and content knowledge* through individual reflection and group reflection on teaching practice. Data analysis showed that most learning experiences resulted in teacher trainers "acquiring" professional knowledge and "intentions" to implement changes in their future lessons. Understanding the strengths and weaknesses in their teaching methods, how their students learn best, and gaining a deeper understanding of content in specific concepts, is something that could lead to change their practices in the classroom.

Teacher trainers proposed alternative teaching methods to improve their practice for areas in which they thought their teaching methods were not effective. They expressed intentions to try their colleagues' teaching methods and they proposed to develop cases from those experiences that they could use during in-service teacher training.

Increased understanding of how students learn and where their learning difficulties lie, afforded teacher trainers opportunities to explore strategies and materials that could help students' understanding of scientific concepts. Individual and group reflection helped teacher trainers to better understand some subject content and procedures.

It can be argued that, based on the reported critical incidents, teacher trainers developed their professional knowledge of *teaching methods, how student learn, and content knowledge.* However, because of the tacit nature of professional knowledge, in some instances, it was difficult for the teacher trainers to understand or articulate their own learning experiences. Teaching and learning experiences, which could have afforded teacher trainers' learning opportunities, were occasionally inhibited by contextual problems.

4.4 Contextual problems

Research has shown that to an extent, activities teachers undertake in class for effective teaching and learning of chemistry are impeded by contextual factors. This research was supported by findings in this study. To identify potential contextual problems, the third sub-research question was posed: *What are the common contextual problems Kenyan County chemistry teacher trainers face which prevent them from pursuing their pedagogical goals in their chemistry classrooms?* Professional learning can result in effective teaching, which plays a vital role in improving student performance and teacher professionalism (Section 2.3). Ineffective teaching partly contributes to poor student performance, as observed with Kenyan secondary students in chemistry, and at times, reasons for this ineffective teaching stems from issues that are context-specific. The desire to identify such context-specific issues was the impetus for this research study.

Contextual problems considered in this study were those specific to their affect on teaching and learning stemming from the classroom (related to teachers and students), the school, and external factors such as external examinations. Chemistry teaching and learning is supposed to be student-centred; thus, students need to be actively involved in the learning process (DottGRD4; RittGRD6). This can only be achieved when students are willing to participate in

their learning (RittGRD2) and when teachers provide opportunities for such active engagement by using appropriate teaching methods and learning materials (DottGRD2; KyttGRD3). Teaching and learning in chemistry is influenced by many factors. Those identified in the data of this study include factors related to: the classroom level, the school level, and other external professional related factors.

4.4.1 Classroom factors

Classroom factors influencing effective teaching and learning included those related to: (a) Teachers, such as teacher trainers' general pedagogical knowledge and their pedagogical content knowledge (DottGRD1; RettGRD2; RittGRD3), assumptions, beliefs, and attitudes (DottGRD3: KyttGRD1), and teaching time (KyttGRD1; RettGRD5; RittGRD3); (b) Students, such as student beliefs and attitudes (RittGRD2), and students' learning abilities (DottGRD1; RittGRD3).

4.4.1.1 Limited pedagogical knowledge and pedagogical content knowledge

For teachers to teach effectively, they need pedagogical content knowledge (PCK), general pedagogical knowledge, and subject content knowledge. Data analysis revealed that in some topics, teacher trainers showed limited general pedagogical knowledge and pedagogical content knowledge required for effective teaching in chemistry (e.g., DottGRDI; DottGRD3; KyttGRD3; RettGRD3). Specifically, they showed limited competency in applying effectively strategies to assess and respond to students' learning difficulties. Teacher trainers also acknowledged their lack of knowledge and creativity in how to utilise local learning materials (DottGRD5; RittGRD5), and in not giving students enough time at an individual level (KyttGRD3).

Limitations in applying effective *instructional strategies* were found in Dott's critical incident discussion (GRD2) when she was demonstrating electrolytes using lemon juice (see Section 4.3.1). The purpose of this activity was to discover whether local materials such as lemons could be used as electrolytes. The use of familiar learning materials was meant to *arouse students' interest, creative thinking and motivate them to learn.* However, Dott, did not adopt an inquiry approach to her teaching. She "introduced the lesson by informing the students that the lemon contains citric acid and it can be a local electrolyte" (r. 7). By informing the students that citric acid in the lemon is an electrolyte ahead of experimenting with it, stifled students' curiosity and

creative thinking. She denied the students the experience of scientific inquiry advocated in the Kenyan secondary school chemistry syllabus (KIE, 2002).

Likewise, when Rett noted an error in the experiment in which she was demonstrating diffusion of gases, she "corrected the error instead of having the labelling as A or B [she] used the real names of the solutions" (GRD2, r. 105). Although she acknowledged that she did not give students an opportunity to make observations, using the real names of the gases also curtailed students' curiosity and creative thinking, both of which form a part of scientific inquiry. In GRD4, Rett recalled that she prepared rings from a nicrome with different diameters and arranged them in order from smallest to largest diameter when she realised students had difficulties in understanding electron configuration of atoms. Although she said that her students showed some signs of understanding, they would probably have understood better if she allowed them to do the activity rather than conducting it herself.

In reporting their critical incidents, teacher trainers often said that they use "a theoretical approach" to their teaching (e.g., RettGRD1; RittGD2; RittGRD3). RittGRDR5 for example said that he normally taught electronic configuration theoretically because he "did not have any other way of teaching" (r. 16). He noted his thinking that, similar to the other teacher trainer participants; this could be why he was experiencing challenges in teaching this topic area. In GRD3, he lamented that students were unable to handle laboratory apparatus because they are not given enough practice, and that teachers "do most of [their] work theoretically" (r. 104). Furthermore, in GRD3 Rett suggested that students should be made to memorise the first 20 elements in the periodic table and their valencies. This is, to a great extent, a theoretical teacher-centred approach to learning that does not give students opportunities to actively engage in scientific investigations.

Several critical incident discussions demonstrated a limitation in teacher trainers' knowledge of formative assessment (e.g., DottGRD5, RettDGR3). They often asked students questions to link previously taught concepts to new topics and to diagnose students' levels of understanding (e.g., DottGRDI; DottGRD5; KyttGRD1; RettGRD5). However, they missed opportunities *to assess and understand their students' thinking and learning difficulties* throughout the learning process because they did not look for students' responses to learning nor follow up on these responses with probing questions. Dott's question to her Form Four class about the pH value of

a strong acid, for example, was primarily aimed at assessing students' prior knowledge of content covered in Form One. When they gave an incorrect answer, "they told me the pH of a strong acid is 6", Dott did not inquire why the students thought that a strong acid has a higher pH value. Rather, she organised for a practical experiment to demonstrate strength of acids. If she had probed further as to why students responded with the incorrect answer, she may have been able to plan instruction that facilitated student learning from the point of their understanding. In demonstrating the strong acid's low pH value, students were only further confused because they "did not seem to agree because [the activity] contradicted what they had given [her]" (r. 15).

In a similar example, in GRD4, when "a student asked the reason to why we have three energy levels and not two" [for sodium atom (2.8.1)], Rett "realised that the student had not understood carefully, the maximum number of electrons that are supposed to be in every energy level" (r. 38). However, Rett did not ask the student why he thought there were only two levels, instead she returned to a beginner-level explanation of the concept. She recalled that she

> "reviewed again, that the first energy level is supposed to have a maximum of two electrons, second energy level a maximum of eight and then, the extra two in magnesium, are supposed to go to energy level three." (r. 39)

Rett did not give this student an opportunity to construct knowledge for himself in order to understand the concept of electronic configuration. *Reviewing* content from the beginning level regardless of students' actual level is to a large extent, a teacher-centred approach.

Students told Rett that the questions she gave them were difficult for them to solve, and that they did not understand the concept of neutralization reactions (RettDGR5). Instead of probing further into why they did not understand, Rett "decided that any time [she] teach[s] [she] will be giving an assignment and follow up those students who will not have understood" (r. 41). There was no evidence in data how she intended to follow up with the students. Rett could probably borrow from Dott's handling of such a problem, who in the same group reflection discussion said because such a thing is common in her classroom, she normally asks students to explain how difficult the questions was. And based on students' responses, she normally goes through the problem with them together.

Several critical incident discussions showed that teacher trainers' teaching methods were not effective (see Section 4.3.1). This was evident in data through expressions such as: "I also

realised that the way sometimes I carry out demonstrations, is not right" (DottGRD3. 18) and "I did not give my students opportunity to make their observations, because when I noted the error I went ahead and corrected the error" (RettGRD2, r. 109). Ritt realised that he was not monitoring student learning following the group reflection discussion 3. He responded:

> but I did most of the work. Maybe I was not very keen of what the students were telling me about the ions, maybe I was writing the oxidation states myself without realising that some of the students had challenges. I only came to discover when I gave them their own example to work on. (r. 80)

Kytt also failed to be responsive to students at their level when he did not attend to some of the students who were afraid to handle weighing balances in his lesson on relative atomic mass of elements. He said that he "was very much concerned with those students who were afraid of handling the weighing balances, but [he] did not have enough time to attend to them, [because he] really wanted to achieve [his lesson] objective of explaining the concept of relative atomic mass of elements" (GRD3, r. 96). This incident showed that Kytt was limited in the strategies he had to help students with diverse learning abilities. He could probably have allowed those students who had no problem with the weighing balance to continue with the experiment and take time to identify why the others were afraid and to encourage them.

Dott acknowledged the general ignorance of teachers in utilising local learning materials such as wild fruits, of which there are plenty and are easily accessible in the locality of their schools (GRD5). She stated that they could utilise such learning materials to involve students in hands-on activities so they could explore and construct knowledge, particularly before introducing abstract concepts. In this discussion, Ritt conceded that creativity was a challenge for many chemistry teachers. He referred to an activity Dott described on how to teach electronic configuration. In this activity she used rings in which only a specific number of balls could fit, for example only two can fit in the first ring and eight on the second ring. Ritt stated: "you know, nobody can think very fast like that. It is something that she made, that has triggered my mind to imagine that kind of a scenario, I would not have thought about it myself" (r. 28). Ritt also noted that sometimes teachers follow the text book strictly and rarely try reagents other than those in the text book (GRD3).

Teachers are supposed to use certain activities for specific subject content, so that it can be understood by students. The aim of the experiment Dott set with balloons, reported in GRD3, was to solve a misconception around acid strength and corresponding pH value. However, the

activity she planned for the students was not specific for this concept. Rather than emphasising the relationship between acid strength and low pH value, the experiment was limited to only demonstrating the strength of HCl compared to ethanoic acid (Section 4.2.3). This example illustrated Dott's limited understanding of how to link pH value with acid strength, and possibly, her repertoire of activities to illustrate the concept.

These critical incidents illustrated areas of teacher trainers' limited general pedagogical knowledge and specific pedagogical content knowledge. Each example had an effect on their teaching and on how and what students were expected to learn. Dott's students, for example, did not understand why the pH value HCl acid was 2 from the experiments Dott organised. Rett did not explain how she intended to help students who had difficulties in understanding the neutralization reactions. Her approach of giving assignments did not explain how she intended students to learn.

4.4.1.2 Assumptions made by teacher trainers in the classrooms

It was found that teacher trainers made a number of assumptions in their classrooms, which hindered effective teaching of chemistry, and consequently impacted student learning. Teacher trainers' assumptions, such as: reagents prepared for them were ready for use (RittGRD1), students understood concepts taught (RettGRD4), and students have a negative attitude towards chemistry (DottGRD3), were identified in data.

It is always a good idea for science teachers to trial experiments they intend to use with students in class. This does not always happen for various reasons; some of which were identified in the teacher trainers' critical incident discussions. Rett, for example, stated that "because of lack of enough time to cover the syllabus, [they] just use the reagents available to [them] to carry experiments without considering their concentrations" (GRD3, r. 25). Teachers also assumed that laboratory assistants and other teachers follow instructions when preparing laboratory reagents. However, this is not always the case, as demonstrated in Rett's GRD2 discussion wherby "the laboratory assistant did not follow [her] instructions" (r. 106) when preparing solutions, she needed to demonstrate diffusion of gases. The experiment was unsuccessful, and when Rett tested the solutions, she found that the labels of the containers containing the solutions had been exchanged.

Similarly, Ritt described a critical incident in GRD1that occurred when he was standing in for a colleague and the experiment failed to yield expected results. In his case, the teacher he was standing in for did not prepare the reagents they were using correctly (Section 4.3.2.1). He said that in future he "should not assume solutions prepared by another person are okay; rather [he] would go through the experiment [himself] before doing it with the learners" (r. 229). He further said that students lost confidence in him when they realised the experiment was not working, he was embarrassed, and he spent a lot of time during the lesson preparing replacement solutions, and therefore, he did not achieve lesson objectives.

Teacher trainers made a general assumption that students had difficulties in learning due to a negative attitude towards chemistry (DottGRD3; RettGRD5; RittGRD3). Dott assumed students were not interested with what she was doing when demonstrating an experiment of testing chloride ions (Section 4.3.3) "because most of them have a negative attitude towards the subject" (GRD3, r. 19). However, when she reflected on her teaching, she realised that she does not involve the students in the demonstration, which may have contributed to their apparent lack of interest.

In GRD1, Kytt reported acting on an assumption that students were not keen on an experiment he had given them in the form of an examination ("I wondered what had really happened; I made one assumption that these students in the second group were not keen, r. 266"). This assumption served as a barrier to his realising that the reagents were not the correct ones for the experiment until the students complained (GRD1, r. 273). He acknowledged his embarrassment when they drew his attention to the issue, and he had to re-mark the papers. The other teacher trainers were surprised that Kytt did not notice the problem before marking the examination scripts because teachers are expected to monitor students as they conduct experiments. Ritt also assumed that students were not keen on making observations in his GRD4 critical incident. When he reflected on this, he realised that the students' responses were a reflection of his teaching approach. He confessed his realisation that his focus, while teaching, is often on the products rather than the processes of learning (r. 78). This same problem was identified by the teacher trainers in GRD2, where they noted that Rett relied on what she knew about diffusion of gases rather than on the experimental results obtained in the lesson.

In some of the reported critical incidents, teacher trainers' assumption that students understood content taught in previous lessons and were thus, ready to learn, were challenged when they realised that they could not proceed with the current lesson as planned (e.g., KyttGRD3; RettGRD4; RettGRD6; RittGRD3; RittGRD6). Ritt could not proceed with the lesson of writing ionic equations because students had limited knowledge of ion formation and oxidation numbers GRD3). Unlike Dott, who in GRD1, GRD5, and GRD6 indicated how she probed for student understanding before introducing new knowledge, Ritt, did not assess students' initial understanding, and subsequently, his students experienced difficulties as the lesson progressed. He recalled that most "[students] could not proceed, they were just there stuck" (r. 74). Rett, in GRD4, also cautioned her colleagues against assuming that students have developed important manipulative skills needed to work with apparatus in experiments. She suggested that when conducting experiments, it is good to observe how the students are managing equipment, and assist them where necessary.

Teachers' assumptions in the classroom can affect teaching and learning negatively, as was demonstrated by the teacher trainers' reports above. Several experiments failed in the teacher trainers' classroom because they assumed reagents were correctly prepared. The failure of these experiments affected learning and teaching. Ritt, for example, said that he did not achieve lesson objectives, and students lost confidence in him. Similarly, Rett spent more time than anticipated, because she had to repeat an experiment.

Assumptions made by the teacher trainers about their students' negative attitudes and learning difficulties also affected teaching and learning in several ways. Kytt, for example, assumed that students were not keen on what they were doing and subsequently failed to identify that reagents were not yielding experimental results on which an examination was based. He was later embarrassed in class when they confirmed that they were actually interchanged. Dott failed to identify weaknesses in her teaching methods when conducting demonstrations because she assumed students were not interested due to a negative attitude towards chemistry. Teacher trainers generally failed to identify and notice students' learning difficulties because they assumed that problems arising in class were a result of students' negative attitudes and beliefs about chemistry, rather than because of the way they approached the teaching (section 4.4.1.2). Reflective discussion on critical incidents helped to raise their awareness of how their teaching might contribute to these issues, and alternatives they might be able to try in future.

4.4.1.3 Time constraints

Time constraints, mentioned by several of the teacher trainers, led them to inadequately prepare for their lessons on a number of occasions. Time was also cited as a reason for their failure to address student learning difficulties in the classroom. The Kenyan Chemistry syllabus requires that teachers have an understanding of Chemistry as a practical subject where scientific concepts, principles, and skills are developed through experimental investigations (KIE, 2002). Despite their knowledge of this requirement, teacher trainers reported that limted time inhibited this practice so, as Rett stated, "in most cases it is us teachers who do the experiments; we do not give students a chance to do the experiments. We do demonstrations maybe because of the challenge of time" (GRD3, r. 27). Such practice results in students lacking exposure to experimental investigations in which they are actively involved. In fact, in GRD1, Ritt recalled that he did not conduct a class experiment but a demonstration because he "did not have time to do the experiment in all the groups" (RittGRD1, r. 226).

In GRD3, Kytt explained that he could not attend to students who had difficulties in handling the weighing balance because of time limitations (5.4.1.1). Rett, noted that guidelines are given on how to prepare solution for testing ions in solutions "However, many of us because of lack of enough time to cover the syllabus, we just use reagents available to us and carry out the tests without considering their concentrations (GRD3, r. 24).

Teacher trainers indicated that they had good teaching approaches in mind but could not implement them in class due to time constraints. In GRD5, Ritt reported that he occasionally used a peer teaching method. In this critical incident, Ritt organised some work for students to research and then teach to their peers. They explained challenges faced when trying to implement such strategies in their classrooms, illustrated in the exchange below:

> **Moderator:** Why are the teachers not using this approach of peer teaching?
> **Ritt:** I tend to think it is time. The methods involve a lot of time on the side of the students. Initially, I had not tried it because of time. Their time table is packed from morning to evening. I allowed my students work over a weekend and they presented the following week. Most of the time, especially us teachers in boarding schools, we have programs even over the weekend. So, we cannot rely on this kind of approach.
> **Dott:** It is worse in day schools. Students cannot work during the weekend. We normally use this kind of approach if a teacher is absent or during preparation time, which still is a challenge because students normally have heaps of assignment from other subjects
> **Rett:** And now you know tuition over the weekend and holidays has been burnt in all schools.

> **Kytt:** I would suggest we try it during our double lessons once in a while to break the monotony of us always telling the students (r. 356-367).

