Supporting science teachers when teaching outside their subject specialism

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Statement of Authenticity

I, the undersigned, declare that I am the author of this thesis. It is based on original work and has not been presented in fulfilment of other course requirements at the University of Malta or any other University.

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Abstract

Integrated science is part of the core curriculum of the first two years of secondary school in Malta. Science teachers teach the three science subjects even though during initial teacher education they only specialise in one area. This study explores how a group of science teachers, who are non-chemistry specialists, approach the teaching of chemistry by identifying the challenges they come across and how they deal with them. A professional development programme was designed with the aim of supporting teachers teaching outside specialism. This programme started during a summer workshop and was followed by ongoing workshops throughout the scholastic year when teachers were teaching, or about to teach, a chemistry topic.

This study adopts a case study methodology. Data were collected over a year-long period using a questionnaire, semi-structured interviews, focus group interviews, class observations and the researcher's journal. It investigated the lived experiences of eight teachers as they taught outside their area of expertise and as they participated in the professional development programme.

The research findings show that teachers experienced realistic challenges both when planning and teaching chemistry topics. The challenges stem from having limited subject-specific content knowledge and pedagogical content knowledge, together with a lack of passion in the subject. These factors affected the teachers' self-efficacy beliefs and their professional identity concerning their ability to teach outside their area of expertise. Teachers decided to seek professional learning opportunities to overcome their difficulties. The professional development programme was developed on a transformative model of professional development. It was not only based on predetermined sessions but took into consideration the teachers' learning needs. Professional learning was enhanced when teachers actively participated in sessions, reflected on their practice, shared their work, planned lessons within a community of learners and when they implemented changes in their classrooms. The outcomes of this study challenge the taken-for-granted assumption that teachers who specialise in one area are capable of teaching the other science areas. The design of a professional development programme and the role of teachers are fundamental to enhance professional learning. By focusing on the teachers' strengths rather than their limitations and weaknesses, teachers can develop their professional knowledge base and expand their teaching identity as science teachers.

Key words: teaching across specialisation; teaching chemistry; professional learning; teacher professional knowledge base; teaching identity

Dedication

To my parents Maria and Michael and

my sisters Christine and Graziella

for their constant support and encouragement

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A word of thanks goes to the participant teachers in this research study for their time and commitment in this yearlong study. Thank you for sharing your personal and professional experiences and for giving me access to your classrooms. Your efforts and enthusiasm to learn were a source of inspiration in designing the professional development programme. I would like to thank the heads of schools who welcomed me at their schools to work alongside the teachers.

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Abbreviations and Acronyms

B.Ed. (Hons).	Bachelor of Education (Honours).
INSET	In-service Education and Training
ITE	Initial Teacher Education
Model of TPK&S	Model of teacher professional knowledge and skill
MTL	Masters in Teaching and Learning
MUT	Malta Union of Teachers
PCK	Pedagogical content knowledge
PCK&S	Personal pedagogical content knowledge and skill
PD	Professional development
PGCE	Postgraduate Certificate in Education
PLC	Professional learning community
POE	Predict observe explain strategy
PRIMAS	Promoting Inquiry in Mathematics and Science across Europe
PSCD	Personal social and career development
RSC	Royal Society of Chemistry
SASP	Science Additional Specialism Programme
SCK	Subject content knowledge
SEC	Secondary Education Certificate
SMK	Subject matter knowledge
STEBI	Science teaching efficacy belief instrument

Part I

Introduction

Overview

Part 1 of my thesis (Chapter 1) introduces the research study by explaining what it means for science teachers to teach outside their area of science specialism. It gives an overview of the Maltese educational system, focusing particularly on science education at secondary school and initial teacher education at tertiary level. In this chapter I reflect on the rationale of this research study. I also describe my personal journey as a science teacher and discuss the reasons that inspired me to carry out this work.

Chapter 1

Introducing the Research

This thesis focuses on teaching outside one's area of science specialism and how science teachers can be supported in teaching a less familiar area that was not studied at degree level. I would like to start with some reflections on three areas related to this research study; the science curriculum in secondary schools, how prospective science teachers are prepared to teach different science disciplines during initial teacher education and the complexity of being a science teacher. In this chapter I refer to my personal experiences in my teaching career and describe how these have inspired me to develop this study. At the end of the chapter I will outline the structure of the thesis.

1.1 Teaching science in primary and secondary schools

Science is generally taught as an integrated subject in primary school (Years 1 to 6) in most European countries[1], in Australia and in the US. In many European countries[2] science is taught as an integrated subject at lower secondary level (Years 7 and 8), which is composed of different strands such as physics, chemistry and biology and other aspects such as astronomy, health education, technology and the environment. In the US, the science curriculum encompasses eight strands[3] and is taught as general science from primary to middle school students aged from 5 to 15 years old (Corsi-Bunker, n.d.). In Australia the

[1] except Denmark and Finland (Eurydice, 2011)
[2] Belgium i.e. the German-speaking community, Bulgaria, Estonia, Spain, France, Malta, Slovenia and Liechtenstein (Eurydice, 2011).
[3] Eight categories include unifying concepts and processes in science, science as inquiry, physical science, life science, earth and space science, science and technology, science in personal and social perspective and history and nature of science.

science curriculum is based on three interrelated strands[4] taught in an integrated way from primary to early secondary level, that is until Year 10 (age 15) (Price et al., 2019).

In the majority of European countries, science is split up into separate science subjects (physics, chemistry and biology or other science areas like astronomy, geology, health education or geography) at upper secondary school that is from Years 9 to 11 (Eurydice, 2011). However in seven European countries[5], science is taught as an integrated subject throughout the whole period from primary to secondary schooling (Eurydice, 2011). Subject specialisation is present in some European countries (such as Slovakia and Finland) throughout all the secondary school years (Eurydice, 2011). Therefore different countries adopt different approaches to science teaching ranging from (1) a generalist approach from primary to secondary school, (2) a combination of a generalist approach in primary and lower secondary school followed by subject specialisation in upper secondary school or (3) a generalist approach at primary level, but they all teach separate science subjects during secondary school years as shown in Figure 1.1.

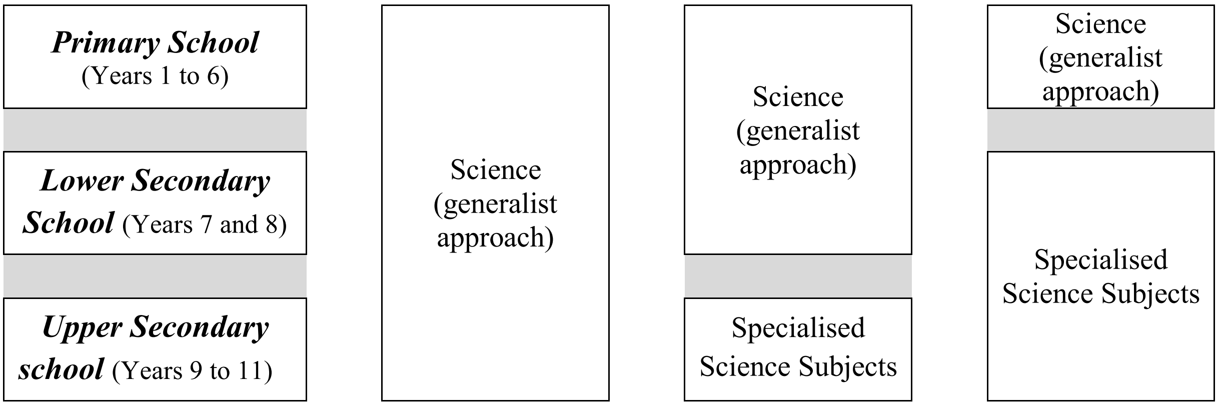

Figure 1.1: Different approaches of teaching science in schools

1.2 The Maltese educational system

All students in Malta and Gozo attend compulsory education from ages 5 to 16. There are three school sectors in Malta; state schools, church schools and independent schools. Students go to primary school for six years (ages 5 to 11). Then they proceed to a secondary school for another five years (ages 11 to 16). The state school system is made up of a

[4] Australia: Interrelated strands include science understanding (comprising biological science, chemical sciences, earth and space sciences and physical sciences), science as a human endeavour and science inquiry skills.

[5] Belgium i.e. Flemish and French communities, Italy, Luxembourg, Iceland, Norway and Turkey.

network system known as the college system. Each college is made up of a number of primary and secondary schools from the same district working in partnership (MEYE, 2005). Church schools are run by various church congregations and independent schools are governed by parents' foundations.

In the state sector, secondary schooling has lately been divided into two stages: the middle school (Years 7 and 8) and the secondary school (Years 9 to 11) (MEE, 2012). All schools from primary to secondary years have a student population that is of mixed attainment. Students attending church schools are admitted through a ballot system. All state schools are co-educational. Church schools are usually single-sex whereas independent schools are generally co-educational.

1.2.1 Science teaching in the Maltese educational system

All Maltese schools are regulated by a National Curriculum Framework (MEE, 2012) which stipulates that the teaching of science and technology should take up 15% of curriculum time at primary level and 12.5% at secondary level. In state schools, science at primary level is taught either by the class teacher or a visiting teacher called the peripatetic teacher whereas in church or independent schools, it is taught either by the class teacher or by a specialist teacher. This implies that students at primary level have different experiences and exposure to science. Being non-science specialists, many primary teachers lack confidence in teaching science and many are reluctant to teach the subject and try to avoid it (MEEF, 2011). Primary teachers feel that the teaching of science in state schools is the responsibility of the peripatetic teacher who visits the primary school once every two weeks. The primary school teacher may not be even present when the peripatetic teacher conducts the science lesson, hence there will be no follow-up lesson in the consecutive week. Primary teachers often opt for traditional teaching approaches by giving information and asking students to fill in worksheets rather than using investigative and inquiry-based methods (MEEF, 2011).

During their first two years at secondary school, that is in Years 7 and 8, (previously known as Form 1 and 2) students study integrated science. The local science curriculum consists of topics from the three science domains: physics, chemistry and biology (see Appendix 1). In Years 9 to 11, students study one science subject as part of their compulsory curriculum. In state schools and in most of the boys' church schools, students generally study physics as their compulsory science (Eurydice, 2014). Students in most of the girls' church schools, in some of the boys' church schools and in independent schools choose either physics, chemistry or biology as their compulsory science. At the end of Year 8 students may also opt to study another one or two science subjects in addition to their compulsory science. Hence students at secondary level study either one, two or three science subjects. Chemistry is rarely or never studied on its own, but it is usually taken in combination with physics and/ or biology. Physics is the most popular science subject followed by biology and finally chemistry. This can be shown by the number of students sitting for the national school leaving certificate, that is the Secondary Education Certificate (SEC) examination at the end of secondary school. In May 2018, 2987 candidates sat for the SEC physics, 1239 candidates sat for the SEC biology and 703 candidates sat for the SEC chemistry (MATSEC support unit, 2019). Table 1.1 outlines the science curriculum in primary and secondary schools in Malta.