4.4.1.4 Beliefs and attitudes toward chemistry

Teacher trainers reported that many students in their classrooms had a negative attitude towards chemistry, which was something they considered to be difficult (e.g., RettGRD5; RittGRD2). Students' negative attitudes affected teacher trainers' teaching and learning because students do not concentrate in class. Rett, in GRD3, strongly and emotionally stated: "Most of our students have a negative attitude towards chemistry. I do not know what we are going to do, but we have to keep on trying. Maybe we continue looking for interesting activities" (r. 55). They were surprised that Rett's students were not attracted by fruits he used. From their comments, illustrated by the excerpts below, suggest Rett and Dott have tried so solve their students' negative attitude towards chemistry without success.

> **Rett:** Like my students! Even if you encourage them, they do not seem to listen
> **Dott:** Sometimes I even wonder whether it is my teaching methods or what? My students do not seem to know where they are heading to, like the current Form Fours! (GRD3, r. 57-58).
> **Dott:** like us in small schools, the moment you write the word mole, they switch. We were told…it cannot work…it is difficult!
> **Rett:** Others start sleeping. (GRD2, r. 197-198).

In GRD2, Ritt discussed how he tried different approaches to change his students' negative attitude towards chemistry, and he encouraged his colleagues to continue doing so. He was aware of his students' negative attitudes and beliefs towards the subject from their conversations and from the way they behaved in class. He described his efforts to change their attitudes:

> there was another idea which was with my students that the topic of the mole was difficult, I learnt this from them. Even you would hear other students like those in Form Four asking those in Form Three, "Have you started this topic of mole?" They would say "That one is very hard". So I decided to use this practical approach. I was optimistic it would work. So when I produced the manual for the practical which was going to be done in fours (I had grouped them in fours). I realised that most of the students were showing less concern with the practical; they were not interested with the practical (r. 173).

Ritt could not proceed with his lesson when he realised that students were not interested in the practical he had organised. He thought that if he did, students would probably not listen to him, and therefore may not get anything at the end of it all. In an interactive session conducted with the students to encourage them, he said that it was clear that they had a perception that this topic

was hard. Kytt supported Ritt, and also encouraged the other teacher trainers to continue trying alternative ways to assist students' understanding of the mole concept. He encouraged them to be patient with their students because, "learning to write equations is like learning how to drive a car. Some of us think you can do it in a day; but it takes time and practice to master the skill (r. 85). He thought the way teachers approached the topic also contributed to students' negative attitudes. He cautioned participants about their attitudes:

> We also have to change our attitude towards our students. I have observed in my school that even some science teachers have a negative attitude towards their students. They assume they are poor. I have even heard it in our discussion here. (r. 56)

As noted in 5.4.1.3, teacher trainers reported having good teaching approaches in mind but not implementing them in class because of the time they demand. Kytt, in GRD5, further noted that because of students' negative attitudes and beliefs about schooling, they do not take research work and peer teaching seriously, especially in chemistry. He said when they try to use such approaches; they end up wasting a lot of time in class trying to persuade students to present their work.

Teaching and learning can be difficult when students are not willing to participate in the strategies adopted by teachers. Ritt reported spending a lot of time encouraging his students when he realised their negative attitude towards chemistry. Teachers are normally frustrated when their students perceive the subject they are teaching as difficult, as illustrated by Dott's and Rett's comments. However, Kytt noted that teachers, including his colleagues in this study, also have a negative attitude towards their students, and because they assume they are poor, they are not keen on addressing students' learning difficulties (Section 5.4.1.2).

4.4.1.5 Students' learning difficulties

Teacher trainers' reports reviewed that effective teaching and learning of chemistry was hampered by students' difficulties in understanding scientific concepts and handling laboratory equipment (e.g., DottGRD1; DottGRD5; KyttGRD3; RettGRD3; RittGRD3). They noted that students lacked knowledge of basic scientific concepts and were generally not used to higher level thinking. It was possibly for these reasons that several misconceptions were reported in the teacher trainers' classrooms. In GRD6, Dott realised that her students experienced difficulties in relating an ion with the electronic configuration of the atom. At the same time, the students did not understand the concept of losing and gaining electrons.

Dott and Rett noted in GRD5, that students often answered questions correctly in class, but when they gave them tasks to do on their own, they could not arrive at correct answers. Dott and Rett concluded that students were replicating what was shown in class without understanding it, and thus it was easily forgotten when they needed to work independently. A situation of this nature was found in Rett's GRD5 critical incident. In this incident, Rett was solving neutralization reactions with students in a lesson. She explained that when she posed questions to students, they seemed to have understood the neutralization reactions, in that they were answering questions correctly. When she did some independent work, however, she realised that only a small proportion of the students could solve the problems. When she asked them later what was inhibiting their progress, some said that the questions were too difficult for them to solve, and others said they did not understand. Although, during the group reflection discussion some teacher trainers critiqued Rett's method of teaching and suggested alternative approaches, the moderator acknowledged that

> The issue of students mixing up terms in this topic is very common. There are several concepts which the students must build on**,** all the way from the valencies, to the radicals which are tied to the periodic table and they must come out very clearly before students can write balanced equations and consequently calculate moles and even molarities of solutions. (GRD5, r. 55)

Dott had a similar experience with her students. The students were answering questions on empirical formulae correctly in class, but when she administered a test on the topic, few students were able to accurately solve the questions on empirical formulae. In GRD3, Ritt also noted that many students in his class had difficulties in writing ionic equations when he gave them some examples to solve; and even encouraged them to discuss their solution ideas in groups. He observed that

> Most of them could not proceed, they were just there stuck. Others were writing funny things. Some of them could not even balance the chemical equation… The worst was when it came to writing the oxidation numbers of the radicals, for example, that of sulphate ion, some of the students did not know that it had a negative charge of two. Some were writing it with a negative charge of one and others did not even have an idea how it is written…. This means student had not understood what they had been taught earlier, and to me this was a big challenge, meaning there is a big problem. (r. 221-223)

Rett and Dott supported Ritt. Rett said that "students generally have a problem with balancing equations, and also writing ionic equations" (r. 73). Dott referred to writing ionic equations as a challenging topic, especially with Form Two students. She thought that it was very important

for teachers to revisit writing correct formulae of compounds and how elements form compounds by exchanging valences when teaching this topic.

Teacher trainers also reported that teaching and learning was hindered by a weakness in students' ability to handle laboratory equipment. Several incidents were reported in this regard. Ritt, in GRD3 for example, recalled that students in Form Four could not read, measure, or even use a pipette, and yet they were taught how to use this apparatus in Form Three. He said that he was discouraged by this because he had to remind students how to use the apparatus before he could continue what he wanted to teach. Similarly, in GRD4, Dott reported that her Form four students could not fold filter paper to make a cone. Ritt also observed that his Four Form students could not fix a clamp to a retort stand (GRD6; Section 4.3.2.1). In GRD3, Dott reported that when students were told to clamp a burette, they sometimes clamped it upside down, and only realised the problem when they wanted to run down the solution, at which point they started to panic. In this discussion, Ritt also reported a critical incident where Form One students could not light a Bunsen burner. Most of the teacher trainers' reports indicated that students' challenges in handling laboratory equipments were largely due to a lack of experience stemming from teaching methods that fail to encourage students' active participation (Section 4.3.1). However, Ritt (GRD6) stated in this critical incident, it was only partly due to ineffective teaching methods, and also due to students' background, as many Kenyan students encounter Bunsen burners for the first time in secondary school.

In conclusion, the reported incidents in Section 4.4.1.5 showed that students in the teacher trainers' classrooms, experienced difficulties in learning some topics in chemistry and in handling laboratory equipment. These challenges affected teaching and learning in their classrooms, especially in regard to time management. Ritt, in GRD3 for example, stated that he rescheduled the content of the lesson he intended to teach to another lesson because he used the intended lesson to re-teach content which students had covered earlier. In the same group reflection discussion, he recalled an incident in which he spent a lot of time showing students how to use apparatus because he could not proceed with the content intended after realising students lacked knowledge in how to use the equipment. He said teachers are unable to cover the syllabus because a lot of time is spent revisiting content taught in previous lessons. He requested Kytt, who is also a school principal, to "advise other school principals in [their]

meetings to stop pushing teachers too much on covering the syllabus because of such challenges" (r. 98).

4.4.2 School factors

School factors, such as limited human resources and physical facilities (KyttGD1: RettGRD1), were identified as issues in the data. These factors and how they affected teaching and learning of chemistry in the teacher trainers' classrooms, are discussed in the next section.

4.4.2.1 Limited skilled human resources

Teacher trainers noted that a lack of qualified teachers, and that some qualified teachers lacked specific skills in some chemistry topics, affected the teaching and learning of chemistry in Kenya (e.g., DottGRD4; Kytt GRD1; RettGRD2). Dott stated that:

> what some schools lack is teachers with adequate knowledge of qualitative analysis. Because you realise, in the upcoming schools, you have the principal as the only trained teacher, and they employ students who have just completed Form Four as teachers. It is so difficult for such teachers to plan for such experiments and most of the time they teach theoretically. The teacher messes up in the preparation, even during the final examination and therefore, the students write funny things. (r. 88)

Dott was supported by Rett, who highlighted the use of school leavers as teachers:

> At the same time, when we get Form Four leavers to teach, they have a phobia of handling the apparatus. They do very few experiments, and by the time the students come to do the final examination, they do not have adequate skills to handle the apparatus, so they do not do well. (r. 89)

Having teachers, both qualified and unqualified, who lack important skills in the same school, can affect the teaching of all teachers. Ritt's (GRD1) experience provides a good example: he said he was standing in for "a young teacher" (r. 245) who had incorrectly prepared the reagents for an experiment. Although there was no evidence in the data of this study, "young" teachers in Kenya, tends to refer to school leavers who are not qualified to teach, or to newly qualified teachers with limited experience. When the Kenyan government suspended employment of new teachers due to financial constraints, schools employed school leavers and newly qualified graduates because they are paid a lower wage compared to teachers employed through the employing government body - the Teachers' Service Commission (TSC). In GRD3, Ritt said that some teachers have difficulties in handling some laboratory apparatus, especially the newly appointed teachers. He thought "the universities are not doing any justice to [their] young

teachers. They are leaving universities actually with very limited skills even to carry out some very simple experiments" (r. 109).

Kytt confirmed that "some of [their] teachers do not have the skills" (GRD1, r. 245). Supporting this, Dott contributed to the discussion, saying "the teacher did not know [how] to quantify the acid to be used to acidify the Potassium Permanganate or completely did not use the acid". Rett also reported in GRD5 that she knows some teachers who have a phobia of teaching the mole concept. She suggested that during INSET, teachers should be given an opportunity to team teach and discuss student learning difficulties in this topic. Unqualified teachers can unintentionally waste precious resources as a result of their lack of knowledge, thus affecting teaching and learning for everyone. Describing such a case, Kytt explained how unqualified teachers can waste chemicals. He recalled a new untrained teacher reporting to him that one of the acids in the laboratory had expired. He was suspicious and decided to test the solution and found that the acid had not expired at all. The pH indicator charts and the universal indicator the teacher was using were from different companies and were not compatible. He commented:

> Actually I thought it was important to share this with my colleague trainers here so that we can think about it during our next INSET training even… It is likely that we have many teachers from our schools experiencing the same problem. Without this knowledge, teachers might dispose of many chemicals thinking they have expired. (GRD2, r. 224)

Teacher trainers acknowledged information shared by Kytt in GRD1 about the pH indicator charts and the universal indicator. For example, Dott recalled: "That is something that most teachers do not know. I being number one. My hydrochloric acid has been giving me 5 and I force it to be 1" (GRD2, r. 230). When Dott was asked to confess her wrong doing by the moderator, she said that she has been "converted", implying she has been changed. This is an indicator that probably she will handle her classes differently in future, because she no longer has to report a false reading to her students as she normally did when she got an unexpected pH value. Rett also reported that she experienced similar challenges to Dott. She stated: "if you do not have the knowledge of what we are learning here today, you are likely to mix them" (GRD2, r. 243). Although the four teacher trainers are experienced teachers, Rett's and Dott's comment suggest that they had limited knowledge regarding the concept of acids, bases and pH values in relation to compatibility with pH indicator charts and universal indicator. Kytt admitted that there was a year he withdrew many charts during the final examination because he thought they were not the correct ones.

Rett acknowledged that many teachers, including teacher trainers, lacked skills in using certain laboratory apparatus, as they were sometimes introduced after their initial teacher training. As noted in Chapter One, professional development for practicing teachers is necessary as science is dynamic, and there are many changes taking place in the education sector. Rett described a problem that was experienced by teacher trainers due to such changes and how it was resolved:

> Initially we were not using pipette fillers, but now because of health issues, we are encouraged to use them…I also noted during our training at the National centre that, some of the trainers are also challenged in handling or using some apparatus. For example, some of the trainers could not use pipette fillers. However, when we were exposed to them, and those who could use them showed the others, everybody left that training satisfied that all of us could now facilitate teachers in our respective Counties to use pipette fillers (GRD3, r. 110).

Teacher trainers reported that some schools do not have laboratory assistants and teachers use their students to help prepare materials and they sometimes make mistakes. Kytt reported such a situation in GRD1, recounting:

> After the first group was through, I had to replace the two solids. Because of lack of personnel (the school does not have a laboratory assistant); I used some of the group one students to help me replace the solids. (r. 265)

In other schools, the laboratory assistants are not qualified and therefore, they occasionally do not follow correct procedures when preparing laboratory reagents. Rett in GRD2 for example did not get expected results in an experiment she was demonstrating diffusion of gases. From this experience, she commented:

> I learnt that some of the lab assistants we have in our laboratories may not give the right information. They are not careful when preparing the solutions and labelling; therefore, it is always important that teachers are very keen with what our laboratory technicians are doing and make a follow up so that right labelling is done.

Limitations in accessing skilled human resources in teacher trainers' schools affected their teaching and student learning. Dott stated that students taught by school leavers "write funny things" in final examinations because these teachers do not prepare solutions used in the practical examinations correctly. These students, according to Rett, are not prepared for these examinations because their teachers rarely conduct experiments. Kytt noted that these and other qualified teachers who have limited skills, can waste a lot of chemicals, affecting opportunities for other chemistry teachers and students. Unfortunately, it was reported that teacher trainers sometimes force students to record information that conflicts with experimental data due to a

lack of knowledge or incorrect use of equipment (e.g., the compatibility of pH charts with specific universal indicator). Unqualified laboratory assistants can embarrass teachers when they fail to prepare solutions correctly, as reported by Rett in GRD2. In schools where there are no laboratory assistants, teachers use students when preparing experiments. Students are also likely to make mistakes, and thus impact teaching and learning, as experienced by Kytt and reported in GDR1.

4.4.2.2 Limited laboratory facilities

Chemistry is a practical subject required to be taught in a laboratory because it is meant to involve a lot of experiments and demonstrations. A lack of access to laboratories and laboratory materials can, therefore, affect the quality of teaching and learning in this subject. Data revealed that teacher trainers lacked essential laboratory apparatus and chemicals in some schools. In light of this issue, Rett noted that in her school, essential safety equipment was lacking:

> we are aware that Nitrogen (IV) Oxide is a poisonous gas, one of our major challenges in our lab is that we do not [have] … a fume chamber. So I just prepared a little. (GRD1, r. 131)

Further, a lack of laboratory equipment and resources forced her to seek alternatives:

> In the conventional method we are supposed to use a round bottom flask, and then pass the gas using a u-tube over ice cold water, for the gas to condense. Because our round bottom flask did not have corks, I thought very fast and decided to use a boiling tube. Also, because we did not have ice cold water, I told the lab assistant to supply as with cold water from a tap. (GRD1, r. 134)

In this incident, Rett wanted to try a practical approach to preparing Nitrogen (IV) oxide gas. Despite the lack of basic laboratory equipment, she decided to use what was available. However, there was an explosion because the boiling tube she used, instead of the round bottomed flask, could not withstand the resulting pressure. Although suggestions were offered by the other teacher trainers and the moderator on how to improve the experiment, she had said that she *"*will never attempt without a flask and [she will] look for a cork and try it [herself] before doing with the students" (r. 162). This is an indication that the lack of facilities can limit teaching and learning, and potentially lead to dangerous practices. As in the case of Rett, it can also de-motivate teachers from trying alternatives and even embarrass the teacher in class as occurred for Kytt (GRD1).

Limited basic laboratory facilities can also affect student learning indirectly. This was reported by Kytt (GRD3) who noted that the limited number of basic laboratory apparatus at a school he

previously taught in, meant that students had no opportunity for handling laboratory apparatus. This led to them developing a fear of handling laboratory apparatus. He thought teachers should be innovative and look for alternatives, such as sharing learning resources among schools. Rett suggested that, "even if those apparatus are not transferred from one school to another, students in schools lacking apparatus could visit those schools with adequate resources" (GRD3, r. 484-485).

4.4.3 External factors affecting teaching and learning of chemistry

External factors affecting the teaching and learning of chemistry refer to those over which teachers had no direct control. In Kenya, as some of the participants noted, factors such as the syllabus, textbook content (DottGRD1), and external examinations (KyttGD1; RettGRD6) are controlled nationally by the Ministry of Education.

4.4.3.1 Chemistry syllabus and textbooks

Teacher trainers revealed gaps in the Chemistry syllabus and textbooks during group reflection discussions. In GRD1, Dott justified the way she teaches acids, bases and the pH values as being the way depicted in chemistry textbooks and the syllabus. When asked by the moderator when students first meet this concept in secondary school, she responded: "In Form One, it is there in KLB Chemistry book 1. They are talking of HCl and other mineral acids being strong acids, and we leave it at that level" (r. 30). At the Form One level, the syllabus and the textbooks require teachers to teach the pH values of acids and bases under the topic acids/bases and indicators. To identify whether an acid or a base is strong or weak, indicators such, as the universal indicator, and the pH scale are used. At this level, as Dott noted, *"We leave it there."* Teachers are not expected to explain pH values in detail. For example, a strong acid such as HCl has a pH value of 2, while a weak acid has a value of 6. In this regard, Rett argued; "You know if you tell me that this is a strong acid I will always think of the value six", and that is probably why Dott's students also gave the value of 6 when asked the pH value of a strong acid (Section 4.2.1.2).

At the Form Four level, teachers in Kenya are required of to explain pH values in more detail. However, following Dott's critical incident and the subsequent group reflection discussion, teacher trainers came to believe that the concept of pH values was beyond the cognitive level of Form One students. Dott and Rett thought that they were bringing this concept to the learners very early. The concept requires students to understand the relationship between the strength of

acid and the concentration of the hydrogen ions present when the acid ionises. Rett stated that: "If you try to mention hydrogen ions then you are bringing another complex word, *ion*" to Form One students (r. 91). At the end of this group reflection discussion, Kytt acknowledged that Dott's problem "*is universal"* among chemistry teachers, and actually occurs at the lower level classes, when students have not been taught a lot of things. But as students move to the upper classes and the concept of hydrogen ions and concentration is introduced, the concept becomes clear; but for the Form Ones and Twos, he agreed that the concept is too hard to demonstrate through practical approaches. Actually, Ritt pointed out that all the alternative practicals and methods they suggested in the group reflection discussion would not be effective because students "have to know this and this, but there is nothing you can do for acids to clear this misconception" (GRD1, r. 77).

In a similar situation, Dott (in GRD2), noted that there were "no experiments in that effect" in the textbooks (r. 70) to support the teaching of electrolytes. She further stated that the textbooks and the syllabus are "silent on the products because [the concept] is well covered in Form Four." The moderator reminded them that the syllabus requires that teachers *state the products of a binary electrolyte.* Kytt was sure those experiments were presented in Form Two textbooks, and in the syllabus, but he explained that: "if you try to explain about the products, you confuse the students". At the end of the discussion, Dott admitted that she missed the important aspect concerning the products. The discussion showed teacher trainers' perspective that this syllabus content was not written with students' abilities in mind, thus what actually happens in the classroom is not what is prescribed in the syllabus.

In conclusion, it was found that teacher trainers find it difficult to teach for understanding if the content they are expected to teach at a particular stage of the syllabus is not aligned with students' cognitive abilities. Dott for example, wondered: "If the students asked what those bubbles are, what would [one] say? [She thought], to avoid confusing them, [she] would want a situation where [she] quickly set the experiment and when the bulb lights, [she] quickly disconnect the set up" (GRD2, r. 84).

4.4.3.2 External examinations

External examinations affect teaching and learning, especially when the examination results are used as criteria for university entrance. This is one of the most recognised challenges in the

Kenyan education system; that the examination offered at the end of four years secondary school education determines who joins public and private universities (Henry, Nyaga, &, Oundo, 2014). Some evidence, reported by the teacher trainers in this section, suggests that this examination influences the teaching and learning of chemistry.

During the first group reflection discussion, teacher trainers were wondering why Kytt did not notice that his students were not doing the right thing when carrying out an experiment on qualitative analysis. They expected him to monitor the progress of the experiment and at the same time assess students' manipulative skills. The reason Kytt did not supervise his students was that he was preparing them for the final examination and wanted then to be independent. Further, he stated that he decided to allow the students to repeat the experiment "because they were candidates, preparing for the final examination, [and he] thought it was important that [they] re-do the experiment" (r. 268).

Although they did not link it directly to the final examination, in some lessons, Kytt and the other teacher trainers did not address students' difficulties in class because, as Kytt mentioned in GRD4, they were rushing to achieve lesson objectives to cover the examinable syllabus. Kenya is an exam-oriented country and teachers are usually under pressure to complete the syllabus before the allocated time so that they can drill their students to ensure their satisfactory performance in the final examination. Other instances of prioritizing coverage of lesson objectives and thus, the syllabus, have been discussed previously (e.g., KyttGRD3; RettGRD3).

Teacher trainers also realised in GRD6 that teachers are only concerned with teaching content because the final examination does not test process skills. They noted, for example, that students are not tested on how the pipette fillers and burettes are used, but rather, on the results they get after titration. As such, this is also where teachers focus their teaching and their students' skill development.

Overall, results from data analysis, presented in Section 4.4, suggest that teaching and learning of chemistry is affected by a number of "contextual problems". These context-specific issues, identified by the teacher trainer participants as relating to a lack of time, students' learning difficulties and negative attitude, a lack of laboratory resources and skilled laboratory assistants, the mis-alignment of some content in the syllabus with students' cognitive abilities, and an examination-oriented education system. These factors may also contribute to the reasons for

teacher trainers' limited general pedagogical and pedagogical content knowledge, reported earlier in the findings of this study. This was not expected because the four teacher trainer participants were experienced teachers and trainers, with ten or more years of teaching secondary school chemistry and training in-service teachers.

The findings also showed that schools in Kenya lacked qualified chemistry teachers, and that some qualified teachers also lack skills to conduct practicals. These teachers effect the teaching capacity of other teachers in the same school as was demonstrated in the case where a teacher did not prepare laboratory solutions correctly for Rett. A lack of knowledge was also shown to be a cause for the waste of precious chemical resources, as was reported by Kytt, which further impacts overall teaching and learning by depriving other teachers' useful learning materials.

Time constraint was also identified as an influential factor on the quality of teaching and learning. Firstly, from their reports, it was noted that teacher trainers are under pressure from the school management to cover the syllabus before the stipulated time, in order to have time to drill students in revision for final examinations. Secondly, results showed that the majority of students in their schools experienced learning difficulties; held perceived negative attitudes towards chemistry and found chemistry to be a difficult subject to learn. A lack of essential, pre-requisite knowledge of basic scientific concepts taught in lower year levels was also identified as having a negative effect on teaching and learning at subsequent higher levels. Dott contended that the lack of pre-requisite knowledge was likely a consequence of poor teaching methods at these lower levels. Ritt and Kytt also noted that students' backgrounds affected their readiness for science learning as many were not familiar with basic laboratory apparatus such as Bunsen burners upon entering secondary schooling.

The consequence of these limitations in students' readiness for chemistry learning meant that teacher trainers spent unanticipated time revisiting assumed knowledge when they realised students failed to demonstrate sufficient understanding of the basic pre-requisite concepts covered in earlier years. Also, compared to traditional teaching methods, the current chemistry curriculum requires teachers to actively involve students in teaching and learning activities, such as practical experiences. These scientific inquiry-related processes are often time consuming and teacher trainers acknowledged that in many instances, they replaced student inquiry experiences with teacher demonstrations because of time constraints. They also noted

that many teachers are not keen on developing their students' manipulative skills because such skills are not tested in the final examination.

A lack of detail about what is expected of the teacher in teaching some chemistry topics, such as pH values of acids and bases and electrolysis at Form One and Two levels constrained Dott and Rett to teaching according to the syllabus. The four teachers concluded more details are required for students to understand these particular concepts, and the extent of this detail would be beyond the cognitive abilities of students in Form One and Two. This limits teachers' ability to use more student-centred approaches to learning in these topics.

Limited physical and human resources in many schools in Kenya were shown to impact negatively on the teacher trainers' teaching (e.g., KyttGRD1, RettGRD1, and RittGRD1). The findings showed that the availability of physical and human resources influenced teacher trainers' planning and sequencing of content in their teaching. They were discouraged and disappointed when strategies and materials they adopted due to issues in accessing these resources failed in their classrooms, as occurred in the cases of Kytt and Rett. They suggested that neighboring schools share resources, and Counties create platforms for teachers to share ideas, especially in emerging curriculum issues, such as the use of pipette fillers as noted by Rett. In this regard, it can be argued that reflecting, discussing and addressing problems they encounter in the classroom appears to have helped these teacher trainers to develop a positive attitude towards launching a professional learning community in their County.

4.5 Chapter conclusion

Findings presented in this chapter provided evidence of potential professional learning activities the four teacher trainers undertook through their classroom practice, and the potential professional learning outcomes resulting from these undertakings. Contextual problems affecting their teaching and learning of chemistry were also presented.

Findings concerned with *how* teacher trainers learned from their teaching experiences were evidenced through three professional learning activities **(**reflecting, experimenting and interacting with contact). First, pertaining to reflecting, participants acknowledged that through reflection on their practice, they could learn and improve their practice and their students' performance.

It was found that teacher trainers engaged in four types of reflection: *reflection-on-action, reflection-in-action, reflection-for-action* and *reflection-with-action,* each of which potentially enabled them to learn about teaching. *Reflecting on* their previous practices helped them to explore strengths and weaknesses underlying their practice. They also questioned and made sense of their teaching experiences, opening opportunities for learning, which enabled them to plan their lessons differently *(reflecting-for-action).* Based on these reflections, they discussed alternative teaching methods and learning materials that they thought could help them teach in a better way and promote student learning.

Likewise, actions they undertook in the act of teaching when they experienced challenges in class (*reflecting-in-action)* provided them with options for improving practice and students learning as lessons were in progress. Finally, regarding reflecting as a potential professional learning activity, it was found that teacher trainers were motivated to think of future actions *(reflecting-with-action)* to improve their teaching and thus, student learning. Findings also showed that a lack of, or ineffective reflection, particularly reflection-for-action, resulted in ineffective teaching because subsequent unreflective teaching tended to lead to: introducing misconceptions, not supporting student learning, and endangering students in the laboratory.

Secondly, it was found that teacher trainers perceived to have learnt through experimenting on teaching methods and learning materials. Various teaching methods and learning materials teacher trainers tried helped them to improve their practice and deepen their understanding of students' learning needs. They were, for example, able to identify their students' learning difficulties and think of strategies to better assist their learning. This motivated them to seek alternative teaching methods. Teacher trainers also realised that they gained new ideas and insights and confirmed concepts they were unsure of when they experimented with learning materials and teaching methods. They also observed that local materials motivated students to learn and enhanced retention of scientific concepts.

Thirdly, teacher trainers said that they learnt through collaboration both with one another, and with their students. From their descriptions of their teaching accounts and from the interview data, it was also evident that they learned from their interactions with students in the classroom. They said that students had good ideas, and that if given a chance to share them with others, they were motivated to learn. Through group reflection discussions, teacher trainers exchanged

knowledge and shared experiences. They perceived to have learned about the strengths and weaknesses in their teaching methods from these interactions, and they discussed alternative ways of teaching concepts that students perceived difficult. As a result, they acknowledged the importance of sharing. Furthermore, group reflections provoked them to try alternative learning materials and teaching methods. They all reported an intention to try their colleagues' teaching methods and ideas.

The focus of the second major theme in the findings was on *what* the teacher trainers learned. Teacher trainers were able to judge themselves whether or not they learned from reflecting on critical incidents from their own teaching. All four teacher trainers reported that they did indeed learn from their engagement. Several findings were emerged regarding potential development of the teacher trainers' knowledge of teaching methods, student learning, and subject content. They expressed an intention to implement what they learned in their future lessons and to share with other teachers during future in-service training they conduct for other chemistry teachers.

In terms of developing knowledge of teaching methods, they reported being embarrassed and disappointed when their lessons did not go well as a result of poor preparation. They admitted that sometimes their teaching introduces misconceptions, and that students sometimes do not understand concepts fully because of the way they teach. They realised that their classes were characterized by teacher-centred approaches, and that sometimes their approaches to teaching and learning was outcome-focused rather than process-focused in particular in regard to laboratory experiments. They also noted that they rarely involved students in practical experiences, followed text book work, and rarely tried alternatives. They acknowledged that it is important for teachers to be flexible and accommodate student ideas.

Participants learnt that they spent a lot of time preparing, for example other reagents, and did not achieve lesson objectives when the initial ones failed to give expected results. They attributed this problem to a lack of proper planning and preparation for their lessons. It was noted that they shared teaching methods they thought were successful in their classrooms, which their colleagues could try with their students.

Regarding development of knowledge of student learning, they became aware of requirements for student learning and areas of students' learning difficulties. Those requirements included involving students in practical experiences, using their ideas and prior-knowledge, using guided

practice and addressing misconceptions. Dott, for example, became aware of students' misconceptions that were unexpected from students in their final year of secondary education. However, it was noted that due to a lack of effective strategies for assessing students' ideas and thinking and in many occasions not giving students opportunities to contribute to the learning process, the teacher trainers missed opportunities to identify *specific areas* of students' learning difficulties. Thus, they did not support students' learning in these instances. They also missed opportunities to learn from students, because when, for example, they became aware of students' errors; they made corrections without giving students an opportunity to make further contributions or explain their misunderstandings.

The last finding was associated with the teacher trainers' perspectives of the contextual problems affecting the teaching and learning of chemistry in Kenya. Several critical incidents described a limitation of pedagogical knowledge among the teacher trainers. This was not expected at the onset of the study, because the teacher trainers were both experienced teachers and trainers of secondary school chemistry, with more than 10 years teaching experience. Participants also complained of a lack of resources and "no time" as factors impacting teaching and learning. In addition, there were a few cases of limited chemistry content knowledge evident in the teacher trainer participants.

Another external contextual factor identified in the data related to the lack of laboratory equipment and laboratory assistants to support the preparation of practical equipment for classes. This affected teacher trainers' teaching in that they were forced to improvise materials, which in one instance resulted in an explosion because the teacher trainer involved assumed the boiling tube she used in place of the apparatus needed, could withstand the pressure of the gas she was preparing. Due to a lack of laboratory assistants, participants reported that they normally used students to assist with preparation tasks, which sometimes resulted in incorrect materials and an experiment's failure. Moreover, according to the teacher trainers' reports, unqualified and qualified chemistry teachers with limited skills were found in many secondary schools and hindered effective teaching and learning of chemistry due to their lack of knowledge, experience and confidence to conduct experiments. They therefore do not prepare students well for examinations and sometimes waste precious laboratory chemicals because they lack knowledge of preparing solutions for conducting experiments.

The findings also revealed gaps in the Kenyan chemistry syllabus and textbooks. Teacher trainers conveyed a belief that some topics in the syllabus were not aligned with the cognitive level of students. For example, pH values taught at the Form One level, and electrolysis at Form Two, despite underpinning concepts related to these topics not being taught until later in the chemistry program. Due to this problem, the teacher trainers found it hard to teach for understanding, and sometimes resorted to encouraging memorisation techniques to assist students' acquisition of knowledge in these areas of the syllabus.

Finally, teacher trainers also noted that the final, external examination, conducted at end of the four years of secondary schooling affected the nature of teaching and learning in chemistry. They said that they were expected to cover the syllabus before the stipulated time in order to create time to drill the students in revision for final examination. This time pressure meant that in some instances teacher trainers did not attend to students' learning difficulties in the classroom, did not check laboratory reagents and experiments before lessons, and did not use teaching methods such as inquiry and peer teaching, which they considered effective but time consuming.

Findings of this study reflected growth in teacher's learning about teaching from the reflection they engage in on their everyday classroom practices. They, for example, noticed important features in their teaching that they were not aware of before the reflection activity that they could use to make teaching and learning of chemistry more effective. They discussed pedagogical learner centred approaches (not common in Kenyan chemistry teachers' lessons) that could be used more frequently to enhance students' understanding and motivate them to learn. They also suggested several ways to address contextual problems they experience while teaching chemistry. The new contribution this thesis makes is (a) an awareness of all the factors that make science teaching challenging as well as (b) pedagogical approaches that could be used more frequently. In the next chapter, these findings are discussed in relation to other studies previously conducted on teacher learning in practice and factors affecting teaching and learning of chemistry.

CHAPTER FIVE
DISCUSSION

5.1 Introduction

In Chapter Four, the study findings are presented. This chapter discusses those findings and responds to the research questions in relation to the literature. The study explored experienced Kenyan County chemistry teacher trainers' learning from reflection on their teaching experiences. Specifically, how they learnt from individual and collaborative reflective practice on the activities they undertake in their classrooms for the teaching of chemistry was explored from their own perceptions of their learning experiences. In particular, the qualitative case study approach used gave teacher trainers a voice to describe and interpret their teaching and learning experiences. The benefits of this approach is that the learning outcomes of this study are related to teacher trainers' own experiences in the classroom, and therefore, are more likely to have immediate effects. According to Munby and Russell (1993) this approach provides participants with the "authority of experience" and can be used to give immediate feedback of what is and what is not effective in the phenomenon under study.

Some of the findings discussed in this chapter confirm findings of previous studies on teacher learning in practice, predominately from Western countries. The lack of comparison to contextually similar studies is due to the limited literature on experienced teacher learning through reflective practice in the African context. The discussion provided in this chapter is organised into three sections, responding to the research questions presented in Chapter Four as follows: In section 5.2, a discussion on *how* the teacher trainers learnt is presented followed by section 5.3 in which a discussion of *what* the teacher trainers learnt is detailed. In section 5.4, contextual problems, reported by the teacher trainers, that impede effective teaching and learning of Chemistry are discussed. Finally, the chapter is concluded in section 5.5 by outlining limitations and delimitations of the study alongside the main discussion points drawn from the chapter.

5.2 How teachers learn—professional learning activities

The focus of the first sub-research question was on *how* chemistry teacher trainers learn from their teaching experiences. As such, the study sought to generate insights about how teachers learn from reflection on the activities they undertake in the classroom. These insights would help us to understand what teachers learn from teaching, the focus of the second sub-research

question. It was found that teacher trainers predominantly used three different types of professional learning activities. These were reflecting, experimenting, and interacting with contact. These types of learning activities are not well grounded in teaching and teacher education in Kenya, especially reflecting, as reported by the teacher trainers in this study.

Teacher trainers engaged in individual reflection on their practice and experimented with different teaching methods and learning materials in their teaching. They expounded these reflections in monthly group reflection discussions organised by the researcher. These three types of professional learning activities have been identified in earlier research into experienced teacher learning (e.g., Bakkenes et al., 2010; Kwakman, 2003). Darling-Hammond and McLaughlin (2011), for example, suggested that for teachers to learn effectively they should be involved in reflection and experimentation activities, which are individually driven and collaborative in nature. The Roth and Tobin (2002) model of co-teaching also supports collaborative learning through which co-generative dialogues facilitate co-teachers' reflections on their shared experiences in the classroom. They contend that such dialogues help teachers to deconstruct and plan alternative instructional activities designed to maximize student learning in the future, similar to those proposed by the teacher trainers in this study.

This study's results showed that teacher trainers had participated in some professional learning activities prior to this study, although not to the extent or diversity that is recommended through research to help them develop professionally. For example, although prevalent in other research studies (e.g., Kwakman, 2003: Lohman & Woolf, 2001), the teacher trainers in this study seemed to participate less in activities that required them to scan professional information, defined in this study as reading books, journals and education information. Such a failure to frequently scan professional information, may have contributed to ineffective teaching practices and development of students' misconceptions that were revealed in the findings. In fact, Nahum et al. (2010) found that students' misconceptions arise from the use of over-simplified models found in some textbooks, something also evidenced in Rett's GRD3 critical incident reflection discussion.