Table 1.1: Science curriculum in Malta from primary to secondary school

School	Core curriculum	Optional subjects
primary school (years 1 to 6)	science	
middle school (years 7 and 8)	integrated science	
secondary school (years 9 to 11)	one compulsory science subject	students can study one and/ or two science subjects

When students complete their secondary schooling a number opt to follow an academic route at post-secondary level. At this level students study two subjects at Advanced level and four subjects at Intermediate level. This implies that students taking the science route will study two of the science subjects at Advanced level and the third subject at Intermediate level. This implies that none of the students would have the same depth of knowledge in the three science disciplines.

1.2.2 Proposed reform in science education in Malta

In the late nineties there were attempts to reform science education within the Maltese educational system. The reform aimed to replace the existing science specialisation in the last three years of secondary school with a single subject called "co-ordinated science," hence moving from a specialist to a generalist approach (Ministry of Education, 1999). This proposed change generated long discussions due to lack of agreement between a number of stakeholders (Mizzi, 2005). Following this, a document called ‘A Vision for Science Education in Malta’ (MEEF, 2011) was published. It suggested a way forward to address the needs of all students in science education. All students would study core science for the first two years of secondary school in order to obtain “a basic science literacy” that would enable students “to make informed choices and decisions about science as citizens” (MEEF, 2011, p. 29). Core science would have a balanced view of science and would be designed on a thematic approach to show how different areas of science are interrelated. A two-tiered system was devised from Years 9 to 11. Those students who would not like to pursue a career in science would keep on studying core science till the end of secondary school. Students who wanted to take up a career in science would study a combination of two or three subjects from the following: materials science, physical sciences and life sciences. The document also emphasised the use of inquiry-based learning as the main pedagogy in science lessons. This proposal was revised and the ‘National Curriculum Framework for All’ (MEE, 2012) stipulates that all students at early secondary school will study core science. Then:

> …in Years 9, 10 and 11, students who wish to specialise in Science and related subject can opt for one, two or three of the following: Life Sciences, Physical Sciences and Materials Science leading to a SEC examination in each of these options. For students who do not wish to specialise in science it is recommended that they study Core Science leading to a SEC examination (p. 61).

In other words, secondary school students would still study one compulsory science subject that is either: life sciences, physical sciences, materials science or core science depending on their career choice.

What is particularly relevant for the current study is the recommendation made in the ‘Vision for Science Education’ (MEEF, 2011) that science teachers would need to be ‘re-trained’ to be able to teach core science. This is the main bone of contention that has kept the reform from being implemented. Following the international trend (Osborne & Dillon, 2008), together with the proposals recommended by ‘Vision for Science Education’ as well as those recommended by a number of Maltese science educators, there has been a move towards ensuring scientific literacy for all. However a study by Zahra (2015) shows that science teachers as well as science academics prefer students who specialise in specific science subjects such as biology, chemistry and physics at an early age. This divergence in opinions has hindered the implementation of this reform in the local context.

To date the science curriculum in Malta is still devised as shown in Table 1.1. This implies that science teachers are expected to teach science to middle school students and/or their specialist subject that is biology or chemistry or physics at secondary level depending on the schools they are in. The next section describes how prospective science teachers are prepared to teach different science disciplines during initial teacher education (ITE).

1.3 Initial teacher education programmes

According to Eurydice (2015) two different ITE models known as the 'concurrent' and 'consecutive' models coexist in European countries. Prospective teachers may follow a professional route that simultaneously includes academic and practical professional training. This is known as the 'concurrent model'. An example of such a programme is the Bachelor of Education (Hons)., B.Ed. (Hons.) programme. Those following the 'consecutive model' first begin with an academic study of their subject. Then they move into professional training as a separate phase to specialise in the teaching profession.

All ITE programmes consist of three main aspects: (1) content: ensuring sufficient academic knowledge of the science subject/s, (2) pedagogy: where prospective teachers are theoretically prepared in how to teach their subject, in classroom management skills and in how to support students in their learning and (3) practice: by gaining concrete experiences in classes through observation or teaching to learn how to handle diverse issues pertinent to the teaching and learning process (Eurydice, 2015). The amount of science content knowledge varies in ITE programmes ranging from a number of science study units in concurrent models to Bachelor's or Master's degrees in a specific science area in the consecutive models.

Nowadays, the trend is shifting internationally towards 'consecutive models' and the implementation of the Master's degree programmes for prospective teachers. ETUCE (2008) recommends that teachers need to be educated to a Master's level because:

> …the demands placed on teachers today in terms of in-depth subject knowledge, advanced pedagogical skills, reflective practice and ability to adapt teaching to the needs of each individual child/pupil/student as well as to the needs of the group of learners as a whole, require that teachers are educated at a highly advanced level and equipped with the ability to integrate knowledge and handle the degree of complexity which characterises studies at a Master's level (p. 20).

Master's degree programmes prepare graduates qualified to teach at lower and upper secondary levels. Prospective teachers take up the Master's degree course after graduating from a Bachelor degree course. This means that prospective science teachers will enter the field with more knowledge in a specific science subject. What might be problematic about this change and in relation to the current study is that teachers might lack the breadth and depth of the different science disciplines required to teach science through a generalist approach.

1.3.1 Initial teacher education in Malta

Up until October 2015, there were two main routes for prospective teachers to become science teachers in Malta. Students could either follow (1) a full-time four-year degree course as B.Ed. (Hons.) in science specialising in one science area, or (2) a one-year full-time Postgraduate Certificate in Education (PGCE), after they completed their first degree in a science area at the University of Malta.

Entry requirements determine the teachers' background and specialisation (Hobbs & Törner, 2019). Figure 1.2 shows the entry requirements for the B.Ed. (Hons.) programme specialising in one science area (Office of the Registrar, 2015a). What is highly significant in this study is that the prospective teachers' would have studied one or two of science subjects at Advanced Level and none of the prospective science teachers would have the same depth of knowledge in three science disciplines.

B.Ed. (Hons.) science with a specialisation in biology	**B.Ed. (Hons.) science with a specialisation in physics**	**B.Ed. (Hons.) science with a specialisation in chemistry**
Two passes at Advanced Level at Grade C or better in biology and in any other subject together with a pass at Grade C or better at Intermediate Level in chemistry.	Two passes at Advanced Level at Grade C or better in physics and any other subject and a pass at Grade C or better at Intermediate level in applied mathematics or pure mathematics.	Two passes at Advanced Level at Grade C or better in chemistry and in any other subject together with a pass at Grade C or better at Intermediate Level in physics.

Figure 1.2: Entry requirements into the B.Ed. (Hons.) science degrees

In the B.Ed. (Hons). programme prospective science teachers studied content knowledge at undergraduate level in their chosen science area (considered as their area of specialism) and followed units in pedagogy related to the teaching of their main area at secondary level (http://www.um.edu.mt/educ/faculty). Throughout the programme they followed a number of study units consisting mainly of the content knowledge in the two science areas that were not their area of specialism in order to obtain a broad knowledge of all the science subjects.

Those students who decided to read for a PGCE after graduating from a science-related degree had to have specialised in one science area (Office of the Registrar, 2015b) as shown in Figure 1.3. As PGCE students they followed a number of courses in pedagogy related to the teaching of science.

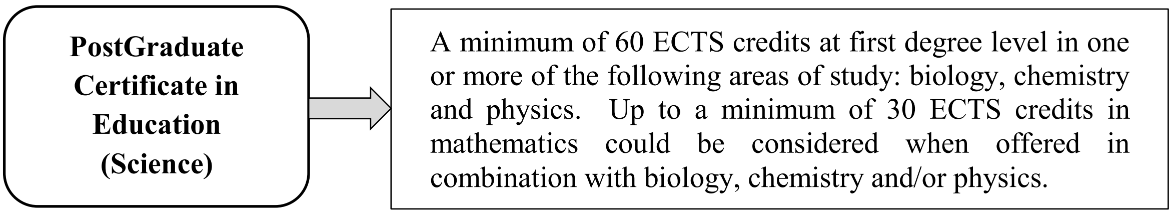

Figure 1.3: Entry requirements for PGCE

In both programmes students had a field placement component (commonly referred to as teaching practice). PGCE students taught science to younger students. B. Ed. (Hons.) students taught either science or their main area of specialism, that is physics, chemistry or biology. The chosen science area of specialism in the B.Ed. (Hons.) course or the area studied in the undergraduate degree of the PGCE students stipulated the teacher's subject specialism.

As from October 2016 the B.Ed. (Hons.) and PGCE programmes were phased out and currently prospective teachers follow a Master's degree programme called 'Master in Teaching and Learning' (MTL) after completing an undergraduate degree. Students starting the MTL programme have similar backgrounds to the previous PGCE science students. MTL students are required to have studied a number of study units in a single science area or a combination of science areas in their first degree as shown in Figure 1.4 (Office of the Registrar, 2016).

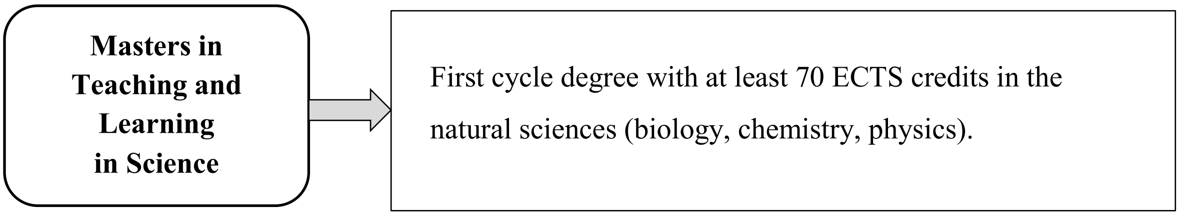

Figure 1.4: Entry requirements for MTL

The MTL curriculum has been designed to attend to the challenges encountered by teachers and learners in today's schools by providing knowledge, skills and dispositions as students start their journey of becoming teachers. Moreover the MTL curriculum:

> …supports the development of a professional teaching identity. It combines school-based practice, inquiry and reflection with academic, disciplinary and research-led knowledge. Developing teacher capacity and competence is achieved by a judicious combination of context knowledge, subject content knowledge, general pedagogical knowledge, pedagogical content knowledge, and research knowledge. The MTL fosters collaborative and life-long learning. It brings practical and theoretical knowledge together, contributing to the development of teacher-as-researcher and reflective practitioner identities.
> (http://www.um.edu.mt/__data/assets/pdf_file/0019/284122/mtlimpinfov3.pdf)

Becoming a teacher involves an ongoing learning process starting at ITE and continues to develop throughout the teaching career. In the process, as prospective teachers learn content knowledge, pedagogy and gain experiences from school placements, they start thinking about the type of teacher they would like to become, thus starting to develop their professional identity. Teachers' personal philosophies about teaching and learning are built and reconstructed through the years. These ideas are further influenced by professional development programmes, interaction with colleagues and their teaching contexts. Siskin (1994) argues that teachers derive their professional identity from the subject that they teach. Teaching science can create demands on the teachers' professional knowledge and skills that may not have been acquired during ITE and their teaching career. When teaching science as an integrated subject teachers need to be knowledgeable in both the content and pedagogy to teach all areas of science. For example a physics specialist teacher becomes responsible for teaching all the science subjects. This can make the role of a science teacher a very complex one and it is to this issue that I shall now turn.

1.4 The role of a science teacher

Since the science curriculum at secondary school encompasses the teaching of an integrated subject at middle school and that of teaching the separate disciplines to senior students it is very difficult to describe the role and remit of a 'science teacher.' If one talks about becoming a mathematics teacher, one is very clear about the kind of knowledge base and skills the teacher will require. Defining the role of a 'science teacher' and what one will actually be teaching is more complex. According to Wellington and Ireson (2012) science teachers have to cope with an extremely demanding occupation that involves the following aspects:

- coping not only with a conceptually difficult subject but with a group of learners who bring all kinds of prior learning and preconceptions to it (p. 3).

- teaching scientific knowledge, developing scientific skills and fostering scientific attitudes; conveying messages about the nature of science and the work of scientists (p. 3).

- managing and controlling all kinds of situations such as laboratory work, demonstrations, small group activities, didactic teaching, discussion work, 'circuses' of experiments; teachers also need to be aware of, and be able to handle, all kinds of health and safety issues in their daily teaching (p. 26).

- teaching their subject specialism e.g. physics or biology and keeping up one's subject knowledge up to date (p. 26).

- teaching outside their own specialism up to the age of sixteen where this makes additional demands on planning, preparation and thinking time (p. 26).

1.4.1 Being a specialist teacher: Teaching within specialism

Science teachers can either be responsible for teaching their subject-specific discipline in their role as specialist teacher and/or they can be responsible for teaching all areas of science as a generalist teacher. Hobbs and Törner (2019) point out that to specialise means to become "immersed and expert in a defined and bounded body of knowledge and skills such that there is coherence, connectedness and flexibility to what is known and what one can do" (p. 4). When teaching their area of specialism, that is, teaching a science area that was studied at degree level, teachers have specialised knowledge in the subject discipline. The specialist teacher is also expected to have an understanding of the "curriculum content structure, big ideas and relationships between ideas; teaching approaches needed to represent the content and support student learning; and how to assist students who do not understand" (Hobbs & Törner, 2019, p. 4). Yet Kind and Taber (2005) note that school science has a particular identity and is very different from the academic disciplines studied at tertiary level. Thus teachers would need to revise the content knowledge studied at secondary level before they teach their specialist area.

The three branches of science have a specific body of knowledge. When teaching subject-specific disciplines, a chemistry teacher for instance, needs to be knowledgeable about the essential questions in chemistry. As identified in the National Research Council report in the US and as summarised by Talanquer (2013) these include: (1) analysis – what is it? (2) synthesis – how do I make it? (3) transformation – how do I change it? and (4) modelling – how do I explain it? A chemistry teacher helps students to understand the physical world by observing the macroscopic properties of the materials around them and interpreting observations in terms of the sub-microscopic properties and forces that account for these properties. One's own understanding of the subject matter and the experience of a chemistry classroom affects one's perceptions of the specialist subject area in terms of outlining the underlying themes and drawing meaningful connections between the different topics with the subject specialism (Talanquer, 2013). Physics explains the natural phenomena of the world (http://study.com/academy/lesson/what-is-physics-definition-history-branches.html). Physics teachers generally teach students about matter and energy and how the two interact. Physics teachers together with their students pose fundamental questions that can be answered through observation and experimentation. Biology teachers teach about the science of life where they study structure, function, growth, origin and evolution of living organisms (Bagley, 2017). Therefore it is important to recognise that subject content of the three science disciplines is widely different. On the other hand there are overlaps in particular content and the three subjects interlink in areas such as energy transformations, kinetic theory and practical skills.

Specialist teachers are expected to transfer their knowledge from their specialist areas to teach other science disciplines. However the multiple disciplines within science "differ not only by topical emphases (e.g., chemistry focusing on matter; biology focusing on living things), but also by their discipline-specific ways of constructing and structuring knowledge" (Nixon, Luft & Ross, 2017, p. 1198). The variations within disciplinary knowledge require different teaching approaches. As proposed by Nixon et al. (2017) the "preparation to teach one science discipline is unlikely to produce adequate knowledge of subject matter or pedagogical content knowledge to teach a different science discipline" (p. 1198). This implies that the assumption that a specialist teacher can teach all science disciplines needs to be investigated further, hence exploring the meaning and implications of teaching outside one's area of science specialism.

1.4.2 Being a generalist teacher: Teaching outside science specialism

Generalist science teachers are expected to teach the various science disciplines. This implies that generalist science teachers teach topics that are within and outside specialism. Indeed teaching outside specialism is a common phenomenon in many countries and this is generally due to shortages of qualified teachers. In the US and in Australia this phenomenon is more commonly known as 'teaching out-of-field,' which refers to when teachers teach a subject or year level for which they have no qualifications or background (Hobbs, 2013a; Ingersoll, 1998). The term field can refer to the subject and the content together with the pedagogy specific to that subject (Hobbs & Törner, 2019). An example of out-of-field teaching is when a mathematics teacher teaches science subjects or vice versa. This term can also be expanded to include the teaching of biology topics by a physics teacher when teaching general science.

In the UK science teachers are required to teach physics, chemistry and biology to 11-to14-year-olds (Key Stage 3). They are frequently asked to teach the three sciences even to 14- to 16-year-olds (Key Stage 4) despite their science specialism. Teachers who do not have a degree qualification in one particular science area are referred to as 'non-specialists'. Very often in UK secondary schools non-subject specialists (mainly biologists) teach chemistry due to a shortage of qualified physical science teachers (Kind & Kind 2011).

The term 'Teaching Across Specialisations' as coined in the teaching across specialists collective symposium (see Hobbs & Törner, 2019) incorporates both the out-of-field and the non-specialist teaching. In this study I choose to use the term 'teaching outside one's area of science specialism' which means that one has not studied a science subject at degree or Advanced level (Childs & McNicholl, 2007).

In Malta, most teachers teach within their area of science specialism when teaching physics, chemistry or biology to upper secondary students (Years 9 to 11). However, when teaching integrated science to lower secondary students (Years 7 to 8) science teachers teach both within and outside their area of science specialism, that is they teach a subject/s they did not study at degree or at Advanced Level or maybe even at secondary level. In the local scenario a number of physics teachers did not study chemistry or biology at secondary level because physics is generally the compulsory science at secondary school. Hence physics specialists may be teaching topics within the science curriculum without a background of the subject. In fact only 21% of the state school science teachers, 24% of science teachers in church schools and 28% of science teachers in independent schools have a degree qualification in chemistry, showing chemistry is a non-specialist area for the majority of teachers in Malta (Director at the Directorate of Educational Services, personal communication, March 22, 2019).

This implies that one must not underestimate the challenges presented when teaching a subject area in which the teachers feel more apprehensive to teach. When teaching science through a generalist approach “science teachers have additional pressures and issues” (Ross, Lakin & McKechnie, 2010, p. 4), because they have to teach all the three sciences to young students and at times even to older secondary school students when most likely these teachers have a degree level qualification in only one science area. Although there is overlap in skills, strategies, language and ways of doing science across the three subject areas, the content knowledge is widely different and teachers will not have the same depth of knowledge in all the areas. This issue is highly problematic and gives rise to serious concerns in terms of how teachers manage to teach outside their science specialism. A number of research studies indicate that teachers face more challenges when teaching outside specialism (Childs & McNicholl, 2007; Kind, 2009a, Hashweh, 1987; Hobbs, 2013a; Sanders, Borko & Lockard, 1993). Consequently, in this research study the main aim was to investigate whether Maltese science teachers experience a similar phenomenon when teaching integrated science. Besides outlining the context of this research study I will now describe my journey as a science teacher and how the experiences gathered along the years have deeply influenced my thoughts and motivation to investigate the phenomenon of teaching outside specialism.

1.5 My journey as a science teacher

From a young age my dream was to become a teacher. I liked science at secondary school but found it difficult to decide which subjects to opt for at the end of Year 8. I was encouraged to take up chemistry and biology whereas physics was the compulsory science subject to study. Whilst studying these subjects I became very passionate about chemistry, probably because my understanding of its logic, principles and patterns enabled application to different situations. I recall struggling with physics since at secondary school I had not yet developed effective study and reasoning skills. I liked biology because I could understand how the body and the different ecosystems work. Being quite a descriptive subject I found biology to be less appealing than the other science subjects probably because I had to rely on memory work.

At post-secondary I opted to study the three sciences, that is chemistry, physics and biology, at Advanced level because at that time students could study three subjects at Advanced level. It was at this stage that I started to enjoy physics. When starting tertiary education I was quite indecisive about whether to opt for a Bachelor of Science (Hons.) degree and then take up PGCE or whether to opt for a B. Ed. (Hons.) degree. My wish to become a teacher was still strong. I decided to opt for the B.Ed. (Hons.) course because when I reflected on my future aspirations I knew that becoming a teacher entailed a process of growth and maturation, thus I preferred to opt for a four-year course rather than a one year PGCE.

My journey as a science teacher started in 1992, when I enrolled in the B.Ed. (Hons.) programme specialising in chemistry and physics. My passion for learning and teaching these two subjects has certainly had an impact on my identity as a science teacher. Although I studied biology till Advanced level I consider myself to be slightly weaker in this area especially in terms of planning and teaching biology topics, since I never had the opportunity to put it into practice. Thus I identify myself as a science teacher with a strong background in chemistry and physics but unfortunately with a weaker background in biology. As a result I feel that my identity as a science teacher is somewhat fragmented since I feel more comfortable teaching chemistry and physics rather than biology.

After finishing my teaching degree I was employed in a boys' church school and started teaching physics. After four years I switched to teaching both chemistry and physics. At times I also taught science to younger students. As a science teacher I came across the phenomenon of teaching within and outside one's area of science specialism. I always felt very confident when teaching chemistry and physics topics but was rather hesitant and lacked confidence when teaching biology topics. When it came to planning biology topics I looked up information to revise my prior knowledge. I asked for support from a colleague who was a biology specialist. We discussed my queries and reviewed the notes and the resources I had prepared. My personal experience as a science teacher made me aware that teachers can experience different levels of confidence and insecurities when teaching within and outside their area of science specialism.

From the school experiences gathered along the years I found that other teachers had similar concerns with teaching science especially those teachers who had only specialised in one area of science. These teachers were generally biology or physics specialist teachers. As non-chemistry specialists they feared teaching chemistry topics because they had limited content knowledge and found it difficult to develop interesting lessons with hands-on activities.