Teacher trainers' reports also showed that they rarely consulted colleagues in their schools when they experienced difficulties in specific topics. This finding aligns with those of Kwakman (2003), who noted that some professional learning activities, such as collaboration, are not common in school organisation. These findings also support those of Daniel, Auhl, and

Hastings (2013) and McLaughlin and Talbert (2006), who found that professional learning dialogues in schools, are sometimes difficult to organise because of the way teachers' work is structured. Many schools' organisations do not encourage shared thinking; teachers make their own instructional decisions (Rahman, 2011). Teaching in some schools is also characterized as an individual task (Loughran & Berry, 2006). Collaborative activities are also demanding because they require more than just talking (Kwakman, 2003). Despite such challenges, in this study, Kytt (GDR2) encouraged his colleagues to share experiences with other teachers in their schools (*What I would advise all of us here is to share experiences because if I had done it in my school with this new teacher, this problem could not have risen)*. Similar sentiments are purported by Schechter et al. (2008) who encouraged teachers to embrace collective types of learning approaches, regarding teaching and learning, rather than isolated ones. Engaging teachers in collaborative learning activities, according to Henze et al. (2009), can help them realise that professional learning experience can also be a social activity.

5.2.1 Reflecting and teacher learning

Although reflection is not a common practice in Kenya, the four teacher trainers looked back on their teaching experiences to solve puzzling situations in their classrooms. In this sense, they reflected *on* their practice, a form of reflection advocated by many (e.g., Dewey, 1933; Schön, 1983). The aim of reflection is to learn from practical experiences (Moon, 2004; Schön, 1987) and from what they reported, teacher trainers did indeed learn from reflection on their teaching experiences. Dott, for example, attributed poor performance of her students in chemistry to be partly due to her lack of reflective teaching. Unlike the findings of some studies, where teachers have been reported to dislike the idea of reflection (e.g., Van Eekelen et al., 2005), *teacher trainers in this study appreciated the opportunity to engage in reflective practice.*

Teacher trainers reported professional growth as a result of using the procedures of guided critical incident reflection and analysis on their teaching experiences. Their focus in individual and group reflection was on improving the performance of their students, especially in challenging situations. When Rett (GRD4), for example, realised that her students had not understood the maximum number of electrons that are supposed to be in each energy level, she made rings and used balls to represent electrons to help students to better understand. Likewise, Dott used balls made from plasticine to help students understand the same concept. These examples demonstrate some professional learning for these teacher trainers, reflecting Dogan et al.'s (2016) proposition that "student learning is both the purpose and mechanism for

professional learning" (p. 570). To some extent, this was expected based on the findings from several authors who have previously used guided reflection and critical incident analysis to explore teacher learning (e.g., Husu et al., 2008: Leijen et al., 2014; Sööt & Lieijen, 2012). Mohammand (2016) related his experience of using critical incident analysis as an effective means of reviewing his lecture design. In his view, critical incident analysis should be viewed in terms of looking for alternatives, possibilities and choices for teaching. Although teacher trainers in this study proposed many alternative teaching methods and teaching materials, and were motivated to think of future actions when they reflected on critical incidents, they also missed many opportunities to learn from their teaching experiences. This is probably because the approach, and generally the notion of reflection, is not commonly used in Kenya, something that Dott recognised in her interview (we teach and we do not do a reflection. We seriously affect the learning of the students because we assume much). A lack of reflection, according to Hoekstra et al. (2007), might contribute to ineffective teaching practices, and is likely to affect student learning, as noted by Dott.

Several occasions were noted in this study, where teacher trainers failed to learn because they did not critically reflect on their own teaching experiences. However, collaborative professional dialogue in the group reflection discussions did help to address these missed opportunities as they negotiated their own and others' teaching experiences in a way similar to that described by Impedovo and Malik (2016). In this way, reflection acted as a tool to stimulate a desired change, not as a solitary process but, as Ahmed and Al-Khalili (2013) encourage, as one they shared with colleagues. In spite of this, there *were still a number of missed opportunities to critique their teaching experiences*, which subsequently reduced potential learning from collaborative group reflection discussion. These findings suggest that there is need for a more guided form of reflective practice, not only to support teachers in their first year of teaching, as recommended by Cochran-Smith and Lytle (1999) and Mansvelder-Longayroux, Beijaard, and Verloop (2007), but for experienced teachers also. Guided reflection, as was the case of participants of this study, better ensures beneficial outcomes from the use of this approach.

Similar to the findings of Ghaye (2011), this study showed that various types of reflection can be utilised to facilitate teachers' learning from their teaching experiences. These included reflection *on, in, for, and with action*, all forms of reflection discussed in the extant literature (e.g., Eraut, 1995; Schön, 1983; van Manen 1991). Findings showed that teacher trainers reflected on their previous teaching to plan for what they intended to teach. This finding

supports Ghaye's (2011) discussion of effective reflection in which he proposed that teachers should weigh options and make decisions as to how to effect future actions (reflection with action).

Prior knowledge is considered important to guide teachers' immediate and future actions (Mkhwanazi, 2013). Prior knowledge is also important for students to learn, as noted by Husu et al. (2008), as it "relates the old and the new and makes way for the new" (p. 44). Husu et al. purports that it is not possible for students to construct and accommodate new knowledge without referring to and making connections with previous knowledge. Such a notion was supported by the findings of this study. For example, Ritt (GRD3) could not procced with the lesson he intended to teach on the writing of ionic equations because students lacked the pre-requisite knowledge. From what Ritt recalled, he had not assessed students' prior knowledge before he planned for this lesson. This outcome may have been avoided had he reflected before action, because, as Loughran (2002) noted, reflection can guide intended actions and subsequent practice. The purpose of reflection for action, according to Ghaye (2011) and Kolb (1984), is to learn from previous experiences to affect future actions, particularly for incidents that might require further attention, as was the case for Ritt's students. Ritt's missed opportunity could most likely, have helped him to better plan for his students' understanding.

Reflecting in action is often difficult for teachers because there are many things that compete for their attention while they are teaching (Eraut, 1995; Tripp & Rich, 2012). Although it was not something they had planned to do, reflection-in-action was evident in teacher trainers' discussions of their practice. When teachers are engaged in reflection-in-action, they use their knowledge in action and past experiences to reframe for immediate action. In other words, teachers use accumulated experience and knowledge learnt in action to seek alternatives in the classroom in response to the emergent needs of the students (Harrison, 2008). Dott (GDR1), for example, learnt that students held a misconception on the pH values of a strong acid. She was not expecting students in Form Four to struggle with this concept. From her previous knowledge and based on this emergent classroom experience, she organised on-the-spot experiments to assist students' understanding. This type of reflection happens in a highly spontaneous manner, as one is attending to what they are doing; the action of doing and thinking on what they are doing occur almost concurrently (Somerville & Keeling, 2004). In this regard, undesirable actions can result as teachers have limited time and are usually under pressure which impacts their capacity to consider viable options and select from these. It is possible that

this is what happened for Dott because, as noted in Section 4.2.1.2, the experiment she spontaneously enacted failed to address the core concept that students had failed to recall. Such an outcome is reflected in the work of Eraut (1995), who argued that reflection-in-action does not take into account the time or the role of dialogue in teachers' learning, which is a variable in understanding professional behavior. However, Schön (1983) argues that professionals become effective in their work, when they learn to separate the things they want to attend to when doing them. Further, he proposes that by attending to practitioner's reflection-in-action it is possible to discover many varieties of practice, something that was also evidenced by Dott in her GRD3 critical incident, when she was testing for chloride ions.

It was found that teacher trainers proposed alternative teaching methods and learning materials to improve their teaching and students' performance as a result of their reflections. For example, they expressed intentions to involve students in practical experiences after realising that they rarely do this. According to Ituma et al. (2015), practical experiences are important to support students' development of scientific investigative skills and their understanding of scientific concepts. Alternative teaching methods and learning materials were discussed and agreed upon in the group reflection discussions. Possible adjustments were also proposed for those teacher trainers who thought their practice needed amendment (reflection-with-action). Teacher trainers expressed confidence in improving students' performance following individual and group reflection discussions. Such an outcome of collaboration is supported by Ghaye (2011) who interpreted reflection "with" action to mean acting alone or with others and noted that better results are likely to be achieved when people work together.

5.2.2 Experimenting and teacher learning

It was found that teacher trainers perceived to have experienced learning through experimenting on teaching methods and with different learning materials, both individually and with students in the classroom. Similar teacher learning through experimentation is documented in the literature (e.g., Hoekstra et al., 2009; Lohman & Woolf, 2001). Experimentation is closely linked to reflection-in-action in that it gives rise to *on-the-spot experimentation* (Schön, 1983). Such experimentation was evident in teacher trainers' classrooms based on this study's findings.

When teacher trainers experienced challenges in the classroom, they trialled new actions to explore newly observed phenomena or to test their tentative understandings of a problem. As a

result of such experimentation, they made decisions to change things for better. This helped them to feel confident in their decision-making regarding their classroom and teaching practices (Schön, 1987). These findings showed that teacher trainers experimented with teaching materials and teaching methods, not to accumulate a range of teaching strategies so much, but rather, and in line with ideas purported by Berry, Loughran, Smith, and Lindsay (2009), to try out new ways of thinking in their classrooms. In line with Loughran's (2012) notion that teaching can be understood better when it is perceived as "problematic", teacher trainers used their reflection to frame and reframe some of their practices to address *problems* encountered in their classrooms, and subsequently, demonstrated their learning from reflection (Schon, 1983).

When Ritt (GDR1), for example, tested and confirmed that solutions provided to him were not correctly prepared, he tried an alternative approach to address students' apparent loss of confidence in him. He involved these students in a group discussion and in the preparation of replacement solutions. According to Loughran (2012), some teachers' actions in the classroom appear quite obvious, as in the case of Ritt, but he argues that they form the basis of developing strategies and approaches to teaching that are helpful for quality learning. The findings of this study agree with Loughran's premise, because, as in Ritt's and other similar examples in this study, he attested that in his future lessons he would be testing solutions before using them with students. He also said that he learned that successful experiments motivate students, boosts their confidence, and can help teachers achieve lesson objectives. He recalled that he did not achieve the lesson objectives because a lot of time was spent preparing solutions for a repeat of the same experiment.

It was also found that following group reflection discussions, teacher trainers expressed intentions to trial their colleagues' teaching methods with their own students. This finding echoes the literature, that teachers can improve their teaching by discerning what works best for their students through experimentation (e.g., Bakkenes et al., 2010; Kwakman, 2003). Teacher trainers' intentions to trial the different approaches of their colleagues are encouraged by Frost and Durrant (2013), who argue that teaching strategies cannot simply be imported, they have to be tried in practice, adjusted, and adapted to fit the particular teachers, classrooms, and students. Such consideration shows learning as something that is highly contextualised.

5.2.3 Interaction with contact and learning

The design of this study provided teacher trainers opportunities to interact with students in the classroom and with their colleagues in group reflection discussions (Section 3.2). Teacher trainers' reports indicated that they learnt from their students' behaviours, from reviewing their written work, and from engaging with them in conversations. Teacher learning from student work is acknowledged in the literature (Borko et al., 2010; Burton, 2013; Dogan et al., 2016; Jones, Gardner, Robertson & Robert, 2013; Little, 2003). Student work, according to Borko et al. (2010), provides teachers with opportunities for collaborative learning without them having to be physically present in the classrooms. Reviewing student work stimulates dialogue in teacher learning discussions (Jones, et al., 2013).

The idea of teachers learning from students' work, according to Findlay and Bryce (2012), is a somewhat under-emphasised professional learning activity in the literature. These authors wondered whether a focus on teachers' learning from their students could help teachers move away from routinised teaching, which, according to the earlier works of Fuller and Brown (1975) and Katz (2011), makes teachers "stuck" at a particular stage of their professional development. This study's findings show that this is possible. For example, Kytt realised that it is not good for teachers to be too rigid in following their teaching plan (*What I have realised, sometimes we teachers we are too rigid. We have a fixed mind, it is also good to check what the students have, and sometimes they are correct).* Dott (GR2) also stated that she learnt *that students can be creative and innovative and improve teachers' ideas.* This is possible because, according to Vermunt & Endedijk (2011), students get a lot of information from the internet. Kytt and Dott's ideas are supported by Henze et al. (2009) who asserted that teachers can learn subject matter together with their students through classroom activities, especially those that support students' active construction of knowledge, rather than teachers providing all of the answers themselves. In fact, Dott (GRD5) stated that as she tried to enhance students' rention capacity through practical activities, she was also "discovering".

Teacher trainers' reports also indicated that they learnt from the group reflection discussions. In this process of "give-and-take", they represented their ideas, and in the process, they perceived to gain greater understanding of teaching methods, student learning, and content knowledge, hence, they learned (Munby, 2012). This finding supports Fraser's (2010) argument that collaborative learning that allows teachers to build their own knowledge about teaching and learning through reflection, can transform their practices. This is in line with other

researchers' claims that providing opportunities for teachers to discuss and develop a common understanding of good science teaching and learning has the potential to change their practice (Roth, Garnier, Chen, Lemmens, Schwille, & Wickler, 2011; Taber 2009). "Change" in this study, was reflected through teacher trainers' intentions to trial new teaching methods to complement their existing practice (Section 4.3.1). Ambler (2016) also found that teachers' stories or descriptions of their day-to-day classroom activities were sources of professional learning. Furthermore, it has been suggested that "knowledge is situated in the day-to-day lived experiences of teachers and best understood through critical reflection with others who share the same experience" (Vescio, Ross, & Adams, 2007, p. 81).

Teacher trainers' comments represented their real experiences; they were not artificially constructed or controlled to produce desired outcomes, something that Roberts (2012) calls for. Moreover, experiences were unique to individual teacher trainers, and when they presented them in group reflection discussions, they were motivated to try new practices that might result in desired changes in their practice and thus, as Darling-Hammond and McLaughlin (2011) suggest, improve student teaching. An example of this was reflected in Kytt's (GRD1) suggestion to his colleagues that they should think about their teaching in terms of students learning of specific content. This according to Loughran et al. (2012) can lead to the development of pedagogical content knowledge that might help them to move beyond simply planning "good" activities.

Although teacher trainers faced many common challenges in their classrooms, in some topics they also reported diverse experiences. Ritt's students, for example, were quick to point to a problem in an experiment involving testing for chloride ions. In a very similar experiment, Dott's students did not know what was expected, so none of them appeared to notice the problem, as none of them commented on what was going on. Ambler (2016) found that teachers learn when they describe details of a teaching situation and explain their reasons for the actions and decisions they took during teaching. For example, in the cases of Ritt and Dott mentioned above, Ritt thought his students had prior knowledge of the content he was teaching, while Dott thought her students were not interested due to what she perceived as their negative attitude towards chemistry. In both cases, reflection revealed alternative reasons for students' reticence in the respective lessons. Consequently, both teacher trainers resolved to involve students in the learning process, although each thought of a different way to do this. Dott thought she would involve students during demonstrations, while Ritt said that he would be informing students'

content to be covered prior to the actual lessons and ask them to research on the said content prior to the actual teaching.

Ambler (2016) also argued that teachers' stories are contextualized within diverse classrooms. She is supported by Girvan et al. (2016) who noted that "professional development is an ongoing process in which teachers adapt what they know to their specific context" (p. 130). Ritt's and Dott's comments above seem to support this argument. They learned and responded differently in relation to how they judged their specific situations even though they were teaching the same content. This demonstrates the need for organisers of professional teacher learning programs to pay attention to individual teachers' stories and descriptions of teaching. Such differentiation could make a positive impact on both teacher and student learning in diverse environments (Ambler, 2016; Little, 2007).

5.3 What teachers learn : Professional learning outcomes

The second, fourth and fifth research sub-questions focused on what teacher trainers learned and what intention they expressed to practice what they learned. From these questions, the study sought to generate insights about what teachers learn from reflection on activities they undertake in the classroom.

Teachers indicated that they intended to change their teaching in specific topics, showed an increase in knowledge of teaching methods and subject content and perceived to have developed how students learn better. Since many teachers in Kenya rarely change their practices following professional development (Gathumbi et al., 2013), these insights could be used by teachers to inform their planning for teaching. They might also be useful to other researchers and education stakeholders in planning teacher professional learning programs, especially in the Kenyan context, where reflection is not prevalent in teacher professional learning programs.

Research shows that teacher professional learning requires time (e.g., Desimone, 2011; Earley, 2010; Hunzicker, 2011) and examining teacher learning requires extensive research (Farrell, 2013). Although this study lasted only nine months, teacher trainers perceived to have learnt from their chemistry teaching experiences. Ratcliffe and Millar (2009) have observed similar teacher learning that they reported occurs when teachers use knowledge acquired in practice. Knowledge acquired in practice, they say, can improve teachers' teaching methods and enhance their insights into how students learn, thus assisting attainment of deeper subject content

knowledge. Lohman and Woolf (2001) and Kwakman (2003) also report on findings where teachers have reported learning from the act of teaching itself. The findings of these examples align with those of this study where many of the outcomes of the teacher trainers' learning experiences resulted in their acquisition of professional knowledge or making a resolution about how they would enact their teaching in future.

Teacher trainers' reports indicating that they intended to change their teaching in specific topics because they realised that the methods they use proved ineffective in helping students' learning align to Guskey's (2002) thinking. Guskey posits that improving students' performance is a key motivator for teachers to change their practices. They for example realised that in some instances, they were not teaching for understanding, something noted by Kytt (GDR3). Following this realisation, they began to examine their practice for underlying assumptions, in order to understand their own conceptions and those of their students better, an aspect of reflection encouraged by Brandenburg (2008) and Farrell (2013). This examination of assumptions about practice helps to inform the development of pedagogical content knowledge (Findlay & Bryce, 2012). It can be considered as learning, as professional learning outcomes according to Kelchtermans (2004), are not only visible in changes in practice but also "in one's thinking about the how and why of that practice" (p. 220). This examination of assumptions and practice also involves thinking about why one teaching method might be more effective than another in a given context, with particular students at a particular time, and even for a particular concept (Stoll, Harris, & Handscomb, 2012). Teacher trainers challenged their taken for granted assumptions to facilitate their students' learning in future lessons (Section 4.4.1.2). Their actions reflect the sort of "powerful professional learning" discussed by authors like Brookfield (1990) and Timperley, Wilson, Barrar, and Fung (2008) that challenging assumptions encourages teachers to formulate their own theories of teaching based on their practice.