This concern about teaching outside one's area of science specialism reappeared when I was reading for my Master's degree in curriculum development and evaluation at the University of Malta. My research study was a case study about the introduction of co-ordinated science (Mizzi, 2005). Being a new and radical reform, the proposal of introducing co-ordinated science in the Maltese context created vast debates and raised serious concerns and questions from various stakeholders. Most of the teachers did not feel equipped and knowledgeable to teach all the areas of science, especially those who had only specialised in one science area in their teaching degree and feared the implementation of this reform.

Today I am head of department in chemistry at the Secretariat of Catholic Education. In this role I meet chemistry teachers in church schools and provide them with the necessary support in teaching chemistry. The experience as a head of department has been very enriching. It has been a cumulative learning experience due to ongoing discussions, reflections and sharing of lessons, resources and various approaches of teaching chemistry with other teachers. Besides this supportive role I am still teaching chemistry to Year 9, 10 and 11 students at the same school I have been employed at since 1996. Recently I have started to focus all my energy on teaching chemistry so I can also identify myself as a chemistry teacher. I feel that the dual role, that is that of a practitioner and that of supporting teachers, complement one another as the teaching context provides me with the impetus and inspiration to research and read relevant literature related to the teaching and learning of chemistry in order to implement changes in practice and develop professional learning sessions for chemistry teachers.

In 2009, I was appointed as a visiting assistant lecturer at the University of Malta within the Faculty of Education. I taught a unit to B.Ed. (Hons.) student teachers who were non-chemistry specialists. In this unit I introduced chemical ideas and principles to those student teachers who had never studied chemistry or had studied chemistry till secondary level. Again I was becoming more aware of challenges and dilemmas related to teaching outside one's area of science specialism and how the student teachers failed to identify themselves with the teaching of a less familiar area.

As a result, my experiences as a science teacher, as a head of department in chemistry and as visiting assistant lecturer at the Faculty of Education, together with the outcomes of the Master's research prompted to me to investigate and look into how science teachers, particularly the non-chemistry specialists approach the teaching of chemistry topics as part of the integrated science curriculum. By describing my biographical journey I want to make explicit to the reader how my personal background, values, biases and culture shaped the process of knowledge construction and interpretation in the research process (Creswell, 2014). My personal experiences gathered along my journey greatly inspired and influenced my decision to enrol as a Ph.D. student and explore the area of teaching outside one's area of science specialism.

1.6 The research area

This thesis focuses on science teachers and their experiences of teaching integrated science. Based on my personal experiences and encounters with science teachers I became interested to explore how science teachers, who were non-chemistry specialists, approached the teaching of chemistry-based topics. I wanted to understand how their background and beliefs were shaping their classroom practices and how this was impacting the way they perceived themselves as science teachers. This led me to my first two research questions which are:

1. *What challenges do science teachers, who are non-chemistry specialists, face when teaching chemistry topics in the Maltese integrated science curriculum?*

2. *How do non-specialist chemistry teachers deal with the challenges that they face when teaching chemistry topics in integrated science?*

The experience gained as a head of department motivated me to develop an interest in the area of professional development (PD). Besides understanding the teachers' perspective and their needs when teaching outside their science specialism, I became genuinely interested in finding ways of supporting the non-chemistry specialist teachers. PD could be a possible way of helping these teachers to develop their professional knowledge base, skills and attitudes in chemistry. In Malta PD courses tend to be short-term, however I wanted to move beyond this and look into the possibility of creating a long-term programme to support non-chemistry specialists to teach chemistry-based topics with more confidence and skill. This led me to my third research question, that is:

3. *What kind of support structures that promote professional learning would teachers who teach outside their area of science specialism benefit from?*

In other words this study aims to shed light on the phenomenon of teaching outside the area of science specialism, particularly the teaching of chemistry units within the Maltese context and how PD structures can support the teachers to teach their non-specialist area.

1.7 Outline of the thesis

This thesis is divided into five parts that are split into a number of chapters. Part 1 includes the introductory chapter which describes how science is taught in different countries. It gives an overview of the Maltese education system focusing particularly on the teaching of science at secondary school. During ITE Maltese science teachers generally specialise in one science area but then they are expected to teach all areas of science when teaching integrated science. This renders the role of a science teacher a complex one. In this chapter I describe my journey and experiences as a science teacher and as a head of department and how these have inspired me to investigate the phenomenon of teaching outside specialism and of finding ways to support teachers teaching a non-familiar area.

Part 2 presents a review of literature about three main areas fundamental to this study; hence it is split into three chapters. Chapter 2 presents the theoretical framework related to the development of the science teachers' professional knowledge base. Chapter 3 focuses on teaching outside specialism and presents the challenges related to this field. It also describes a number of strategies that teachers use to overcome these challenges. Chapter 4 focuses on PD and outlines important features derived from research required to design a PD programme that supports professional learning for non-specialist teachers. At the end of part 2 the gaps in literature are identified.

Part 3 presents the methodology adopted in this research study. Chapter 5 describes the ontological, epistemological and methodological considerations that guided the conduction of this qualitative research study. I also present the ethical issues related to this case study. In Chapter 6 I discuss how I developed and implemented the long-term PD programme after gaining the teachers' consent to voluntarily participate in this study. Then I explain how different research tools were used to collect the data and how the data were analysed to outline the main themes of the study.

Part 4 of the thesis presents the research findings and the main themes that emerge from the teachers' experiences when teaching chemistry topics together with their experiences of the PD programme. This is split into five chapters where Chapter 7 introduces the eight participant teachers, their backgrounds and experiences and how they identify themselves as science teachers. Chapter 8 describes the main challenges that teachers encountered when planning and teaching chemistry topics, whereas Chapter 9 outlines the main strategies that teachers used either to cope or overcome the challenges presented. In Chapter 10, I present snapshots of the teachers' professional learning journey together with their reflections as they participated in a community of learners. Chapter 11 closes this section by describing each teacher's journey and how they came to review their beliefs about teaching chemistry.

Part 5 consists of two chapters. Chapter 12 presents a discussion on the main research findings by answering the research questions and discusses the implications of the findings of this study. Chapter 13 presents a conclusion to this study by summarising the main salient points that emerge from the findings and discusses the main contributions to knowledge in the research field. The thesis comes to end by discussing and analysing how my journey as a researcher and as a teacher educator has evolved throughout this doctoral research.

Part II

Literature Review

Overview

In Part 2 of my thesis I present a review of the literature that led me to develop the theoretical framework of this study. In Chapter 2, discusses the professional knowledge and skills required to develop the necessary competences to become a science teacher. Chapter 3 then looks at the main focus of the thesis: teaching outside one's area of science specialism. The chapter delves into the challenges that teachers experience when planning and teaching outside their science specialism. This chapter also presents a number of strategies that teachers employ in overcoming the difficulties encountered. Finally, Chapter 4 looks at different models of PD and draws out the key features of professional learning for teachers to develop competence and confidence to teach their non-specialist area.

Chapter 2

Becoming a science teacher: Starting the learning journey

2.1 Professional knowledge and skills of science teachers

Learning to teach is such a complex process because it involves, according to Feiman-Nemser (2008), learning how to think, know, feel and act like a teacher. Feiman-Nemser (2008) further explains that learning to teach involves examining one's existing beliefs in view of new understandings, learning subject matter knowledge and ways of teaching it. It also entails developing a professional identity and acquiring a repertoire of skills and strategies. All of this is learnt and developed during one's career, including ITE.

The main underlying theme throughout the research process and subsequent analysis of data in the current study is how teachers develop their professional knowledge and identity as science teachers. Bullock (2011) defines teacher professional knowledge as that which "encompasses the knowledge, beliefs and values that teachers possess and create in the course of their careers as educators in elementary and secondary schools" (p. 22). In other words, teacher professional knowledge is constructed from propositional knowledge, beliefs and experiences which are based on the contextual and the social processes arising from interactions among people, knowledge of students and classroom contexts. Therefore the journey of 'becoming a teacher' and developing a personal teacher identity is recognised to be a complex process involving a diverse knowledge base and affective motivational facets (see Kaiser, Blömeke, Busse, Döhrmann & König, 2016). What is also recognised in the current literature about professional knowledge is the basic tenet that developing professional knowledge is not a neutral process but one which takes place within a cultural, social and historical context that greatly influences the journey taken to become a science teacher. As Lave and Wenger (1991), contend "learning is situated activity" and will involve "changes in knowledge and actions" (p. 29).

As I tried to make sense of the vast amount of literature that has been written about teacher professional knowledge, I realised that somehow I needed to organise the literature so that I could develop the theoretical framework for the current study. In this literature review I outline the major ideas that shape the development of science teachers' professional knowledge. Furthermore I also look into the factors that influence the development of the teachers' professional identity. The literature provided the lens through which I could eventually analyse the data collected throughout the research process.

For organisational purposes, the chapter will be divided into the four main sections: (1) professional knowledge from the cognitive perspective, (2) knowledge developed from the affective perspective, (3) learning to teach science through a sociocultural perspective and (4) the development of teacher identity. Throughout, I outline links between the respective theories and critiques of the different theories in order to try to come up with a theoretical framework that could guide my research.

2.2 Development of professional knowledge from a cognitive perspective

The first ideas about teacher professional knowledge that are significant for the present study are the ideas of Shulman (1986) and his colleagues who focused on the professional knowledge and skills required for teaching from a cognitive aspect. They studied teachers from different subject areas and attempted to answer the question: "what knowledge is essential for teaching?" Shulman (1986, p. 8) defines seven categories as part of the knowledge base for teaching that include; (1) subject matter knowledge, (2) general pedagogical knowledge, (3) curriculum knowledge, (4) pedagogical content knowledge, (5) knowledge of learners and their characteristics, (6) knowledge of education contexts and (7) knowledge of educational ends, purposes and values and their philosophical and historical grounds.

Shulman's knowledge base emphasises that teachers need to have subject-specific knowledge for teaching and according to his view the process of learning to teach involves the development of pedagogical content knowledge (PCK) based on the transformation of subject matter knowledge (SMK) for teaching. Other researchers have over the years tried to refine Shulman's (1986) categories. For example Grossman (1990) identifies four general areas of teacher knowledge that is SMK, general pedagogical knowledge, knowledge of context and

PCK. She places PCK at the centre of the model since it is influenced by the transformation of the three other knowledge bases and these in return influence the development of PCK. From a cognitive perspective a competent science teacher needs to have a good knowledge base in the categories mentioned by Shulman (1986) and Grossman (1990). Most importantly a teacher needs to have a sound knowledge in the subject matter content and in ways of understanding, organising and transforming the content knowledge into representations to enhance students' learning. From the seven categories mentioned by Shulman (1986), SMK and PCK are fundamental to the development of the teacher's professional knowledge.

2.2.1 The importance of subject matter knowledge

Subject matter knowledge (SMK) is a crucial component of the teachers' knowledge base as outlined by Shulman (1986) and Grossman (1990). Shulman identifies SMK as the missing paradigm because previous research ignored the importance of the content of instruction and focused only on pedagogy. Subject-specific knowledge is essential for effective teaching. It plays a central role in lesson planning and influences the organisation of lessons and the quality of classroom discourse and interaction. When teachers have a wide and integrated knowledge base they are more able to plan and deliver better lessons (Magnusson, Krajcik & Borko, 1999).

My critique of the literature on SMK relates to understanding what it really means for a teacher to have a good foundation of SMK. For example, Grossman, Wilson and Shulman (1989, pp. 27-29) highlight the importance of teachers' knowledge in both the content and process of science and they identify four dimensions of SMK:

1. *Content knowledge:* factual information, organising principles and central concepts that enable one to find the relationships between concepts within the discipline as well identifying links with concepts in other domains.

2. *Substantive knowledge:* explanatory frameworks or paradigms used to guide inquiry in the field and make sense of data.

3. *Syntactic knowledge:* knowledge of the ways in which new knowledge is generated, introduced into the field, tested and evaluated and accepted in the community.

4. *Teachers' beliefs about subject matter:* significantly affect what teachers choose to teach and how they teach it.

A science teacher requires a sound basis of the knowledge of subject content, the processes of science, together with a good understanding of how science works. Furthermore the teacher's beliefs about the subject determine how content is presented and translated into the classroom context. Teachers often integrate the subject matter content with other forms of knowledge such as the students' interest, the resources available, other topics in the curriculum and the context they are actually teaching in.

The organisation and the depth of SMK are crucial components in teaching and are especially important for the current study. When teachers lack knowledge in content and in the structure of the discipline, they can lack confidence in teaching the subject (Appleton, 1995) and can present a distorted picture of the content and the nature of the discipline (Grossman et al., 1989). Lack of SMK would have serious implications when teaching outside specialism.

2.2.2 Developing pedagogical content knowledge

Having a deep, rich background in subject matter is essential but this is not enough for effective instruction. SMK needs to be translated into representations to enhance students' learning and understanding. Pedagogical content knowledge (PCK) is the special characteristic that distinguishes the subject matter specialists from the pedagogue. PCK is a theoretical construct that was introduced by Shulman (1986; 1987) as part of the teacher's knowledge base. Shulman (1986) refers to PCK as the "special amalgam between content and pedagogy that is uniquely the province of teachers" (p. 9). He further describes PCK as follows:

> It represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interests and abilities of learners and presented for instruction
> (Shulman, 1987, p. 8).

For Shulman (1986) SMK is central to PCK. PCK as portrayed by Shulman (1987) is topic-specific since it encompasses teachers' representations of knowledge, instructional strategies, alternative conceptions and students' difficulties of a particular topic. Daehler, Heller and Wong (2015) endorse this view by stating that PCK is "the knowledge for teaching topic-specific content" (p. 45). Even Magnusson et al. (1999) state that PCK is subject-specific, which means that the knowledge for teaching chemistry is different from the knowledge needed to teach biology (Abell, 2008).

It can be argued that PCK is developed through action (Abell, 2008) and in context. Shulman (1986) contends that PCK involves the transformation of SMK, pedagogical knowledge and knowledge of context into teaching. Grossman (1990) states that teachers construct their knowledge of teaching a specific subject from a range of sources such as 'apprenticeship of observation' where teachers look back at their own teachers and recall particular teaching approaches used during their student days, knowledge of their discipline, subject-specific methodology courses at university and actual classroom experience. PCK is not a fixed body of knowledge but it is dynamically constructed throughout the teaching career (Abell, 2008). This implies that the development of PCK is an important component of teacher learning and development.

2.2.2.1 Models of pedagogical content knowledge

Drawing on Shulman's first model of PCK, other researchers and educators have developed their own model of PCK. In this literature review I present aspects of some of these models related to science teaching. Lately a model of teacher professional knowledge and skills including PCK (Gess-Newsome, 2015) has been developed. This model has been influential in the development of my personal framework of teacher professional knowledge.

Shulman's 1986 model

Shulman (1986) proposed that PCK is made up of two components comprising:

1. *knowledge of representations or instructional strategies* which includes the most "powerful analogies, illustrations, explanations and demonstrations" that is "ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 9).

2. *knowledge of students' subject matter learning difficulties* which includes "an understanding of what makes learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons" (Shulman, 1986, p. 9).

Teachers need to be knowledgeable of various representations either derived from experience or from research to transform SMK for teaching. They also need to be knowledgeable of strategies used to address students' learning difficulties as well as to challenge students' preconceptions to help them re-organise their concepts.

Grossman's 1990 model

Grossman's (1990) model of PCK includes four components. The first two were Shulman's initial ideas. An additional two components include 'knowledge and beliefs about the purposes for teaching a subject at different grade levels' and 'knowledge of curriculum material available for teaching a particular subject' (that is including knowledge about the horizontal and vertical curricula of the subject).

Magnusson, Krajcik and Borko's 1999 model

Magnusson et al. (1999, p. 99) proposed a PCK model specifically for science teaching and stated that PCK is made up of five components which include:

1. *orientations towards science teaching:* the teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level.

2. *knowledge and beliefs about science curriculum:* the teachers' knowledge of both horizontal and vertical curricula of a subject as well as the knowledge of programmes and materials available to teach a particular area and specific science topics.

3. *knowledge and beliefs about students' understanding of specific science topics:* takes into account the requirements for learning particular science concepts, variations in students' approaches to learning and the areas of science that students find difficult to learn.

4. *knowledge and beliefs about assessment in science:* knowledge of what to assess in study units and knowledge of various assessment methods.

5. *knowledge and beliefs about instructional strategies for teaching science:* knowledge of subject-specific strategies to instruction such as inquiry-based learning and topic-specific strategies such as analogies, representations, models, demonstrations and activities.

Magnusson et al. (1999) replaced the 'knowledge and beliefs about purposes for teaching a subject' in Grossman's model (1990) with 'orientations towards science teaching.' They added another component that is the 'knowledge of assessment strategies.'

Lee and Luft's 2008 model

Lee and Luft (2008) explored the concept of PCK among experienced science teachers. They found that teachers proposed that PCK is composed of seven components. In Lee and Luft's (2008) study each teacher created a personalised representation of how these components link together to represent their own PCK. The knowledge components include:

1. *knowledge of science:* knowledge of science content, scientific practice, nature of science and the scientific process.

2. *knowledge of goals:* determined by the subject area.

3. *knowledge of students:* the students' background, interests, prior knowledge, learning difficulties and misconceptions.

4. *knowledge of curriculum organisation:* drawing connections between science concepts and other subjects.

5. *knowledge of teaching:* including the various teaching methods, the use of motivating activities as well as the ability to select effective activities.

6. *knowledge of assessment*: using a variety of assessment techniques to gather evidence of students' understanding about scientific concepts.

7. *knowledge of resources:* including activities, multimedia, local facilities, laboratory technology that can complement their practice and bring the scientific world outside the classroom to the students.

These science teachers emphasise that they need to have a strong science background to teach science and the possession of SMK is an important prerequisite for PCK. Teachers also need to have knowledge of resources to make teaching relevant to their students where the latter influences curriculum organisation, the selection of teaching strategies and the use of assessment.

If one compares the models presented, starting with Shulman's original components it can be seen that while Shulman's original ideas have been retained in all the models, some additional ideas have been added as seen in Table 2.1. So far these models show that a consensus with regard to what constitutes PCK has not been reached. However these models outline the important components that teachers make use of in an integrated and complex fashion in their planning and teaching process, as well as during their reflections and evaluations to improve their practice.

Table 2.1: Comparison of models of PCK

Components of PCK including knowledge of:	**Shulman (1986)**	**Grossman (1990)**	**Magnusson et al. (1999)**	**Lee & Luft (2008)**
representations or instructional strategies	✓	✓	✓	✓
students' subject matter learning difficulties	✓	✓	✓	✓
purposes for teaching a subject/ orientations towards teaching science		✓	✓	✓
curriculum material (knowledge of curriculum & resources)		✓	✓	✓
assessment in science			✓	✓
knowledge of science content				✓

2.2.3 A critique of the cognitive model of professional knowledge

The cognitive model of teacher professional knowledge moves away from the idea that knowing one's subject is enough to be able to teach it. The model identifies PCK as an important component for the development of teacher professional knowledge. However Shulman (2015) himself pointed out several weakness and limitations to the original model. The roots of PCK were embedded in cognitive theory and the affective and moral dimensions of PCK were not taken into consideration. PCK was portrayed as lacking emotion, affect, feelings and motivation. The affective dimension is important because teachers' knowledge, decisions and actions are based on feelings and motivation that in turn impact the feelings and motives of their students. Secondly PCK not only involves the teachers' thinking process but it needs to encompass actions in the classroom. Shulman (2015) also argues that the original definition of PCK does not consider the impact of the social and cultural context on teaching and learning and that it does not include any reference to students' outcomes.

In fact other critics of the cognitive model have argued that this model does not problematise the context in which teachers learn and views them as passive participants in their own professional development. Bullock (2011) argues that this model portrays teachers as consumers of knowledge rather than producers of knowledge. It cannot be assumed that once teachers acquire this knowledge base they will know how to teach. As argued by Brickhouse (2001):

> …learning is not merely a matter of acquiring knowledge, it is a matter of deciding what kind of person you are and want to be and engaging in those activities that make one part of the relevant communities (p. 286).

In light of these arguments, more recently educational researchers have recognised the importance of considering sociocultural influences on teacher learning (Lee & Schallert, 2016). Greeno (1997) argues that learning how to teach is not only a set of knowledge and skills, but it is also a "situated perspective" where "the participation of each individual is considered in relation to the other individuals and the material and representational system that contribute to the activity that occurs" (p. 8). From the 'situative perspective' learning to teach is viewed as a "participation in social practice" and "assumes that all instruction occurs in complex social environments" (Greeno, 1997, p. 9). This is an important shift from viewing learning how to teach as an individual construction of knowledge to one that views the process of learning as social participation within a community of practice (Lave & Wenger, 1991). The question that needs to be asked is whether the knowledge base of teachers is located within the individual teacher's head or whether "it is somehow a social asset, meaningful only in the context of its applications" (Rowland & Ruthven, 2011, p. 3).

2.2.4 A model of teacher professional knowledge and skill including PCK

A number of researchers came together in a PCK summit in 2012 and aimed to reach a consensus to develop a unified model of PCK. This has been called "a model of teacher professional knowledge and skill including PCK" (model of TPK&S) (Gess-Newsome, 2015). It is commonly known as the 'consensus model of PCK' and combines previous features of PCK into a multi-layered structure (Neumann, Kind & Harms, 2018). The proposed operational definition of PCK arising from the summit is that:

> PCK is the knowledge of, reasoning behind, and enactment of the teaching of particular topics in a particular way with particular students for particular reasons for enhanced student outcomes
>
> (Carlson, Stokes, Helms, Gess-Newsome & Gardner, 2015, p. 24).