5.3.1 Teacher trainers' development of knowledge of teaching methods and subject content knowledge

Findings reported in Sections 4.3.1 and 4.3.3 showed an increase in teacher trainers' knowledge of teaching methods and subject content. They identified strengths and weaknesses in their teaching methods and expressed a need to revise their pedagogical approaches in future lessons. Rollnick, Bennett, Rhemtula, Dharsey, and Ndlovu (2008) considered such an intention as a sign of likely action to promote conceptual understanding in the teaching of content knowledge.

Teacher trainers realised that their classrooms were characterised by teacher-centred teaching methods. They reflected on these methods and suggested alternatives to improve the quality of their teaching. In this study intention to practice was considered as learning (Section 4.3).

In several incidents teacher trainers recalled that after realising that they taught "theoretically", that is, with teacher-centred approaches, they tried practical approaches such as conducting experiments, demonstrations, and peer teaching. This reflected a shift in the teacher trainers' efforts to adopt more student-centred approaches once they had reflected on instances in which their previous didactic teaching was not successful. Following individual and group reflections, they also expressed intentions to use further student-centred approaches in future lessons. Teachers, according to Dogan et al. (2016) and Kyndt et al., 2016) do not often report changes in practice in research studies as these teacher trainers did; possibly because professional knowledge is tacit and not easily articulated (Loughran, 2012; Schon, 1983). Moreover, changes in teaching methods also take time (Borko, 2004). Ultimately, though, engagement in professional development should result in changes in science teaching practices (Dogan et al., 2016).

5.3.2 Teacher trainers' development of knowledge of practice: Student learning

One of the common areas of professional knowledge that all four teacher trainers perceived to have developed, was about how students learn better. They expressed their intentions, for example, to use practical experiences with their students when teaching future chemistry lessons. They also indicated that they would encourage such practice with other teachers when conducting the INSET professional learning workshops in their roles as teacher trainers (Section 4.3.2.1). The use of practical experiences to enhance students' understanding in science subjects is supported in the literature (e.g., Bamberger & Davis, 2013; Ituma et al., 2015: Kim & Chin, 2010). None of the four teacher trainers criticised the purpose of using practical experiences as envisioned by the Kenyan chemistry syllabus for secondary schools (K.I.E, 2002). However, in some specific topics, they critiqued the nature of some of the practicals outlined in the syllabus and in textbooks. They felt that some of the provided examples were not suitable for the grades/forms they were written for in terms of students' cognitive abilities at the given level.

A common perception among teachers is that practical activities enhance student learning (Abrahams, 2009). Whilst this was generally true for the teacher trainers in this study, there

were some critical incident reports where this was not the case. In these critical incidents, teacher trainers expected students to learn from practical work, but this did not appear to happen (e.g., RettGR6, RittGR3). For example, in Rett's experience, even if students recorded correct experimental results of endothermic and exothermic reactions, they could not use them to plot energy levels diagrams. This was because the results probably contradicted their thinking from their daily life experiences about gaining and losing heat. This incident suggested that students had not constructed learning about the concepts being illustrated by the experiments. This incident corresponds with Abrahams (2009) and Abrahams and Reiss (2012) view that although practical work is an effective tool for enhancing student learning, concepts behind practical work are sometimes not learnt. Ituma et al., (2015) argued that this is especially true when students are required to conduct practical work by following recipe-type instructions. Following the group reflection on this critical incident, Rett realised that her teaching of this topic was not enabling students' understanding of the intended concepts. She expressed her intention to approach the topic differently in future. Rett's concession here, suggested that she acquired new knowledge and understanding of instructional strategies from her colleagues.

Participants discussed different approaches they could use to involve their students in practical experiences such as class experiments and guided demonstrations. They emphasised a need for increasing the frequency of students' exposure to practical work. Unfortunately, in Kenya some students never have an opportunity to handle laboratory equipment until they are sitting their final examination (Sifuna & Kaime, 2007). This clearly impacts students' capacity to perform in these examinations. Practical work prior to this is often impeded by a lack of access to required equipment, qualified laboratory assistants, and many other challenges as reported in this and previous studies. Given these challenges, teacher trainers discussed how they could be more innovative in accessing resources for practical work such as by using locally available materials like beads and fruit, and by sharing ideas and materials across schools.

Participants also realised that they needed to be cautious of the language they used in their teaching. This was realised after discussing Rett's experience in which students could not participate in a combustion experiment because the language she used in outlining basic safety precautions instilled fear in them. Rollnick (1998) and Sifuna (2007) found that language of instruction can impede student learning in many African countries. Rett's GRD3 critical incident reflected such an example in this study. Doppenberg, Bakx, and Brok (2012) and Meirink, Meijer and Verloop (2007) propose that collaborative models of professional learning

where teachers share and discuss a variety of teaching methods and ways of explaining content can be used to mitigate challenges associated with language barriers in teaching and learning. Similary, teacher trainers proposed alternative teaching methods that Ritt could have used (Ritt's GRD3 critical incident, Section 4.3.2.6).

Teacher trainers also acknowledged the importance of being aware of the prior ideas and knowledge that students bring to the learning situation, and attempted to elicit such ideas to inform their planning for teaching. Findings showed that the teacher trainers did not make a visible effort to elicit students' prior knowledge, thinking, and ideas before providing teaching instruction. Campbell and Campbell (2008) believed that students' prior knowledge and beliefs influence how they learn in a paradoxical way. Sometimes, this knowledge facilitates student learning; acting as "hooks" that serve to anchor instructional concepts and sometimes can lead to failure. This emerged as a strong feature in the present study. For example, in two of Dott's critical incidents (GRD1 and GRD2). In GRD2, she found students' ideas useful; they influenced the teaching and learning in a positive way. Alternatively, in GRD1, her students' prior knowledge inhibited them from learning as they held strongly to their inaccurate conception that strong acids had high pH values.

During group and individual reflections, teacher trainers suggested several strategies to elicit students' ideas. Teachers and students can benefit from taking time before instruction to identify what students know about a specific topic (Campbell & Campbell, 2008). Kytt and Rett, in this study, noted that a lot of time can be wasted in the classroom if prior knowledge is not taken into account. They provided the examples of wasting class time when introducing teaching and learning materials that students are not familiar with, or by introducing new concepts before confirming whether students accurately recall previous concepts taught. These examples are illustrative of Barke, Hazari, and Yitbarek's (2009) encouragement of teachers to be aware of their students' prior knowledge before introducing new concepts.

During group reflection discussions, teacher trainer participants also identified contextual problems that they perceived to be limiting their teaching effectiveness such as time constraints, as noted by Kytt and Rett above. Participants realised that many topics are challenging; something likely to be due to the abstract nature of many chemistry concepts that make it difficult for teachers to teach and for students to learn (Özmen, 2008; Sirhan, 2007; Taber, 2014; Woldeamanuel, Atagana, & Engida, 2014). Most students in participants' classrooms,

for example, found it difficult to write the electronic configuration of simple atoms such as sodium and magnesium. This happened because most of them found it difficult to apply the rule of $2n^2$. Johnstone (1991) argued that for students to understand chemistry, they must make connections between the macroscopic, sub-microscopic and symbolic levels (Section 2.2). The moderator thought teachers were too theoretical in their approaches to teaching about this rule. They did not create an environment for students to make connections between the three levels proposed by Johnstone.

Dott, when she realised students were having difficulties in writing electronic configuration of atoms, developed a model using balls made from plasticine which she thought helped her students to better conceptualize electronic configuration. The model enabled the students to make connections between the macroscopic, sub-microscopic and symbolic levels as encouraged by Suat et al. (2010). Ritt was impressed by Dott's model and decided to trial it with his students who were experiencing a similar problem. Other areas of teaching difficulty reported included the mole, writing ionic equations, conducting qualitative analysis, and understanding energy changes in chemical reactions. The concept of endothermic and exothermic reactions seemed challenging to both students and teacher trainers. Rett admitted that she was not aware that she was not doing the right thing when teaching this concept. The concept of electrons moving around the nucleus in an atom is quite abstract, and teacher trainers expressed difficulties in teaching it in a format that students could understand. Erman (2017) also noted that the abstract nature of the atomic structure topic often leads to students' misconceptions, making it difficult for them to understand the associated basic concepts. This, according to Erman, can lead to further student misconceptions in related topics such as the mole, chemical bonding, and electrochemistry, all of which were also evident in this study. To enhance students' learning in chemistry, and particulary in handling students' misconceptions, Chandrasegaran (2015) and Meyer and Land (2006) suggested that inservice teacher courses should be considered for practicing teachers whereby they can share and discuss students' pre-concepts with their colleagues.

This section shows that, similar to previous studies on teacher learning in practice, predominately from Western countries, this study showed that the teacher trainers developed: (a) knowledge of teaching methods and subject content knowledge and (b) knowledge of student learning. These findings thus contribute to the limited literature on experienced teacher learning through reflective practice in the African context.

5.4 What hinders effective teaching and learning of chemistry in Kenya ?

The third sub- question in the research regarded contextual problems faced by Kenyan County teacher trainers in providing students with valuable learning experience through their teaching of chemistry. The question sought to identify problems that teachers perceive to inhibit them in providing quality learning and teaching experiences. Teacher trainers reported a sense of being limited in their general pedagogical knowledge and pedagogical content knowledge for teaching chemistry. Their teaching decisions and actions may well have been influenced by a lack of knowledge, however, as Kennedy (2011) has noted elsewhere, there could well be a myriad of contributing factors and what may appear to be a lack of knowledge may actually be a considered decision that prioritises these other factors. In several of the critical incidents reported in Chapter Four, for example, teacher trainers used time constraints as a justification for their ineffective teaching approaches.

Time constraints, to some extent, is a reasonable explanation for some of the less effective approaches to teaching. This is because, firstly, teacher trainers are under a lot of pressure from the school management to cover the full syllabus before the stipulated time, in order to have time to drill students in preparation for final examinations. Secondly, reports showed that the majority of students in their schools have learning difficulties; a negative attitude towards chemistry; and a perception that it is difficult to learn. A lack of essential pre-requisite concepts covered in lower year levels affect learning time at higher levels. Dott proposed that the lack of retention in students of this pre-requisite learning is likely to be a consequence of poor teaching methods at the lower levels when they were covered.

5.4.1 Contextual problems related to teachers' knowledge of practice

Quality teaching and learning of chemistry is affected by teacher quality (Ali, 2012; Edomwonyi-Out & Abraham, 2011; Sifuna, 2010). Teachers need both content and pedagogical knowledge in order to contribute to the learning of their students (Luft et al., 2015; Shulman, 1986). Findings of this study related to teacher quality were concerning. Teacher trainers appeared to have limited general pedagogical knowledge and pedagogical content knowledge in some topics. These limitations appeared, in turn, to affect their teaching and their understanding of what and how students were expected to learn. According to Ituma, et al. (2015), this is a widespread problem with chemistry teachers in Kenya. Ituma et al. also noted that many Chemistry teachers focus on students' acquisition of knowledge instead of helping

students develop scientific investigative skills. Ineffective teaching methods among trained teachers in Kenya have also been observed by Kodero et al. (2011). Such an observation was not expected at the outset of this study because participants were experienced chemistry teachers who had been selected on merit to also conduct in-service training for other chemistry teachers in their County. Experienced and qualified teachers are often assumed to be more effective (Rice, 2010). They are expected to have accumulated extensive professional knowledge from their teaching experience. The findings of this study suggest that this is not always the case, something that is mirrored in the research of Henry, Fortner, and Bastian (2012). Henry et al. challenged the assumption that experienced teachers are more effective and found that after four years of teaching experience, there were diminishing returns from experienced teachers in terms of student performance. Similar findings have been observed by Rice (2010) in America. She found that in some cases, experienced teachers were less effective than those with less experience and proposed that the problem might be due to teacher burn out or a failure to engage in professional learning regarding new curriculum and teaching methods. Rice recommended these teachers engage in professional learning and development to advance their professional knowledge. This same recommendation has also been made by Sifuna (2010) and Chepkorir et al. (2014) in Kenya.

When the teacher trainers realised that their teaching sometimes made it difficult for students to understand scientific concepts and potentially introduce misconceptions, they expressed a need to change their practice (e.g., Rett GRD6). This realisation is in line with recommendations of others (e.g., Nilsson, 2014), who posit that awareness of students' misconceptions can be a useful starting point for teachers to assist their students' construction of knowledge for understanding, and to inform the teaching strategies adopted to deal with these misconceptions.

5.4.2 Contextual problems related to students' learning

The study's findings revealed that students found it difficult to make sense of some chemistry concepts. Similar difficulties are found in international reports showing that in many countries, students struggle to understand basic scientific concepts and skills, including the processes of scientific inquiry (e.g., OECD, 2014). Teacher trainers were able to identify major chemistry topics in which students experienced such difficulties, such as bond energies (Rett, GRD6) and the mole concept (Ritt, GRD3). One of the major impediments of students' understanding of chemistry appeared to be their negative attitudes and beliefs about chemistry. Supporting the findings of Woldeamanuel et al. (2014), teacher trainers noted that students perceived chemistry

to be a difficult subject that was hard to understand. They attributed this behaviour to negative peer influences and poor teaching methods that do not involve students in the learning process. Chepkorir et al. (2014) also found that teaching, to some extent, contributed to students' negative attitudes. Such a notion also emerged in the present study when Ritt realised that his students were negative in their mindset about learning the mole concept, and about chemistry in general. Participants recommended that teachers should improve their teaching methods and spend time encouraging students. Subsequently, they called for increased in-service training opportunities for teachers, and that these opportunities should incorporate the reflective practice approaches to professional learning adopted in the current study.

5.4.3 Contextual problems related to the school and external factors

Quality teaching and learning requires quality teachers. According to the teacher trainers' reports, many secondary schools have both unqualified and qualified chemistry teachers with limited skills to conduct practicals, particularly in qualitative analysis. Such an issue is echoed by Bett (2016), Sifuna (2010) and Chepkorir et al. (2014). Bett claims that a large proportion of Kenyan teachers are not adequately prepared to conduct practical work, and do not receive sufficient professional support to mitigate this problem. Sifuna found that Kenyan universities are currently thought to be unsuccessful in equipping graduate teachers with skills and knowledge to teach practical subjects. This same issue was evident in the critical incidents discussions of Kytt (GRD2) and Ritt (GDR1), in which the newly employed teachers were challenged in preparing chemical solutions and using laboratory materials.

Similar observations were made by Edomwonyi-Out and Abraham (2011) in Nigeria; and Ejidike and Oyelena (2015) in South Africa. These findings suggest that schools across Africa experience similar challenges regarding teaching and learning of chemistry. Frequent in-service professional learning is recommended for both qualified and unqualified teachers, as is the improvement of existing in-service professional learning programs (Gathumbi, Mungai & Hintze, 2013).

This study also identified that a lack of basic laboratory equipment and laboratory assistants affects the teaching and learning of chemistry. The experiment Rett was preparing Nitrogen IV Oxide gas, for example, exploded because the school lacked the required equipment and she mis-judged the suitability of the replacement equipment she used. Ejidike and Oyelana (2015) observed that a lack of adequate laboratory facilities in Nigeria made teaching and learning of

chemistry ineffective in many schools. A series of statements made by researchers, point to the need for well-equipped laboratories and qualified teachers for the achievement of effective chemistry teaching and learning (e.g., Chen & Wei, 2015; Ejidike & Oyelana, 2015; Kodero et al., 2011).

It was found that teaching was almost exclusively based on what would be examined after four years of schooling. Examination-oriented teaching encourages drilling and rote learning (Kibos et al., 2015; Sifuna, 2010). Teacher trainers reported that they feel pressured by school management to cover the syllabus before the stipulated time to create time for drilling students in preparation for the final examination. Examination-oriented teaching is also linked to a loss of student interest in learning science (Rahman, 2011). Teacher trainers also relied heavily on the text book in their teaching. Others have found text books to be a significant contributor to the development of students' misconceptions in science (e.g., King, 2010). Teacher trainers rarely consulted other teachers or scanned academic information to plan for their teaching (Section 4.2), but rather, relied heavily on information found in the text books. In the use of this information, teacher trainers rarely framed the content in ways that students would easily understand, as such, they introduced misconceptions (e.g., RettGRD3).

5.5 Chapter conclusion

Overall, this chapter has illustrated that a critical incident approach to reflection seems to support teachers in changing their role in their learning process, and also changing the way they perceive their teaching. Moreover, this approach was effective in assisting chemistry teacher trainers in thinking about their teaching and about the learning process. It also helped them to identify strengths and weaknesses in their own and one another's teaching, as well as ways to correct and/or enhance their teaching. In addition, reflection on teaching practice enabled teacher trainers to analyse, discuss, evaluate, and potentially change their own practice in future lessons. This was evident in the present study where teacher trainers utilised observations and written work of students to evaluate teaching and learning practice. The study's findings demonstrate that when teachers: "see" their own problems separately to other external problems, and understand their own strengths and weaknesses, they can develop professional knowledge and skills for increased quality in their teaching.

Although examining teacher learning outcomes requires extensive research, this study has shown that teacher trainers perceived to have learnt from their teaching experiences of

secondary school chemistry, following their participation in this nine-month study. They reported having increased their pedagogical content knowledge. This helped them to understand how students learn better and alternative teaching methods. They also reported having increased knowledge in Chemistry content and contextual problems hindering their teaching and their students' learning.

Findings also showed that implementation of reflective practice is possible in a global-south nation. Many teachers in global-south nations face many challenges in their science classrooms which deny them opportunities to improve their practice. However, from the findings of this study, it seems reasonable to suggest that the protocol writing approach adopted in this study, was helpful in creating conditions for the teacher trainers' self-and group-reflection and enabled them to articulate their professional practice in ways that extended beyond basic talking and describing. However, given the small scale of this study, further research is needed to confirm whether this would apply generally in teacher professional learning in Kenya, as well as whether the outcomes of engaging in such reflective practice does indeed translate into actual classroom practice.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This study sought to explore teacher learning from reflective practice on teachers' own experiences of teaching secondary school chemistry. How and what Kenyan County chemistry teacher trainers learned through their engagement in both individual and collaborative reflective practice was examined. Findings of the study were presented in Chapter Four and discussed in Chapter Five. This chapter describes the conclusions, limitations, delimitations and recommendations of the study. Further areas of research in reference to the current study are also suggested.