This new model of TPK&S is shown in Figure 2.1.

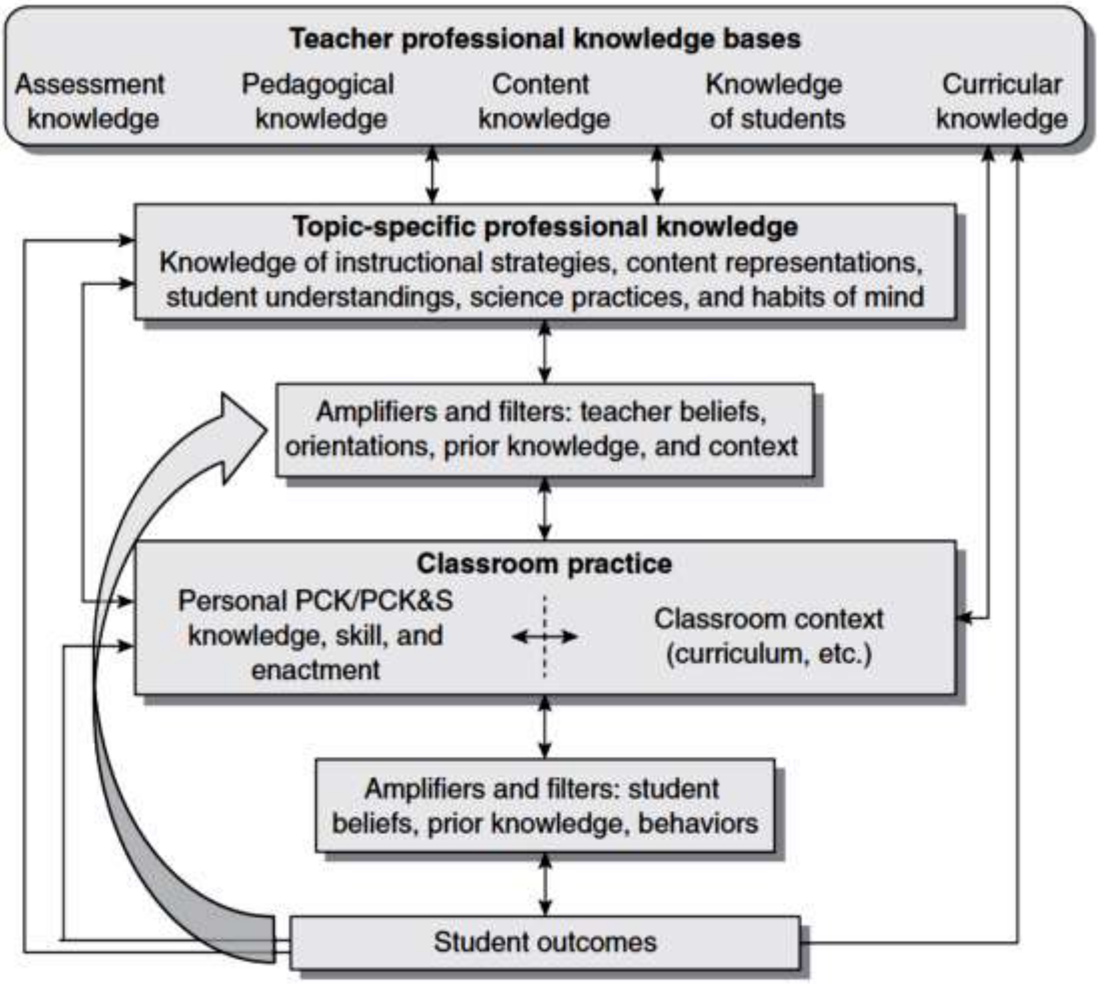

Figure 2.1: Model of teacher professional knowledge and skill including PCK and influences on classroom practice and students' outcomes
(Source: Gess-Newsome, 2015, p. 31)

The 'teacher professional knowledge base' is made up of five domains (knowledge of assessment, pedagogical knowledge, content knowledge, knowledge of students and curricular knowledge) and it feeds forwards and backwards into the 'topic-specific professional knowledge' which includes knowledge of topic-specific instructional strategies and knowledge of students' developmental level.

The 'topic-specific professional knowledge' base passes through filters and amplifiers which "acknowledge the relevance of affective aspects of teachers'… experiences for the development of and efficacy of teachers' knowledge" (Neumann et al., 2018, p. 9). Teachers' beliefs, views and goals together with their orientation towards preferred teaching approaches and organisation of curriculum content are acknowledged as influencing classroom practice. Other factors such as teachers' enthusiasm, motivation, disappointment, efficacy, risk-taking, personal knowledge base and contextual factors shape teacher learning and choices implemented in the classroom. As a result 'teachers can act as amplifiers or filters' because they have the ability to embrace, change or reject knowledge, skills and practices derived from the professional knowledge base. Here the teachers' orientations and beliefs are not part of the PCK as described by Magnusson et al. (1999) but have an important influence on classroom practice.

The 'topic-specific professional knowledge', filtered by teachers, is transformed and adapted for classroom practice but the latter also shapes the 'topic-specific professional knowledge' as indicated by the upward arrow in Figure 2.1. Teachers make use of their 'personal PCK' in designing lessons plans and in making particular decisions related to their instruction. Their personal, idiosyncratic PCK can be observed in classroom practice. This model emphasises that PCK is enacted during the teaching process when teachers adjust their lessons plans according to the students' participation and their needs whilst teaching. In the process teachers engage in "reflection-on-action" when planning lessons and carry out "reflection-in-action" whilst teaching (Schön, 1983). This model distinguishes between personal PCK and personal PCK and skill (PCK&S) as explained in the following definitions:

- **Personal PCK** is the *knowledge* of, *reasoning* behind, and *planning* for teaching a particular *topic* in a particular *way* for a particular *purpose* to particular *students* for enhanced student *outcomes*.

- **Personal PCK and skill (PCK&S)** is the *act of teaching* a particular *topic* in a particular *way* for a particular *purpose* to particular *students* for enhanced *student outcomes*.

(Gess-Newsome, 2015, p. 36)

This model also emphasises that specific classroom contexts impact teaching and classroom decisions, for instance the type of curriculum materials, resources, the number of classes and year groups assigned, disruptions to schools life, reform initiatives and support available. PCK also varies with different topics and this can mean that different PCK is required when teaching within and outside specialism.

Students can also act as *'amplifiers and filters'*. They play an active role in the learning process and can decide whether to engage or not in their learning. Students' successes or failures depend on many factors such as age, gender, race, language, socio-economic status, parental help and motivation. Students' behaviour and disposition to learn can encourage or put down teacher motivation or willingness to introduce innovative teaching approaches.

The student outcomes and classroom practices can also inform the 'teacher professional knowledge base', the 'topic-specific knowledge base' and the 'personal PCK' as indicated by the upward arrows in Figure 2.1. This model shows the complexity of teaching and learning. Neumann et al. (2018) argue that the model of TPK&S does not really indicate what PCK is made of but the model shows "PCK as teachers' personal knowledge that drives their planning, for, implementation of, and reflection on instruction" (p. 10).

In my view, one of the shortcomings of the model of TPK&S is that it only highlights the aspects that make up the teachers' knowledge base (that is the cognitive, affective and contextual aspects) and gives a limited explanation of the components of PCK. Indeed, the definition of PCK given in this model is mainly related how the teacher's knowledge is used whilst planning and teaching. Drawing on the literature outlined in this section, I would argue that there is no one model that encompasses all the components that make up the development of teachers' professional knowledge. While the models described in section 2.2.2.1 outline the components that make up PCK, they do not take into consideration the affective aspect of teacher professional knowledge. More recently a new model for PCK, The Refined Consensus Model of PCK has been developed (see Carlson & Daehler, 2019). This model looks at three distinct aspects of PCK, namely collective PCK, personal PCK, and enacted PCK. The ideas behind this refined model is that PCK is developed on the basis of professional knowledge held by specialised educators in the field, by the personal experiences of the individual teacher, and by the subset of knowledge that the science teacher draws on to engage in planning, teaching and assessing a lesson. In my view, what is important for the current study from this refined model of PCK, is the basic tenet that both teacher professional knowledge as well as context are important in the development of PCK.

2.3 Development of professional knowledge from an affective perspective

The cognitive perspective including SMK and PCK are important aspects of the professional knowledge of science teachers. However, as indicated in the critique of the cognitive model and in the model of TPK&S, knowing the subject and knowing how to teach the subject are not the only aspect of a teacher's professional knowledge base. Indeed Hobbs and Whannell (2018) argue that the teachers' knowledge base:

> … could be considered as more complex than ‘content knowledge’, or even ‘pedagogical content knowledge’ as described by Shulman (1986), because knowledge is impregnated with beliefs about teaching and learning, the subject, and what is means to personally engage with the subject (p. 241).

Teachers’ beliefs involve feelings, emotions and subject evaluations and need to be carefully attended to because they “can serve as a means to define goals and tasks” (Nespor, 1987, p. 319). Kagan (1992) defines teachers’ beliefs as “tacit, often unconsciously held assumptions about students, classrooms and the academic material to be taught” (p. 65). On the other hand Mansour (2009) states that the “concept of belief is used to characterise a teacher’s idiosyncratic unity of thought about objects, people, events and their characteristic relationship that affect his/her planning and interactive thoughts and decisions” (p. 26). This implies that teachers’ behaviour and style of teaching are more often guided by their own personal beliefs. Kagan (1992) argues that teachers’ beliefs cannot be directly inferred from teacher behaviour because teachers can use similar practices but for different reasons. Inferring teachers’ beliefs is rather difficult as very often teachers’ beliefs are implicit and teachers rarely have the opportunity to openly articulate their beliefs. Yet one cannot underestimate their impact on the teachers’ perceptions, judgments, classroom behaviour and even on cognitive knowledge. As Nespor (1987) argues beliefs are far more influential than knowledge in determining one’s actions and can be used as predictors of behaviour.

Beliefs are formed from personal experiences, prior teaching and learning experiences, events, teacher education programmes and from interacting with other people. These beliefs are shaped by the social, cultural, political and historical contexts throughout the teaching career (Nespor, 1987; Pajares, 1992). As a consequence teachers’ actions and thoughts are very much intertwined within a particular context. Putnam and Borko (2000) argue that “the classroom is a powerful environment for shaping and constraining how practicing teachers think and act” (p. 6). In other words context greatly influences the teachers’ attitudes and beliefs about teaching and learning. In view of this Levin (2015) argues that teachers’ beliefs and practices need to be examined in their own particular context because “teachers’ beliefs and actions cannot be separated from situations in which they occur; including the larger social, political and economic climate as well as the immediate school context” (p. 51). Beliefs are also created through a process of enculturation and social construction (see Pajares, 1992), so beliefs are shaped by the interactions that occur in a social context.

The literature identifies two important aspects related to teachers’ beliefs which include teachers’ sense of self-efficacy and content-specific beliefs. Within the context of teaching outside specialism, the teachers' beliefs about themselves as teachers, their views about the content and their self-confidence impact the quality of teaching and learning. Both aspects are significant to this research study.

2.3.1 Teachers' self-efficacy

Teachers hold beliefs about their teaching capabilities. Bandura (1997) defines perceived self-efficacy as the "beliefs in one's capabilities to organise and execute the course of action required to produce given attainments" (p. 3). When this concept is applied to science teaching, self-efficacy incorporates the beliefs that a science teacher can teach science effectively that positively influences student learning and achievement (Haigh & Anthony, 2012). The perceived self-efficacy is concerned with the judgment of personal capability and shapes the course of action to be taken, the effort made, the perseverance to face difficulties, the degree of stress one can endure and level of accomplishment achieved. Like Haigh & Anthony (2012), I would argue that success or failure can strongly impact one's perception of self-efficacy. Successful teaching episodes strengthen the teachers' efficacy. When self-efficacies are high, teachers are more likely to take risks, undertake challenges and engage in new ways of doing science (Evans, 2015). The higher the self-efficacy, the more effort and persistence will be made by the teacher that will lead to improved performance. Such results increase one's self-efficacy (Tschannen-Moran, Woolfolk Hoy & Hoy, 1998).

On the other hand, teachers who are apprehensive to experiment with challenging teaching methods have reduced self-efficacies and there is a high probability that they will not take any risk to try them out (Evans, 2015). As a result lower self-efficacy leads to fewer efforts and there is more chance of giving up leading to poor teaching outcomes. This will produce a lower efficacy since self-efficacy is cyclical in nature in both positive and negative ways (Tschannen-Moran et al., 1998). Furthermore teacher self-efficacy impacts the teaching style where teachers can adopt a transmissive or restrictive approach to teaching if they lack confidence in the knowledge and understanding of a particular curriculum area (Jones & Cowie, 2011). From their research Park and Oliver (2008) have shown that teacher's efficacy plays a critical role in determining instructional strategies and it can be considered as an affective component of PCK. Self-efficacy is specifically relevant to the current study because in their study Sanders et al. (1993) have shown that teachers' self-efficacy differs when teaching within or outside their area of expertise. It also affects the development of lessons and pedagogies used as will be explained in Chapter 3.

2.3.2 Content-specific beliefs

Content-specific beliefs focus on the teachers' orientations to specific academic content. Teachers teach their own subjects according to the values and beliefs they hold about the nature and content of their discipline (Nespor, 1987). Content-specific beliefs or 'teachers' beliefs about subject matter' featured as the fourth component of SMK by Grossman et al. (1989) (see section 2.2.1). One of the components of PCK in Magnusson et al. (1999) model also refers to the 'orientations towards science teaching' that is the teachers' knowledge and beliefs about the purposes and goals for teaching science at a particular grade level (see section 2.2.2.1) and content-specific beliefs act as filters to classroom practice as in the model of TPK&S (Gess-Newsome, 2015).

Content-specific beliefs affect the way teachers understand and interpret the nature of the scientific knowledge as well as the way they choose to teach that subject matter content at different grade levels. The teacher's content-specific beliefs influence the type of instructional activities chosen such as using lecturing methods or making use of constructivist views of teaching and learning by actively engaging students to construct knowledge through inquiry methods and co-operative learning. Some teachers use a mixed approach of these methods (Mansour, 2009). Hobbs (2013a) argues that teaching a subject not only requires knowledge of teaching strategies and knowledge of the curriculum, but also knowing how to bring the subject alive for the students. Teachers can lack enthusiasm when teaching an unfamiliar area especially if they had poor experiences of the subject as young learners. Based on my experiences with science teachers, I would agree with Hobbs (2013a) that content-specific beliefs formed from their personal experiences influence the way teachers engage with a subject and the way they present the subject to the students.

Both the teachers' level of self-efficacy and content-specific beliefs influence the teachers' knowledge base. Indeed Kagan (1992) views beliefs as a form of personal knowledge and argues that teacher's professional knowledge can be regarded as a belief. He argues that when teachers gain more classroom experience, their "professional knowledge grows richer and more coherent, forming a highly personalised pedagogy – a belief system that constrains the teacher's perception, judgment and behaviour" (Kagan, 1992, p. 74). With time teachers' beliefs become embedded as part of their knowledge base and skills needed for teaching (Bullock, 2011). Beliefs eventually act as filters in interpreting experiences, in redefining knowledge that affects planning, decisions and courses of action and in adopting new practices or instructional strategies (see Pajares 1992) as has also been demonstrated in the model of TPK&S (Gess-Newsome, 2015).

2.4 Learning to teach science: A sociocultural perspective

The literature outlined in the previous sections suggests that SMK, PCK and beliefs shape the teachers' professional knowledge base. The knowledge needed for teaching is dynamic in nature and is developed in a specific context as a result of social interaction. In this literature review I looked at the process of learning from a 'situated perspective' (Greeno, 1997) and socio-cultural theories of learning since I believe that these shape the teacher's professional knowledge base and skills.

Petrou and Goulding (2011) claim that "teacher knowledge can only be understood in the context in which they work" where the context can be viewed as the "structure that defines the components of knowledge central to … teaching" (pp. 20-21). The educational system, the aims of education, the curriculum, resources and the assessment system are part of this context. Situative theorists challenge the early cognitive theories in which learning is seen as the acquisition of knowledge and skills, that is independent of the context in which learning takes place. From the cognitive perspective it is assumed that knowledge acquired in one setting can be transferred to other situations. However situative theorists view learning as located in experience and both the learner and what is learnt is situated in activities, process and contexts (Prescott & Cavanagh, 2008). As Putnam and Borko (2000) argue "the physical and social context in which an activity takes place are an integral part of the activity, and that the activity is an integral part of the learning that takes place within it" (p. 4). Therefore learning involves both how a person learns a particular set of knowledge and skills and the situation in which learning takes place where a person is more likely to learn by actively participating in the learning experience, hence context is central to the learning process.

The situative perspective also has a social dimension and focuses on the role of other persons or materials in determining both what is learnt and how it is learned, that is it looks at the "interactive systems that include individuals as participants, interacting with each other as well as materials and representation systems" (Greeno, 1997, p. 7). Therefore teacher professional learning takes place through interaction and communication with others and is developed in a social context. This sociocultural theory of learning as proposed by Vygotsky (1978) emphasises that learning is a social process resulting from the co-construction of knowledge through a process of social interaction between individuals which is influenced by the skills and abilities valued in a particular cultural context. The interaction between the social, cultural-historical and individual factors are important to human development as they stimulate cognitive growth, where "learning and meaning-making are portrayed as originating in social interaction between individuals or as individuals interact with cultural products that are made available to them in books or other sources" (Leach & Scott, 2003, p. 93).

Teacher professional learning can also be conceptualised as a way of participating and sharing practices in a particular community (Lave & Wenger, 1991). When Lave and Wenger (1991) observed different apprenticeships they noted that situated learning involves participation in communities of practice. When people join a community they start learning at the periphery. As they become more competent and experienced, they become more involved in the main practices of the particular community, thereby moving from legitimate peripheral participation into full active participation in the shared practice at the centre of the community of practice. Legitimate peripheral participation is the process by which newcomers become part of a community of practice (Lave & Wenger, 1991). In this model learning is viewed as a process of social participation and engagement in practice, rather than the acquisition of knowledge by individuals. A similar process is observed as one learns to become a science teacher. New teachers learn from other teachers, from their mentors and from their practices in a community. As they gain more experience they engage in further participation with others. By forming part of a community of practice one's ideas and ways of thinking can change as other members bring forward their different ideas and practices. As Stein (1998) argues "knowledge is created or negotiated through the interactions of the learner with others and the environment" (p. 2). Therefore becoming a science teacher involves the interactions of learners in a community occurring in a context or in practice (Wenger, 1998).

In my view and based on the principles of sociocultural learning theory outlined by Vygotsky (1978), Greeno (1997) and Lave and Wenger (1991), becoming a science teacher (that is learning to think, talk and act as a science teacher) does not only involve the development of individual knowledge and competences by acquiring the relevant SMK and PCK but learning to teach "is becoming enculturated into the teaching community" (Putnam & Borko, 2000, p. 9). Knowing the subject content and developing PCK are important aspects of becoming a teacher but this is not enough for teachers to become experts. Teachers learn to teach as they interact socially with other teachers and by taking part in organised activities and practices. The context also shapes the teachers' perception of themselves, their beliefs and their practices and the way they learn to become science teachers.

2.5 Developing an identity as a science teacher

Becoming a science teacher involves more than gaining a professional knowledge base as it encompasses the formation of one's professional identity. Sachs (2005) argues that development of the teacher's professional identity "stands at the core of the teaching profession. It provides a framework for teachers to construct their own ideas of 'how to be', 'how to act' and 'how to understand' their work and their place in society" (p. 15). Lately researchers have attempted to understand and define the concept of identity, (Beauchamp & Thomas, 2009; Beijaard, Meijer & Verloop, 2004) however Beauchamp and Thomas (2009) argue that it is rather difficult to define identity due to various issues that emerge when examining this concept. They contend that:

> …identity is dynamic and that a teacher's identity shifts over time under the influence of a range of factors both internal to the individual such as emotion and external to the individual such as job and life experiences in a particular contexts
> (Beauchamp & Thomas, 2009, p. 177).

Beijaard et al. (2004) also note that "identity is an ongoing process of interpretation and re-interpretation of experience" (p. 122). They further argue that identity involves both a person and a context and that within a professional identity there are sub-identities which must be balanced to avoid conflict between the different facets. Beauchamp and Thomas (2009) note that there is a close connection between identity and the self. Identity development involves understanding of the self where the concept of self stems from the persons' actions, affiliations, beliefs, values and future aspirations of the person (Helms, 1998).

Gee's theory of identity has been very influential in the educational field. According to Gee (2000) identity is defined as "being recognised as a certain "kind of person", in a given context" (p. 99). Here identity is viewed as a socially situated construct because as Luehmann (2007) argues "one is recognised by self and others as a kind of person because of the interaction one has with others" (p. 827) and thus external influences can shape one's identity. Gee (2000) also contends that everyone has multiple identities that operate across different contexts and that identity can be viewed in four different ways which include (1) nature-identity, that is describing oneself as a certain kind of person, (2) institution-identity, which is derived from the position occupied in society, (3) discourse-identity, where one's individual accomplishments are recognised by others through discourse and (4) affinity-identity which refers to the experiences shared within groups that have common interests and practice. This shows the multifaceted nature of identity and that these four perspectives are interrelated in complex ways. In this thesis I use Luehmann's (2007) definition which is based on Gee's (2000) definition of identity where a "teacher professional identity is how one is recognised by self or others as a certain kind of teacher" (p. 827). This will be necessary to understand how the science teachers participating in this research study understand and recognise themselves and in relation to others when teaching outside their science specialism.