6.2 Conclusions

In this study, the professional learning activities undertaken by the Kenyan Country chemistry teacher trainers and subsequent professional learning outcomes were ascertained through teacher trainers' collaborative discussions on critical incidents, and follow up interviews. A limitation of the study was the lack of classroom observations of the actual professional learning activities and outcomes, and as such, findings are based on the perceptions of individual teacher trainers and what they reported and discussed about their experiences. The overarching question investigated through these data were: *How and what do Kenyan county chemistry teacher trainers learn from participating in a study in which they reflect on their secondary school teaching experiences?*

To answer this question, five sub-questions were explored in the research:

1. How do Kenyan County chemistry teacher trainers address pedagogical critical incidents arising from their lessons through reflection?
2. How does reflecting on pedagogical critical incidents facilitate Kenyan County chemistry teacher trainers' learning?
3. What are the common contextual problems Kenyan County chemistry teacher trainers face that prevent them from pursuing their pedagogical goals in their chemistry classrooms?
4. How do the Kenyan County chemistry teacher trainers say they intend to operationalize their reflection experience to improve teaching and learning in secondary school chemistry in the Kenyan context?

5. How do the Kenyan County chemistry teacher trainers say they intend to operationalize their learning from reflection in their roles as County chemistry teacher trainers?

The conclusions and recommendations presented in this chapter are based on the findings discussed in Chapter Four, framed within the five research sub-questions.

6.2.1 Professional learning activities: how teachers learn

How teachers learn was investigated though the first sub-research question: *How do Kenyan County chemistry teacher trainers address pedagogical critical incidents arising from their lessons through reflection?* Teacher trainers used three different professional learning activities to address pedagogical critical incidents arising from their lessons. These included reflecting, experimenting and interacting with contact. Teachers can, for example, improve their practice and enhance student learning if they look back at what they taught, what they want to teach, what they are teaching, and what they intend to teach in future—i.e., reflecting. Teachers look back on their teaching— reflecting on practice to plan for, in, and with action to improve teaching and student learning. Teachers reflect on practice to understand students' prior knowledge, evaluate students' understanding of previous content taught, and link previous content taught with current content before planning for lessons. Such practice can help teachers to plan for quality teaching (reflecting for action) in that they can avoid repeated mistakes and incorporate practices they have learnt from their own experiences or from other teachers with whom they reflect. Teacher trainers reflected on teaching methods and learning materials they had used in previous lessons and planned current lessons based on their experiences.

Teachers can also improve their teaching and learning by reframing their actions in the classroom. Practice can be enhanced if teachers monitor their own actions in the classrooms (reflection in action) rather than reacting unconsciously. Teacher trainers made necessary adjustments in the act of teaching to better aid students' understanding, and for their lessons to proceed. Finally, teachers can improve teaching and learning by planning to incorporate successful practices they have learnt from their own experiences or from other teachers in their future lessons (reflection-with-action). Teacher trainers suggested actions they would take to respond to problems they noted with their students and from their own teaching in their future lessons.

Teaching and learning can be improved if teachers use diverse teaching methods and learning materials. This can be achieved by teachers trying those methods that are suitable for their students in their context—i.e., experimenting. Teacher trainers tried different teaching methods and learning materials. Experimentation can also be used to test students' understanding of content taught and to confirm ideas and concepts. This helped teacher trainers to understand their students better, their learning needs and difficulties, which appeared to motivate them to seek alternative teaching methods and learning materials.

Teachers learn when they interact with students and colleagues. Teacher trainers interacted with students in the classroom and with their colleagues in the group reflection discussions. Through interaction with students, teacher trainers were able to identify learning difficulties from students' written work, through conversations, and by observing student behaviors. In group reflection discussions, teacher trainers learnt about teaching methods, students' leaning needs, and subject content by exchanging ideas and critiquing their own and their colleagues' practices. Through these interactions, they appeared to acquire knowledge which they can use to handle instructional issues and students' problems; and also to explore innovative teaching methods and learning materials.

6.2.2 Professional learning outcomes: what teachers learn

What teachers learn was investigated though the second, fourth and fifth sub-research questions: *In what ways does pedagogical critical incident reflection facilitate Kenyan County chemistry teacher trainers' learning; how do the Kenyan County chemistry teacher trainers say they intend to operationalize their reflection experience to improve teaching and learning in secondary school chemistry in the Kenyan context,; and how do the Kenyan County chemistry teacher trainers say they intend to operationalize their learning from reflection in their roles as County chemistry teacher trainers?*

Changing practice and intentions to change practice were considered as learning in this study. Reflecting on a critical incident facilitated teacher trainers' learning from their teaching experiences. They also expressed intentions to implement what they learnt in their future classroom teaching and with other teachers when they worked in their capacity as County teacher trainers during INSET. Teacher trainers demonstrated that they can develop knowledge in, for, and of practice from their teaching, and the knowledge they acquire can be used to develop ideas about teaching methods, student learning, and subject content. Acquisition of

knowledge in, for and with practice enables teachers to identify their strengths and weaknesses and seek alternative approaches to teaching. Teacher trainers realised that they were not involving students in practical experiences, they were not teaching for understanding because their classes were characterized by teacher-centred approaches, and their teaching was examination-oriented. In other words, their focus was on products rather than processes in experiment work, and learning in general. They also noted that they do not reflect on their practices. Teaching methods such as peer teaching were found to be effective in enhancing students' understanding of concepts they otherwise perceived as difficult. Teacher trainers expressed intentions to trial their colleagues' teaching methods and to adjust their practice to improve teaching and student learning.

Knowledge teachers acquire in, for and with practice also enabled teachers to develop knowledge of student learning. From their own reflections and those of the group, teacher trainers realised that practical experiences, use of students' ideas, use of guided practice, understanding and addressing misconceptions; use of students' prior-knowledge; and care with language use all contribute to enhanced student learning. They proposed alternative teaching methods based on how students could learn better.

Knowledge teachers acquire in, for and with practice also enable the development of content knowledge. Teacher trainers realised that content taught in some sub-topics, such as pH values, were beyond the level of students in Form One. Abstract concepts and misconceptions arising from an over-reliance on text book content without appropriate deconstruction and interpretation to a level that students can understand, was an issue. Teacher trainers also gained knowledge about other subjects from their colleagues, such as mathematics used to interpret some of the chemistry concepts.

6.2.3 Contextual problems Kenyan County chemistry teacher trainers face that prevent them from pursuing their pedagogical goals in their chemistry classrooms?

Contextual problems affect teaching and learning in teacher trainers' classrooms. Contextual problems arising in this study were those associated with classroom factors (related to teachers and students), school factors, and external factors such as external examinations. It was found, for example, that teacher trainers were limited in general pedagogical knowledge and pedagogical content knowledge specific to selected topics, and that these limitations affected student learning. Assumptions made by teacher trainers about students' negative attitudes and

learning difficulties, also affected teaching and learning, because they sometimes failed to notice students' learning difficulties, blaming poor attitudes instead. Teacher trainers generally neglected to address students' learning difficulties; test experiments before lessons; and used reduced-quality approaches to teaching because of time constraints.

Students' attitudes, beliefs, and learning difficulties can affect teaching and learning of chemistry. It was found that many of the teacher trainers' students had a negative attitude towards chemistry, possibly arising from experiences of ineffective, unengaging teaching methods, previous negative experiences and/or peer influences. Many students in the teacher trainers' classrooms also lacked knowledge of basic scientific concepts resulting in further misconceptions. A lot of class time was also spent by teacher trainers trying to explain difficult concepts. These examples of unexpected use of time often meant that they were unable to cover the syllabus adequately and within the stipulated time frame.

Chemistry is a practical subject requiring equipped laboratories, qualified teachers and laboratory assistants. Teacher trainers reported that many schools in Kenya lack such resources, which affects teaching and learning of the subject in a negative way. Gaps were also identified in chemistry textbook content and the syllabus. Teacher trainers realised that some content found in chemistry textbooks and the syllabus were beyond the cognitive abilities of the students, especially at lower levels, and the examination-oriented education system also affected teaching and learning in a negative way. Teacher trainers failed to address students' difficulties or plan their lessons well because they were rushing to cover the syllabus in order to create time to "drill" students in revision for the final examination.

This chapter has illustrated that the objectives of the study were achieved. Teacher trainers were given an opportunity to reflect on a critical incident individually after their normal teaching and in group reflection discussions organised by the researcher. Teacher trainers documented their reflections on their teaching and learning experiences and the contextual problems they face while teaching in written protocols. They then used these protocols in group reflection discussions where professional learning was observed through sharing of ideas and approaches, and through the professional discussion about practice.

6.3: Overview of the main study findings

Overall, the study indicated that:

1. Although reflection is not a common practice in Kenyan schools and teacher education, a critical incident approach to reflection seemed to support teacher trainers in changing their role in their learning process, and also changing the way they perceive their teaching.
2. Teacher trainers appreciated the opportunity to engage in reflective practice, unlike the findings of some studies where teachers have been reported to dislike the idea of reflection.
3. Teacher trainers missed many opportunities to learn from their teaching experiences in both individual and collaborative reflection.
4. Although prevalent in other western countries based research studies, the teacher trainers seemed to participate less in activities that required them to scan professional information.
5. Teacher trainers encouraged each other to share experiences with other teachers in their schools, although collaborative activities are also demanding and are not popular in many school organizations.
6. The study confirmed that teachers can learn from their students, a somewhat under-emphasised professional learning activity in the literature.
7. Teacher trainers perceived that the nature of some content and practicals outlined in the Kenyan secondary syllabus and in textbooks was not suitable for the grades/forms they were written for in terms of students' cognitive abilities at the given level. They also found that their students did not always learn from practical work, and identified their own teaching methods as a possible contributing factor to this, alongside students' existing misconceptions in some topics.
8. Experienced teachers can also be limited in pedagogical content knowledge. Teacher trainers appeared to have limited general pedagogical knowledge and pedagogical content knowledge for some topics, even though they were all experienced chemistry teachers who had been appointed as chemistry teacher trainers in their County based on merit.

6.4 Limitations and délimitations

From the findings presented in Chapter Four, and discussed in Chapter Five, it can be argued that this study provides new ideas to consider regarding teacher professional learning in the context of secondary chemistry education in Kenya. There are, however, limitations and delimitations to consider in the study, which are discussed in the following sections.

6.4.1 Limitations related to research participants

The researcher acknowledges that there is a limitation in the sample size for the study by the small numbner of participants; that being a total of four County Chemistry teacher trainers. Such a small number of participants do not allow generalization of the study findings to the wider population of chemistry teachers and teacher trainers in Kenya. However, given the case study nature of the study, generalization was not intended. Case study research is aimed at providing insights and ideas (Stake, 1995, 2006) about experiences, something that is applied to the particular participants of this study and their experience of learning informally from their own teaching experiences.

Whilst not intended to be generalisable, the study may, however, have transferability – the qualitative researcher's equivalence to generalisability. Transferability is provided through the rich description and detailed information regarding context and background of the study. As such, the findings of this study could be assessed for their applicability and transferability to other contexts. Strategies detailed in the research methodology section have been employed to ensure that the researcher had a deeper understanding of the phenomenon under investigation from the four participants. These strategies included: selecting participants who had prolonged experiences of teaching and representing two communities of practice (chemistry teacher trainers and classroom chemistry teachers); engaging participants in critical reflection, which according to Lincoln and Guba (1985), scales up the scientific rigour of a study in terms of credibility and conformability; and analysis of the participants' teaching experiences using a detailed coding scheme. Knowledge generated from this analysis is "local" to the Kenyan context. However, it is knowledge that can be "borrowed, interpreted, and reinvented in other local contexts" (Cochran-Smith & Lytle, 2009, p. 132).

A further limitation with respect to participants is that they volunteered to participate. They may have considered the study an additional opportunity to their usual training, an opportunity to try something new. In this regard, they may have had a favourable bias to the professional

development program, making it questionable whether the findings may have been different if other teachers, and not volunteers, had been involved. A more enforced model of participation may have yielded less enthusiasm for the program and its particular learning experiences, which may have in turn, affected the extent of participation and subsequent nature of the learning (Bobrowsky, Marck, & Fishman, 2001; Desimone, 2009; Hoekstra, Kuntz, & Newton, 2017).

6.4.2 Limitation related to research methodology

Although a strong link has been recognized between teachers' beliefs and practice, and student achievement (Mojavezi & Tamiz, 2012) limitations of self-data were also acknowledged. Self-data can be subject to bias (Hoekstra et al., 2017; Maggioni & Parkinson, 2008). Learning activities and learning outcomes were treated as *"potential professional learning activities" and "potential learning outcomes"*, however, participants' teaching and learning outcomes were not observed first hand, so it was assumed that the participants gave honest and accurate responses. Group discussions, and interviews were used to collect data. The study therefore succeeded only in identifying teacher trainers' perceptions and possible effects on their teaching, rather than visible learning outcomes through direct observations or assessments. Use of a different method, for example classroom observations, might result in different findings (Van Eekelen, Boshuizen & Vermunt, 2005).

A second bias in the research methodology may have occurred because participants were free to choose which critical incident they wanted to discuss. They might not have included learning episodes that reflected negatively on them.

To minimize potential bias of self-reflection, individual participant reflections were supported with group reflection discussion and interview data. During the group reflection discussions, participants had opportunities to probe for further explanation and clarification from their colleagues. Probing questions were also used during the interviews. While probing questions facilitated additional anecdotes, participants found it difficult to recall learning experiences, possibly because they did not consider their day-to-day activities to be part of a learning process.

6.4.3 Delimitations

To reduce time and expense the research was delimited to one geographical County in Kenya. In this County, permission to conduct research was obtained and County teacher trainer volunteers were sought who were willing to reflect on their practice. Participants of the study

were selected from a community of teacher trainers who have rich teaching experiences and who interact with many teachers in their roles as County trainers. The trainers, who are mandated to develop training content to deliver to other chemistry teachers, were willing to participate in this study to enrich their expertise. Also, as County teacher trainers, they were in a better position to transfer findings of this study to chemistry teachers more broadly, compared to if a group of classroom teachers only were targeted. The study was delimited to chemistry because of students' poor performance compared to the other two science subjects (Biology and Physics) offered at the secondary level in Kenya, and because it was also the researcher's area of expertise.

6.5 Recommendations

Based on the research findings and consideration of the extant literature in the field, the following recommendations are made:

Recommendation #1: Teachers' experiences should be included in the design and delivery of professional learning programs, especially in African countries like Kenya. Teacher trainers' learning in this study proved successful when they chose and analysed a critical incident from their own teaching that they thought they could learn from.

Recommendation #2: To support teachers in their professional learning and development, in-service training programs should offer different types of professional development activities, rather than adopt a single type approach. The later is unfortunately quite common in many professional learning programs. The study's findings showed that teacher trainers have preferred professional learning activities which they can use to learn.

Recommendation #3: There is a need for guided reflective practice procedures in Kenya since teacher trainers missed many learning opportunities in reflecting on their practice. Schools in Kenya should introduce school-based in-service training, where teachers are encouraged to reflect on their practices and share teaching experiences between one another. The frequency of in-service training, for both classroom teachers and teacher trainers, should also be increased from the current one or two weeks per year.

Recommendation #4: Teacher trainers reported that many secondary schools in Kenya lack qualified teachers, laboratories with basic equipment, and laboratory assistants. Practical experiences are an integral part of teaching and learning in chemistry, and of the country's

chemistry syllabus. Therefore, the government should ensure these facilities are provided if the current trend of poor student performance in chemistry is expected to improve.

Recommendation #5: Gaps reviewed between the chemistry syllabus and text books, and what is actually taught in the classrooms and the content of external examinations conducted at the end of the four years of secondary schooling were found to affect, to some extent, teaching and learning of chemistry. These findings should be considered in the current education review in Kenya, and any other country faced with similar challenges.

6.6 Recommandations for further research

1. A follow-up study should be conducted with the four participants to determine how, over time, they have changed (if at all) their practices of teaching chemistry, how any changes have continued to evolve, and even more importantly, how (if at all) they have changed their practices as teacher trainers**.**

2. Further research should be directed to further scrutinise the actual teacher trainers' learning experiences reported in this study through additional methods, such as classroom observation. Findings were based on reported outcomes but actual teaching practice and outcomes were not directly observed. Also, the research design was limited in the opportunities teacher trainers had to implement what they learnt during the study.
3. The current study included only four Chemistry teacher trainers. As such, a repeat of the same/similar study using a larger number of participants would be beneficial and assist in providing increased capacity to generalise the findings to a wider population.
4. Since the findings showed that the teacher trainers intended to implement what they learnt, not only in their secondary school classrooms, but also in the professional learning they deliver to other chemistry teachers through their roles as Country chemistry teacher trainers, it would be worthwhile investigating differences and similarities between the professional learning outcomes of these teacher trainers and those of other classroom teachers.
5. Further research should examine whether the students of teachers undertaking a reflection professional learning program like this study experience improved learning outcomes, and subsequently better performance on the national examinations.

FINAL REMARKS

The aim of all professional learning and development programs is to enhance classroom teaching and subsequently, improve outcomes in student achievement. The research described in this thesis is an example of practising chemistry teachers' learning from the act of teaching. I found the teacher trainers in this study enthusiastic to learn new knowledge and share with each other in group reflection discussions about their own and their colleagues' teaching experiences. They also expressed a desire to change their practice and to try new teaching methods and learning materials to enhance their teaching and training for better student learning.

The experience of listening to these chemistry teacher trainers made me realise that professional learning and development for practising chemistry teachers is a worthy subject for research. I hope the ideas and insights presented in this thesis have been made clear and are presented in a way that might be meaningful and applicable to other contexts. Most importantly, I hope the findings of this study can assist in enhancing the quality of chemistry teaching and learning in the classrooms of Kenya and beyond.

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APPENDICES

Appendix A : Affiliation letter CEMASTEA

CENTRE FOR MATHEMATICS, SCIENCE AND TECHNOLOGY EDUCATION IN AFRICA
(CEMASTEA)

Tel:+ 254-20-3873811/3874830
Safaricom: 0706722697
Airtel: 0789797648
Fax +254-20-3873811/884756/882632
E-mail: comastea@education.go.ke

P. O. Box 24214-00502
Karen, Nairobi
Kenya

CEMASTEA/TSC 287456/06

20th January, 2014

AUSTRALIAN CATHOLIC UNIVERSITY
GRADUATE RESEARCH
Lvl5, 250 Victoria Parade, East Melbourne, Vic.3002
Locked Bag 4115, Fitzroy, Vic 3065
www.acu.edu.au

Dear Sir/Madam

REF: REQUEST FOR AFFLIATION: MERCY WANGUI MACHARIA

This is to confirm that the above named is a member of staff of Centre For Mathematics, Science And Technology Education In Africa (CEMASTEA) currently undertaking her Doctor of Philosophy studies in your institution- Ballarat Campus. She has requested to be affiliated to CEMASTEA to fulfil The National council for Science and Technology (NCST) requirement that overseas students be affiliated to local institutions to secure permit to conduct research in Kenya
The tittle of her thesis is, '***Professional Learning and Development through Reflective Practice: Lived experiences of Kenyan Chemistry Teacher Trainers***

CEMASTEA has no objection to her affiliation and will give necessary assistance to enable her to conduct her research in Kenya

Yours Faithfully,

Stephen M. Njoroge
DIRECTOR

Appendix B : Certificate to conduct research in Kenya

THIS IS TO CERTIFY THAT:
MS. MERCY WANGUI MACHARIA
of AUSTRALIAN CATHOLIC UNIVERSITY,
24214-24214 NAIROBI,has been
permitted to conduct research in
Machakos County

on the topic: *PROFESSIONAL LEARNING AND DEVELOPMENT THROUGH REFLECTIVE PRACTICE: LIVED EXPERIENCES OF KENYAN CHEMISTRY DISTRICT TEACHER TRAINERS*

for the period ending:
29th February,2016

Permit No : NACOSTI/P/15/4859/6260
Date Of Issue : 3rd July,2015
Fee Recieved :Ksh 2,000

[redacted]
Applicant's Signature

[redacted]
Director General
National Commission for Science, Technology & Innovation

CONDITIONS

You must report to the County Commissioner and the County Education Officer of the area before embarking on your research. Failure to do that may lead to the cancellation of your permit
Government Officers will not be interviewed without prior appointment.
No questionnaire will be used unless it has been approved.
Excavation, filming and collection of biological specimens are subject to further permission from the relevant Government Ministries.
You are required to submit at least two(2) hard copies and one(1) soft copy of your final report.
The Government of Kenya reserves the right to modify the conditions of this permit including its cancellation without notice.

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH CLEARANCE PERMIT

Serial No. A 5622

CONDITIONS: see back page

Appendix C : Advertisement for researchers' notice

AUSTRALIAN CATHOLIC UNIVERSITY

ADVERTISEMENT FOR RESEARCHERS NOTICE

RESEARCH PARTICIPANTS NEEDED

Who
Males and Females
Chemistry district teacher trainers who have taught and trained for more than five years
What
You will be required to reflect on your practice, isolate and analyse one key teaching/learning experience (critical incident) from your chemistry lessons each week for six months. From a series of four critical incidents isolated weekly in a month, you will be required to select one incident and share your experiences with colleague participant in a group reflection to be held once a month for six months. A critical incident is not necessary an emergency but an ordinary everyday classroom event that teachers would wish to understand better. You will also participate in an individual interview which will be conducted towards the end of the study where you will be asked to answer a few questions regarding your experience from participating in this study. The interview will last for about 30 minutes but you are free to withdraw at any stage of the interview without any consequences and data collected from you will not be used and will be shredded. You will also attend a two days orientation workshop before the start of the study.
Where
Individual reflection on your practice takes place at your convenient time. Orientation workshops and group discussions will be held in your school or any other place that you and that you and other participants will agree on. Individual interviews will be conducted at your convenient time and place. You will be reimbursed transport expenses and lunch and teas will be provided. Funds equivalent to your one day pay (about Ksh 3,000) will be paid to you each day during the days you will attend orientation and group reflection discussions. Any other materials required e.g., USB, writing materials will be provided.

About the Research
The aim of the research is to improve secondary school teaching and in-service teacher training in chemistry. The purpose of the study is to examine whether Kenyan chemistry district teacher trainers can learn and develop their pedagogical skills from participating in a professional development program in which they reflect on their secondary school teaching experiences. The research is being undertaken by the student researcher for partial completion of the Doctor of Education at the Australian Catholic University.
Contacts
If you choose to participate please contact Mercy Macharia (Student researcher) through the following email addresses wangomacharia@yahoo.com. or mwmach001@myacu.edu.au or call +254708019522

Appendix D : Completed critical incident reflection questionnaire

#Rett GRD1: September 2015

Topic: Nitrogen and its compounds
Topic: Laboratory preparation of Nitrogen (IV) oxide
Class-Form 3S

***Critical Incident description*:** It was a double lesson and a demonstration on laboratory preparation of nitrogen (IV) oxide. All the apparatus were available except a cork for round bottomed flask and ice-cold water. The school fume-chamber was not in order so the alternative was to carry out the demonstration in the open air. A test-tube was used in place of round-bottomed flask while cold water was used for the ice-cold water.
After some few minutes of heating, the small test-tube exploded and the gas was in the air. A little of the dinitrogen tetra-oxide formed at the U-tube. Students got chocked on inhaling the gas.

I thought over it and used a boiling tube instead of the test-tube. Heating was gentle and the Lead (II) nitrate underwent slow decomposition.
Nitrogen (IV) oxide was formed steadily and condensed in the U-tube to form a yellow liquid. The amount of dinitrogen tetra oxide was too little. A better condensing substance was needed. It was obtained. When it was used in the U-tube, much of the nitrogen (IV) oxide was obtained having been condensed to form yellow dinitrogen-tetra oxide.
From the explosion of the test-tube, I learnt that the salt required a large surface area for the decomposition and the heating was to be gentle not strong. When improvising chemicals and apparatus, it is important we consider the properties of each chemical or apparatus for the success of the experiment. This is because the used cold water could not condense the nitrogen (IV) oxide to liquid until proper ice was used.

As a teacher I learnt that, its important to test the workability of chemicals and apparatus before done in class. Not all apparatus can be improvised, some cannot be improvised, but a prior test of an experiment will always be necessary.
The conventional set up is as shown below which a challenge was because a round-bottomed flask was missing and a test-tube was used.
With gentle heating and use of a boiling tube to heat the Lead (II) nitrate was the solution. Ice cubes were used to condense nitrogen (IV) oxide which was collected as yellow liquid dinitrogen tetra oxide. In the future, any demonstration be tested the workability before presented as class demonstration. The necessary precautions should be observed for security of the participants.
Overal, from the reflection I have learnt the following:

1. Always test the workability of experiments.
2. To be present when chemical reagents of our experiments are being prepared.
3. Always look for an alternative way of carrying out experiments.
4. To be very careful when improvising apparatus because they may not work.

Appendix E : Section of group reflection discussion transcript

Section 1: Group reflection discussion 5 Jan 2016: Dott
Topic: Atomic structure
Sub-Topic: Electronic configuration
Class: Form Two

Dott:(Description of the incident). My incident comes from the sub-topic electronic configuration of atoms. I had covered this topic adequately in class with Form Twos. During class, I could give them work, and I could see the student write the correct electronic configuration of atoms. After we finished the topic, I decided to go back and give a question to recap—to see whether they were able to remember what we had learnt in the previous lessons. I gave them sodium and magnesium, and I asked them to write their electron arrangement. To my surprise, what they wrote for sodium was 2.9 and magnesium 2.10. Then I thought what I could do for students to understand that the second energy level should have a maximum of eight electrons. I made balls using plasticine, two small size for the first energy level, eight bigger size for the second energy level, in that order. Then I carried them to class and drew circles representing energy levels on a manila paper. The circles were drawn in such a way that they could only fit balls representing the required electrons (maximum number of electrons). I asked the students to fix the balls on the circles I had drawn on the manila paper, the two small ones on the inner energy level after the nucleus, and then the others on the next energy levels the way they were following in size. When they fixed the eight on the second energy level, we realised there was no space for the ninth one, we fitted them, the eight of them, in such a way that a ninth one could not fit there. I told them to do the same with magnesium, and again, the ninth could not fit in the second energy level.
What was I trying to achieve? I was trying to increase their retention to the fact that the second energy level can hold only a maximum of eight electrons, and the ninth cannot be held there because there is no space. The activity I created with different balls of plasticine was to increase the students' retention of the knowledge that electrons follow the $2n^2$ rule when occupying the various energy levels from the nucleus. I thought with that, students would understand and I would not have a repeat of 2.9 and 2.10. Thank you.

Group reflection
Moderator: Thank you, I would request the other members to also give their own input on whether you have had a similar experience on the same sub-topic.
Rett: I am teaching something similar in Form Two, and I have encountered a similar problem. I think one of our major problems is that our students do not concentrate, especially when we are teaching. I have a number, who have a negative attitude towards the subject. So, when we are teaching, it is good that we be very observant on the behavior of the students, because you may tell students to copy something you have written on the chalk board, and some may not write, and even when you check what they have written on their note books, you may find that they have written totally different things from what you have taught. To assist students place electrons on the right energy levels, I normally give them some practice, with some examples to practice. And through practice, actually some will internalize on how to do it.
Moderator: Okay.
Ritt: I have had a similar challenge with what my colleagues have been having. I have been giving a theory approach. You just tell the students that the first energy level always have a maximum of two electrons, the second energy level eight electrons and so on. I have even been

giving them this formula of the maximum number of electrons to be contained in an energy level as $2n^2$. I think when we see our students writing the configuration of sodium as 2.9, and not 2.8.1, it is because they have not really conceptualized why it is 2.8.1; for example, why the first energy level must only hold only 2 electrons. I did not have any other way of teaching and I think that is why I have been having the same problem my colleagues have been having, but today I have gotten a new idea. From what Dott has described, the way she has been doing it. I think I will adopt her method, and see whether it can change my students.

Moderator: I think we are too much theoretical. We always start with the formula —$2n^2$. Do our students understand what this n is so that they can calculate the number of electrons for each energy level mathematically? Even that formula sometimes brings confusion. After calculating the number of electrons of the first energy level and we get 2, we normally tell them to calculate for the second energy level which they get eight, which is Okay, but what about the third energy level, for example in calcium? Mathematically, it is supposed to be 18, but we tell them that for the first twenty elements of the periodic table, the third one holds a maximum of eight, you see, total confusion. With her idea, we can try to do it practically for the first twenty elements. But we should be very careful not to introduce another misconception; electrons are of the same size. From her explanation, she had small balls representing electrons occupying the first energy level.

Kytt: I think containers would help clear that misconception; we have containers of different sizes, such that the small container will only accommodate two balls and so on. Using the same idea, one can also construct a model using wood and make several layers. Then, depending on the number of electrons an energy level can hold, you make holes of the same size along the layers. The student can play about with the balls. All what you need is to give them the atomic numbers of the elements you want them to write their electronic configuration for and then instruct them how to do it. They should fill the energy levels and at the same time write down the number of electrons each hold. It will be like a game, once this energy level is full; I go to the next one, and write the number of electrons I have used. I think with that kind of practice, they will internalize.

Moderator: What about during INSET? How do you share these ideas with the teachers? Who wants to begin?

Dott: I think during INSET, we can pose a question for participants to tell us if they are faced with such problems, where the second and the third energy levels are given the wrong number of electrons. We could give teachers materials to improvise models to teach in this area such as: plastic containers, wood, mangoes, plasticine and the like. Then, we tell them to try them out using different elements. You know, 'seeing is believing', we will then advise them to use them with their students.

Ritt: You can also bring it out as a case. Ask teachers—participants in the INSET, the kind of answers they get from their learners when they ask them to write electronic configuration of atoms. Definitely, I know some of them will come up with answers like 2.9 for sodium and 2.10 for magnesium. We make it an activity and discuss why students could come up with such answers. To sum up later, we ask participants to come up with ways of assisting students internalize the concept of the second energy level in the first 20 elements of the periodic table holds a maximum of eight electrons. We might get valid ideas on how we can do it. At the end of the session, we could give them the ideas we have suggested here today, if none of the teachers raised the same ideas. By doing that, we will have given our trainees an opportunity to come up with other ways of solving this problem.

Rett: Personally, I would use a participatory approach, you give your colleagues time to share their experiences from their schools and maybe how they approach this concept. I know

different teachers will approach it differently. Maybe if we use the approaches our teachers use in their schools, they will own the process and also we will have different approaches of solving the same problem because at the end of the day, what we want is for our students to internalize the concept. From there, we can give an example of how it can be done, maybe by using a model.

Kytt: We could capture several images of such answers because the 2.9 and 2.10 may not be the only unique ones, we may also have another one like 1.8, where the first energy level is assigned less electrons. During INSET, we could discuss and try to find out where the problem is emanating from; reflect on how we have been teaching and suggest solutions. Also, ask teachers how they have been doing it? Or, maybe they have been giving up, because I know most of us have been giving up. We can then propose a practical approach, so that students will internalize and have a justification of what they are doing, not just writing, the way they have been doing it.

Researcher: Are there local challenges that hinder you from doing practicals in this area?

Dott: I think in this area there are no local challenges; it is just ignorance on our side. For example, wild fruits are all over this place, which can be used to represent electrons. I think you can make such an activity becomes practical, and we involve our students with hands-on activities, for them to discover, before we introduce the abstract information.

Researcher: What about other challenges not only on materials, what about time? How many hours are allocated for this topic in our syllabus? Maybe there is no time to do practicals. Is this topic given enough time? Who knows?

Dott: I think even if we do not know, it is the approach we give to it, not the time, because if I start by giving a practical activity, retention will be higher with the learners. Because as I give this, I am also discovering, I cannot start by telling my student it is 2, why 2? Let's do it practically, and then bring the rule, that rule that is 2, then 8 like that, they will understand.

Ritt: I think apart from lack of resources and time, also the creativity part of it is a challenge. Because, like what my colleague here was saying, making rings which only specific number of balls can fit, for example only two can fit in the first ring and eight on the second ring, you know, nobody can think very fast like that. It is something that she made, that has triggered my mind to imagine that kind of a scenario, I would not have thought about it myself.

Dott: Once we introduce a platform for chemistry teachers in the Counties, as Moderator has proposed, you will be posing questions to the teachers and you will be getting reactions from them (Correct, group members are in agreement). Maybe this will help out teachers solve some of the problems we are having with our students.

Moderator: We have not addressed the issue of why the students do not understand.

Dott: I think we have agreed that it is the way we approach the topic; sometimes we bring misconceptions and also we do not give our students opportunities to internalize those concepts.

Moderator: Thank you.

Appendix F : Interview

 # Dott interview transcribed 25/08/2016

Preliminaries: This study seeks to explore whether Kenyan chemistry district teacher trainers can learn and develop their pedagogical skills from participating in a program in which they reflect on their secondary school teaching experience. Before we start this interview, I want to highlight a few important points: firstly, I want to assure you that even if you and I share many experiences, your experiences are unique because you operate in two communities at the same time (that of a trainer and that of a classroom teacher) which personally I have not experienced. Therefore, your participation is of high importance in this investigation and you are welcomed. Secondly, your voluntary participation in this interview will be greatly appreciated and I want to assure that your responses will be COMPLETELY CONFIDENTIAL and thirdly, this interview is scheduled to take at least ONE HOUR but you are free to withdraw before completion if you desire.

Introduction:

Moderator: Welcome Rett for this interview. I will ask you a few questions regarding the exercise we have been carrying out for the last seven months.

Dott: Thank you.

Moderator: From the study we have carrying out, have you learnt any pedagogical lessons from individual reflection on your practice?

Dott: Yes. As an individual I have learnt a lot out of the critical incidents that we had. One I realised as a teacher, there are many things I have been assuming in my teaching and out of the discussion I realised that I don't do a reflection of what I have taught, probably students have had misunderstanding of my concepts and maybe that is why they do not do well in the examinations. And again in the group discussions I have also realised other teachers have been faced with same challenges I have, we teach and we do not do a reflection. We seriously affect the learning of the students because we assume much.

Moderator: Can you site an example something you have learnt from your individual reflections.

Dott: I realised for example when I am teaching chemistry in Form One about separation, I dwell much with teacher demonstrations and I do not involve my students actively. For example, I realised that in Form One I can show students how to fold a filter paper, and I do not tell them to fold it themselves, so when we come to Form Four, I realised in Form Four, when I am telling students in an experiment to fold the filter paper so as to do filtration, they do not know how to do it. I realised when we teach in Form One, we should not leave the work there, we should bring it on board even to the upper classes.

Moderator: Good. There is how we reflect on our own and sometimes we can also learn from our students. Do you always learn from our own individual reflection or are there moments you also learn from your students?

Dott: Yes, sometimes I have also learnt from students because I can give a particular concept and I give it to be done this way, and then the students give me a different suggestion, instead of doing this way we can do it this way. For example, connecting cells when we are doing electrolysis, they normally tell me let's connect this way or instead of using the galvanometer or a voltmeter they have told me we can use a musical card especially those who take physics and the musical card has responded the same as the galvanometer. I have realised the students' initiative is very important even when we do our teaching.

Moderator: So you have learnt from both your individual reflections and from the students?

Dott: Yes.

Moderator: How did you find the group discussion sessions?
Dott: What I learnt from the group is about the way the other members were reflecting on certain concepts. I learnt that a teacher may approach a particular concept in a different way from mine and we all achieve the same goal. I realised that involving other teachers in what we were doing, you will learn doing a particular concept in a different way and the end result is the same.
Moderator: How will you apply lessons learnt in your future classes? Are there lessons that you have learnt during the seven months that you think you will apply in your future lessons? Give me an example of how you might use one in your future classes)
Dott: Yes, there are several things that I have learnt that I will apply in my future lessons, one, I need to teach learners for understanding; I need to give students time to give their own ideas on a particular concept on how they are understanding. I have also learnt that if I am not good in a particular concept, I can call another teacher or another member of another group to do that particular teaching of a particular concept. I have realised that I need personally to be involved in the actual preparation of some of the experiments we give our laboratory assistants to do in the laboratory, I should be at the forefront.
Moderator: We were also looking at our INSET, the one which has been training our teachers, remember you wear two hats. You have several roles, you are a classroom teacher teaching chemistry and also training other teachers as a trainer. How will you apply lessons you have learnt from individual and group reflections from this study in your future training for chemistry teachers?
Dott: During our future INSETs I will apply what I have learnt from my own reflections. I will tell the teachers it is important to reflect on what we have taught so that we understand how the learners have understood the concepts we have taught. I will encourage our teachers during INSET to also find out some of the critical incidents that happen in their classroom during their everyday teaching and reflect on them; a kind of reflection that we had, and maybe they will get the kind of feedback we got from our students. They will be able to gauge whether they teach for understanding or they just teach and assume students have understood. And again in the future INSETs I can ask participants, because they are also teachers, if they are faced with similar challenges like the ones I realised during our group discussions, again then we share so that we improve during our classroom and also during workshops.
Moderator: I know you have learnt a lot and I hope you will improve your future classes and trainings. Once again thank you for your cooperation and also your time.
Dott: Yes. Welcome

Appendix G : Human Research Ethics Committee approval

AUSTRALIAN CATHOLIC UNIVERSITY

Human Research Ethics Committee
Committee Approval Form

Principal Investigator/Supervisor: Associate Professor Gloria Stillman

Co-Investigators: Dr Mellita Jones

Student Researcher: : Ms Mercy Macharia

Ethics approval has been granted for the following project:
Professional Learning and Development through Reflective Practice:Lived Experiences of Kenyan Chemistry District Teacher Trainers

for the period: 29/02/2016

Human Research Ethics Committee (HREC) Register Number: 2015-45E

Special Condition/s of Approval
Prior to commencement of your research, the following permissions are required to be submitted to the ACU HREC:
1. Approval by the National Council for Science and Technology, Ministry of Education, Kenya to conduct research in Kenya; and
2. Permission by the District Education Officer (DEO) to contact research participants and conduct research in the chosen district.

The following standard conditions as stipulated in the *National Statement on Ethical Conduct in Research Involving Humans* (2007) apply:

(i) that Principal Investigators / Supervisors provide, on the form supplied by the Human Research Ethics Committee, annual reports on matters such as:
- security of records
- compliance with approved consent procedures and documentation
- compliance with special conditions, and

(ii) that researchers report to the HREC immediately any matter that might affect the ethical acceptability of the protocol, such as:
- proposed changes to the protocol
- unforeseen circumstances or events
- adverse effects on participants

The HREC will conduct an audit each year of all projects deemed to be of more than low risk. There will also be random audits of a sample of projects considered to be of negligible risk and low risk on all campuses each year.

Within one month of the conclusion of the project, researchers are required to complete a *Final Report Form* and submit it to the local Research Services Officer.

If the project continues for more than one year, researchers are required to complete an *Annual Progress Report Form* and submit it to the local Research Services Officer within one month of the anniversary date of the ethics approval.

Signed: ..... [redacted] ..... Date: .... 22/04/2015.....

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Appendix H : Participant information letter and informed consent form

AUSTRALIAN CATHOLIC UNIVERSITY

PARTICIPANT INFORMATION LETTER

Project Title: Teacher professional learning and development through reflective practice: Lived experience of Kenyan chemistry district trainers
Principal Supervisor: Associate Professor Gloria Stillman
Co-Supervisor: Dr. Mellita Jones
Student Researcher: Mercy Wangui Macharia.
Student's Degree: Doctor of Education

Dear Participant,
You are invited to take part in research exploring teacher professional learning and development through reflective practice. The aim of the research is to improve secondary school teaching and in-service teacher training in chemistry. The study seeks to examine whether Kenyan chemistry district teacher trainers can learn and develop their pedagogical skills from participating in a professional development program in which they reflect on their secondary school teaching experiences. The research is being undertaken by the student researcher for partial completion of the Doctor of Education at Australian Catholic University.
You will be reimbursed transport expenses, lunch and teas will be provided and funds equivalent to one day pay (about Ksh 3,000) will be paid each day during that you will be attending orientation and group reflection discussions. Any other materials required e.g., USB, writing materials will also be provided.

What will I be asked to do?
The project requires participants to reflect on their practice, isolate and analyse one key teaching/learning experience (critical incident) from their chemistry lessons each week for six months. A critical incident is an ordinary everyday classroom event that you as a teacher would wish to understand better. From your individual series of four critical incidents identified during each month, you will choose one incident and share your experiences with colleague participants in a group reflection to be held once each month for six months. You will also participate in an individual interview that will be conducted towards the end of the study where you will be asked to answer a few questions regarding your experience from participating in this study. The interview will last for 30 minutes but you are free to withdraw at any stage of the interview without consequences. If you choose to participate you are encouraged to ask questions regarding your role as a participant in this study or in any area you feel that you are not satisfied with.

Are there any risks?
It is unlikely that you would experience any discomfort and there are no foreseen risks from participating in this research. If you do experience any discomfort during the research you are

advised to contact Gloria Stillman (Principal Supervisor) at Gloria.Stillman@acu.edu.au or Mellita Jones (Co-Supervisor) at Mellita.Jones@acu.edu.au. Participation is completely voluntary and confidential, protecting your privacy and self-disclosure of sensitive information. If you do agree to participate you can withdraw at any time during the project without comment or consequences.

How will my answers be used?
The data from this study will be reported in a thesis, parts of which will be published. Results may be provided to other researchers for training in teacher professional learning and development programs however these will not identify you in any way. Two copies of the thesis will be submitted to the National Council of Science and Technology which is a legal requirement in Kenya.

How much time will the project take?
The study will take place over eight months excluding school holidays (August and December). You will attend two orientation workshops in the first month of the study. Each workshop will last four hours on a single day. You will be required to reflect on your practice, isolate and analyse one critical incident weekly and then share your experiences using one of the weekly one critical incident in a group reflection to be held once a month in the subsequent six months excluding school holidays. The group reflection workshops will run for about six hours on a single day. Individual interviews will be conducted towards the end of the eight months. These interviews will last for 30 minutes and will be audio recorded.
What are the benefits of the research project?
If the critical reflection approach adopted to promote learning in this study can affect your quality of teaching in chemistry positively, then, it becomes significant to your students' learning outcomes. Since you are also a chemistry teacher trainer, if you positively embrace reflective practice and if you transfer knowledge gained from experience in this study to the in-service teacher training you conduct, the study then becomes significant not only to the secondary school students, but also to the other chemistry teachers and teacher education community generally.

Can I withdraw from the study?
Participation in this study is completely voluntary. You are not under any obligation to participate. If you agree to participate, you can withdraw from the study at any time without adverse consequences and, data already collected part way through from you will not be used and will be shredded.
Will I be able to find out the results of the project?
Results, or a summary of the results of this study, will be available to you in electronic form. You can contact Mercy W. Macharia (Student researcher) at
wangomacharia@yahoo.com or at mwmach001@myacu.edu.au

What if I have a complaint or any concerns?
The study has been reviewed by the Human Research Ethics Committee at Australian Catholic University (review number……..). If you have any complaints or concerns about the conduct of the project, you may write to the Manager of the Human Research Ethics Committee care of the Office of the Deputy Vice Chancellor (Research).
Manager, Ethics
C/o Office of the Deputy Vice Chancellor (Research)

Australian Catholic University, North Sydney Campus
PO Box 968 North Sydney, NSW 2059, Ph.: +61 2 9739 2519, Fax: +61 2 9739 2870
Email: res.ethics@acu.edu.au
Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

Want to participate! How do I sign up?
If you do agree to participate you can contact Mercy Macharia (Student researcher) through the following email addresses wangomacharia@yahoo.com or mwmach001@myacu.edu.au or call +254708019522

Who do I contact if I have Questions?
The following individuals are available to answer questions about the project or discuss any concerns, before, during or after participation:
Gloria Stillman (Principal supervisor) at Gloria.Stillman@acu.edu.au
Mellita Jones (Co-Supervisor) at Mellita.Jones@acu.edu.au
Mercy Macharia (Student researcher) wangomacharia@yahoo.com. or mwmach001@myacu.edu.au

Yours sincerely,
Mwm
Mercy Macharia (Student Researcher)

INFORMED CONSENT FORM – PARTICIPANT'S COPY

TITLE OF PROJECT: Teacher Professional Learning and Development through Reflective Practice: Lived Experiences of Kenyan Chemistry County Teacher Trainers
Principal Supervisor: Associate Professor: Gloria Stillman

Co-Supervisor: Dr. Mellita Jones

Name of Student Researcher: Mercy Wangui Macharia

Program: Doctor of Education

Please sign <u>both</u> copies of the consent form and keep this copy for your records

I..... *(The participant)* have read and understood the information in the letter inviting participation in the research, and any questions I have asked have been answered to my satisfaction. I agree to participate in the undermentioned research, which involves reflecting on my practice, sharing my ideas with my chemistry teacher trainer colleagues and responding to questions in an individual interview. I understand that I will be reimbursed transport expenses, lunch and teas will be provided and funds equivalent to one day pay (about Ksh 3,000) will be paid each day during the days I will be attending orientation and group reflection discussions. Any other materials required e.g., USB, writing materials will also be provided. I realise that I can withdraw my consent without adverse consequences. I agree for audio recordings to be used and that research data collected for the study may be published or may be provided to other researchers in a form that does not identify me in any way. I also agree that the government of Kenya will have access to data and research premises of this study and on completion of the study, two copies of the thesis will be submitted to the National Council of Science and Technology which is a legal requirement in Kenya also in a form that does not identify me in any way.

Name of Participant: .....Phone: .....

Contact Address: .....

Signature: ..... Date: .....

Signature of Principal Supervisor: ……. Date: …….

Signature of Student Researcher: …… Date: ……

Appendix I: Code Book

Focus area	Codes		Anchor items
	Categories	**Sub-Categories**	
Potential professional learning activities	Reflecting	Reflecting-on practice	TT considers/thinks/wonder about their own and those of their colleagues' past teaching practices and students' learning, individually or in collaboration *I think according to me, the problem is the way we are introducing acids and bases and the pH values in Form One* (DottGDR1, r.18).
		Reflection on practice-in-action	TT considers/thinks/wonder about current practice to decide on how to proceed, triggered by unexpected incident in class about teaching methods/student learning/teaching and learning material/subject matter while teaching *I thought very fast how I would engage the learners in a discussion with the same experiment. I asked them to come up with possible causes as to why it might be that the experiment did not work* (RittGDR1, r. 212).
		Reflecting on practice-for-action	TT considers/thinks/wonder about past teaching practices/content to link up new content/evaluate students' understanding of previous content taught or to try different teaching methods/ materials. *In the past I have been teaching this particular preparation of this gas theoretically. I looked at the conventional way of preparing the gas represented diagrammatically in our text books and I thought of trying it practically* (RettGDR1, r. 121-122).

	Reflecting on practice-with-action	TT considers/thinks/wonder about teaching methods/student learning/teaching and learning material/subject matter to plan for future teaching. *I think in the future… because we were doing it last week, I look for a good cork, we heat gently, we give it time to decompose and see if we will be able to collect enough gas* (RettGDR1, r. 138).
Experimenting	Experimenting with a teaching method	TT's deliberate/purposeful effort to try out a self-invented /alternative teaching method individually or with students. *I thought of trying it practically* (RettGDR1, r. 122).
	Experimenting with a teaching materials	TT's deliberate/purposeful effort to try out teaching and learning materials method individually or with students. *I thought if I pass this over cold water, I may be able to form the dinitrogen IV Oxide* (RettGDR1, r. 124).
	Confirming an idea/concept	TT's deliberate/purposeful effort to try out something to confirm an idea/concept individually or with students. *I took two conical flasks and 50ml HCl and 50ml of ethanoic acid, and went to the class because I wanted to iron out that misconception that the pH of a strong acid is 6* (DottGDR1, r. 21)
Learning from others in interaction	Discussing and exchanging knowledge	TTs discussing and exchanging knowledge of one's and others' teaching methods, experience, and ideas and tips about students' learning and education. *I could chip in something small, it means like in this class, because when we talk of the pH scale we actually make use of the universal indicators in Form One to test the acids* (KyttGDR1, r. 40).
	Sharing/ telling/ recounting	TTs sharing/ telling/ recounting insights, experiences or ideas about teaching methods, teaching materials or students' learning. *This is how I introduced acids and bases in Form One (*RettGDR1, r. 34).

	Consultation	TTs asking for help, giving help, asking for opinions or explanation about teaching, student learning, and subject content/education matters from a colleague. *I want to know from her, since there was some little condensing before the burst, what happened to it?* (RittGDR1, r. 169).
	Critiquing practice	TTs critiquing each other's teaching methods/teaching and learning materials used. *I think according to me, the problem is the way we are introducing acids and bases and the pH values in Form One* (DottGRD, r. 22), *Yes, you did but even the issue of balloons is still emphasising on reactivity and strength not the numbers* (RittGRD1, r. 53)
Learning in interacting with students	Oral conversations	TTs gaining an insight/idea from students through conversations, such as discussions, asking questions or answering questions about teaching methods, teaching materials or their learning. *I realised there was a problem when the students complained* (Kytt, GDR1, r. 257).
	Written work	TTs gaining an insight/idea from students written work about teaching methods, teaching materials or their learning *After marking, I realised that something must have gone wrong somewhere. The students in the first group we were getting most of the questions right, but those in the second group, none of them was getting anything right. I wondered what had really happened; I made one assumption that these students in the second group were not keen* (Kytt, GDR1, r. 250).
	Student behavior	TTs gaining an insight/idea from students about teaching methods, teaching materials or their learning from their behavioural expressions *When they saw the set up, they were exited and ready to the practical. The students were excited to see the gas, nitrogen IV Oxide* (Rett, GDR1, r. 131).

	Environment scanning		TTs looking over resources such as reading a book, written texts by others, or browsing the internet to acquire professional knowledge or information or data about education issues from journals and educational *I looked at the conventional way of preparing the gas represented diagrammatically in our text books and I thought of trying it practically* (Rett, GDR1, r. 122).
Potential professional learning outcomes	Change in knowledge, attitudes, and beliefs	Awareness with no immediate action	TT noticed something important in class about student learning/teaching methods/teaching materials *The students were thinking that the higher the pH value the stronger is the acid or the stronger is the base. They think the six is for strong acids* (DottGDR1, r. 8).
		Awareness and adjusting practice	TT noticed something important in class about student learning/teaching methods/teaching materials and adjusted/reframed course of action/sought for ways to address the situation in class *However, they did not seem to agree because this contradicted what they had given me. I thought of a better way of doing it later alone* (DottGDR1, r. 11).
		New ideas	Statements made by the TTs stating that they have learnt something from their own or other's practice. *What I actually learnt is that sometimes we may make a lot of assumptions as [Moderator] said. When I gave them everything and I…went around and confirmed that nobody was having a challenge I left them to carry on with the practical* (KyttGDR1, r. 310) *I have also learnt that, in small scale experiments, everything must be scaled out. She scaled all the apparatus but heating was not scaled down* (KyttGDR1, r. 191).

	Intentions to practice	Intention to practice new skill	Statements made by the TTs that they intend to continue to practice new skill. *Yes, I did not respond to that question, but I think following this discussion, I will not mark them wrongly. It was a long process and a very tedious one before I re-marked the papers. We had to test the solids again* (KyttGDR1, r. 308).
		Intentions to practice new skill with adjustment	Statements made by the TTs that they intend to continue to practice new skill with adjustment. *I think in the future… because we were doing it last week, I look for a good cork, we heat gently, we give it time to decompose and see if we will be able to collect enough gas* (RettGDR1, r.138).
		Intentions to try new practice	Statements made by the TTs that they intend to try new skill/with adjustment. *Kytt: Maybe we could try [moderator's] idea and see whether it works.* *Rett: Yes, let's go and try (GRD1, r.68-69).*
Contextual problems	Classroom	Teachers' professional knowledge	TTs' knowledge about: objectives of teaching chemistry at particular grade level, instructional strategy, students' prior knowledge science content and assessment. *Yes, you did but even the issue of balloons is still emphasising on reactivity and strength not the numbers (RittGDR1, r. 49).* *Which means as they were doing this practical you never paid attention to the kind of skills, that is, manipulative, observation and recording skills they were supposed to get from this experiment? The results can tell those areas were avoided. (Moderator 1GDR1, r. 267).*
		Teaching time	Adequacy of teaching hours, enough science practical periods. *However, many of us because of lack of enough time to cover the syllabus, we just use reagents available to us and carry out the tests without considering their concentrations (RittGDR1, r. 240).*

	Beliefs and attitudes	Teacher's and students' belief and attitudes about chemistry *Also there was another idea which was with my students that the topic of the mole was difficult (RittGDR1, r. 217).*
	Assumptions	Statements made by TTs suggesting that teaching and learning was affected because something important in class about teaching and learning was not taken into consideration. *In future, I should not assume solutions prepared by another person are okay (RittGDR1, r. 155).*
	Students' abilities	Students' abilities to/or not demonstrate a good understanding of every basic concepts of the subject. *Our students generally have a problem with balancing equations, and also writing ionic equations (RettGRD3, r. 73).*
School	Teaching resources	Availability of standard and equipped laboratories *One of our major challenges in our lab is that we do not have eeee (group fume chamber) a fume chamber. So I just prepared a little. Okay… there this is the precautions; because the gas is poisonous. You're supposed to use a fume chamber and if the fume chamber is not available then you prepare the gas in the open. So, I decided to prepare outside. At the same time, we are supposed to use a round bottomed flask to…to have a large surface area to heat but I did not have a cork for the round bottomed flask, so I decided to use a boiling tube (KyttGDR1, r. 123; 127).*
External factors	Examinations	Focus, administration, and relevance of examinations *Kytt: I get what you are saying, and it is ok if it was a normal class experiment; actually it can happen. But this time I was preparing them for the final examination, so I did not want to interfere with their work.* *Being a test which was very now close to the final examination and we were trying to look at their confidence in doing practicals, and sometimes during such a practical as a teacher I try to minimize the assistance to the students after I ensure everything is in order. It is like a pre-test to the Kenya Certificate of Secondary Examination (KCSE) (National*

		examination). We normally check whether students are able to follow the instructions to carry out the activities on their own (KyttGDR1, r. 310).
	Syllabus	Statements made by TTs suggesting that teaching and learning was affected because of the way topics are organised in the Secondary school Chemistry syllabus *Here is a student in Form One, you are defining an acid as a substance that is sour. They will ask you what makes that substance to be sour. If you try to mention hydrogen ions then you are bringing another complex word, ion. That is why I normally use fruits, the lemon, the orange, and fermented milk (RettGRD1, r. 87).*
	Teachers' academic and professional qualification	Teachers' academic and professional qualification *Actually, we have realised that some [teachers] do not have some of the skills, they rely on the lab assistant and if the lab assistant is not there (KyttGRD1, r. 233).*
	Chemistry workshops/in-service training	Opportunities for teachers to attend in service training and their perceptions to those training *But I think it can still be used to emphasise on change of attitude. All the way from 1998 teachers have been complaining that SMASE (Strengthening Mathematics and Science Education program) is wasting their time. They even say it is a money eating project. But if we bring external speakers to talk to them they can change their attitude, which actually has happened and they give positive comments (DottGRD2, r. 194).*

Note. TT indicate teacher trainer; in italics are examples from the first group reflection discussion transcript