Researchers have identified various factors that shape the development of teaching identity. I tried to delve into and examine how the different factors shape the teacher identity so as to understand how different individuals develop meanings, decisions and beliefs in their journey of becoming a science teacher.

2.5.1 Identity development shaped by personal histories

Personal histories, actions, events and prior experiences with science play a crucial role in the formation of teachers' identity (Avraamidou, 2014b; 2016a). Experiences have past (by looking back and remembering experiences, feelings and stories), present (by looking at current practices, experiences and their related feelings) and future references (by looking forward to possible experiences). Teachers' experiences as science learners during their school days and at university shape the development of their identity as science teachers. Avraamidou (2016b) suggests that positive experiences as a young learner positively influence one's identity, making the teacher more enthusiastic towards science and increasing self-efficacy as a science learner. Negative science learning experiences can lower teacher's self-confidence in teaching science and instil a negative attitude towards science. Since personal histories of science teachers influence their teaching identity, Avraamidou (2016b) argues that teachers should constantly examine and re-examine their stories in order to understand how their level of confidence is affected when teaching particular science topics. This issue is especially important in the current study as the level of teachers' confidence can vary when teaching different science topics (Kind, 2009a).

Understanding where one is coming from is also important because our personal histories are strongly connected to our emotions. The emotional state of a teacher influences teaching and learning. As Rivera Maulucci (2012) argues "emotions influence the goals teachers set and indicate the intensity of their relationship to ideas, to their beliefs about science, to others and to science teaching" (p. 137). Therefore emotions can be linked with one's self-perception, with the level of confidence in teaching a particular subject and with one's self-efficacy with regard to science teaching.

2.5.2 Identity development shaped by interactions with others in context

Besides being strongly influenced by personal experience and background, identity is also shaped by the social context and influenced by interactions with others. Rodgers and Scott (2008) argue that context shapes the way we perceive ourselves and how others look at us. They further argue that "identity is formed in relationship with others" (Rodgers & Scott, 2008, p. 733), since to gain an identity one needs to be recognised as a particular kind of person by others. Identity is not a fixed construct but it is constantly changing and developing due to the effect of ongoing experiences and interactions with other people living in a social context (Avraamidou, 2014a).

Professional identities are developed by participating in discourse where discourse as expressed through language "consists of a system of beliefs, attitudes, and values that exist within particular social and cultural practices" (Danielewicz, 2001, p.11). The discourse or narratives told by teachers about themselves and their practices enable teachers to express the different facets of their identity. When teachers participate within professional discourses they are given the opportunity to reflect and review their own interpretation of themselves. The process of engaging in discourse and interacting with others in a professional context encourages teachers to construct and reconstruct their identity (Beauchamp & Thomas, 2009). Teachers can more readily develop their identity through support of other teachers by engaging in interaction and forming part of a community of practice.

Wenger (1998) states that "we define who we are by the ways we experience ourselves through participation" (p. 149). He associates identity with practice, thus professional identity develops when teachers participate in communities of practice. Engaging in a community of practice creates relations between members, social negotiations and provides experiences of participation that provide specific meaning of the lived experience that is shaped by practice. By actively participating in practices of social communities one constructs identities in relation to these communities (Wenger 1998). Identity can also be viewed as a way of how "learning changes who we are and creates personal histories of becoming the context of our communities" (Wenger, 1998, p. 5). In other words learning as a means of social participation in communities of practice can transform who we are, that is it can change our professional identity.

2.5.3 Identity development linked to the subject taught

Beijaard, Verloop and Vermunt (2000) describe the teacher professional identity in terms of the professional knowledge that the teachers need to acquire to become the subject matter expert, the pedagogical expert and the didactical expert. On the other hand, Avraamidou (2014b) expands the notion of identity and refers to it as the "ways in which a teacher represents herself through her views, orientations, attitudes, content knowledge, knowledge, and beliefs about science teaching, and the ways in which she acts within specific contexts" (p. 224). Luehmann (2007) adds that professional identity includes more than the teachers' knowledge and beliefs about their practices that is the "professional philosophy, passions, commitments, ways of acting and interacting, values and morals" (p. 828). These views show that identity is a complex notion encompassing many aspects related to teachers' knowledge, beliefs, attitudes and values.

The choice of teaching discipline influences the teacher's actions and attitudes and it can have an impact on identity since disciplines have particular cultures of their own (see Beauchamp & Thomas, 2009). Secondary school teachers tend to describe themselves in terms of the subject(s) that they teach because teachers develop a set of values, norms and viewpoints based on the subject discipline. Siskin (1994) argues that "teachers frequently explain who they are, what they do, or how they do it by anchoring their identities, actions and understandings in their subject matter itself" (p. 153). Even when teachers may not directly refer to the subjects that they teach, Siskin (1994) argues that the teachers' background knowledge is revealed through one's own "choice of words, the structure of their arguments or the goals they hold" (p. 154).

This implies that subject discipline has an influential role on one's teaching identity; however few studies discuss how this applies to science teaching. Helms (1998) explored how the nature of the teachers' sense of personal and professional identity could be influenced by one's understanding and beliefs about the subject content and the nature of subject matter. She found that five secondary school teachers defined "themselves in large part by their practice, by what they do, and the subject they teach" (Helms, 1998, p. 832). Subject matter featured considerably in the teachers' descriptions of themselves and in what they would like to be. As a result science and teaching played a key role in how they viewed themselves as science teachers.

Volkman and Anderson (1998) argue that "professional identity depends on social confidence and content security" (p. 307). In their study the teacher first thought that her insecurities in subject content would not affect her desire to teach and to develop good interactions with students but throughout the year she recognised that teaching is intricately connected to disciplinary knowledge. Insecurity about content knowledge can upset one's self-efficacy and perception of the professional identity.

In connection to this study, teaching outside specialism can subject teachers to internal struggles because lack of content knowledge can create dilemmas in one's teaching identity. Additionally teachers may not be completely fulfilled if they are teaching a subject they do not enjoy teaching (Hobbs, 2013a). Hence teachers may also not identify with an area of the subject that they teach. This is commonly found with primary teachers (Akerson, Carter & Elcan, 2016), where for instance many primary teachers do not enjoy teaching science at primary level (Appleton, 1995). However, I think that this notion can also be extended to teachers teaching science at secondary school through a generalist approach.

Beeijard et al. (2004) argue that a teacher's professional identity consists of sub-identities where the teacher can adopt different identities according to different contexts and relationships. In my view, this notion of sub-identities or multiple identities can be applied to science teachers when teaching within and outside their area of science specialism. They may look at themselves more as subject specialists rather than generalist science teachers due to the lack of content knowledge and skills to teach the different science areas effectively. For instance, science teachers with a specialisation in physics can view themselves more as physics specialists, thereby identifying with physics as their specialist area and dis-identifying with biology and chemistry being their non-specialist area. The effect of sociocultural factors, teachers' personal biographies and experiences can provide an explanation as to why teachers view themselves as specialist teachers rather than generalist teachers. The school experiences or even the absence of studying particular science subjects, as in the case of Maltese teachers, explains why science teachers may not be confident and willing to teach a subject that they never learnt at school. These teachers cannot rely on apprenticeship of observation to teach their non-specialist area even though the latter concept has been considered to be problematic in the formation of teacher identity during ITE. Teaching outside specialism presents a number of challenges as teachers are trying to take on a new identity. In view of this, "taking a new identity always involves risk" (Luehmann, 2007, p. 831) especially of not being successful.

However, Beijaard et al. (2004) argues that professional identity involves agency where teachers need to be active during identity constructions. The notion of agency helps teachers to make sense of themselves and to move forwards to reach their goals. Their sense of agency can provide the impetus to find ways of overcoming challenges in one's teaching profession. One way to demonstrate agency is to involve teachers in the process of professional development to pursue their own targets. The teachers' sense of agency can help them to tackle the challenges experienced when they are teaching a subject that they least likely identify with by finding ways of overcoming the difficulties encountered.

2.6 Becoming a science teacher

The journey of becoming a science teacher is a complex, multifaceted undertaking and entails a lifelong learning process. In formulating the theoretical framework for the current study I have come to understand that the cognitive, affective, contextual and sociocultural aspects shape the teachers' professional knowledge base for teaching. Figure 2.2 shows how the main areas that have been identified in this chapter are interrelated and influence the development of each area.

As Shulman (1986) originally proposed SMK is a fundamental pillar since it plays a central role in lesson planning and guides the teaching process. Science teachers need to have a good foundation of the subject content to teach all areas of science. They also need to be aware of the students' learning difficulties and misconceptions. In the process of becoming a science teacher they learn to transform the subject content into representations, analogies and explanations in order to make the subject comprehensible to their students. Hence teachers learn to develop their PCK. Kind (2009b) argues that SMK is an essential prerequisite in the development of PCK. When teachers have a good knowledge and structure of the discipline, they can come up with different ways of teaching the same concept showing that they have flexible PCK (Childs & McNicholl, 2007). In other words, I would argue that it is crucial for science teachers to have a strong knowledge base in all areas of science, if they are to take up the role of generalist science teachers.

Teachers develop subject content and pedagogical knowledge within a social context and through the interaction of others (see section 2.4). As described in the model of TPK&S (Gess-Newsome, 2015) the teachers' knowledge base is developed in a particular context. This means that becoming a science teacher does not take place in a vacuum but it is highly influenced by the context and teacher learning is shaped by the interaction of others within the school's learning community. In their study McNicholl and Childs (2010) argue that "PCK is the product of a social process" especially when teachers discuss their lesson plans, ways of explaining concepts or conduct experiments with their colleagues. As I reviewed the literature on PCK, I tried to make sense of the different models of PCK and the factors that influence the development of teachers' professional knowledge.

In Figure 2.2, I suggest that the development of professional knowledge is highly influenced by context and that the affective dimension that is the teachers' beliefs is another important dimension in the teachers' knowledge base. As shown by the interconnecting arrows in Figure 2.2, there is a constant interaction between the teachers' knowledge base, teachers' beliefs (Gess-Newsome, 2015), and self-efficacy beliefs (Park & Oliver, 2008). As illustrated in Figure 2.2 teachers' beliefs as personal constructions and their personal self-efficacy beliefs influence knowledge formation, the decisions made and the teachers' behaviour in lesson planning and delivery. Like Luft, Whitworth, Berry, Navy & Kind (2018) I would argue, that teachers' beliefs are often derived from personal experiences and are shaped by classroom experiences (context) and by the interaction with peers (social dimension). This is shown by the interlinking arrows in Figure 2.2.

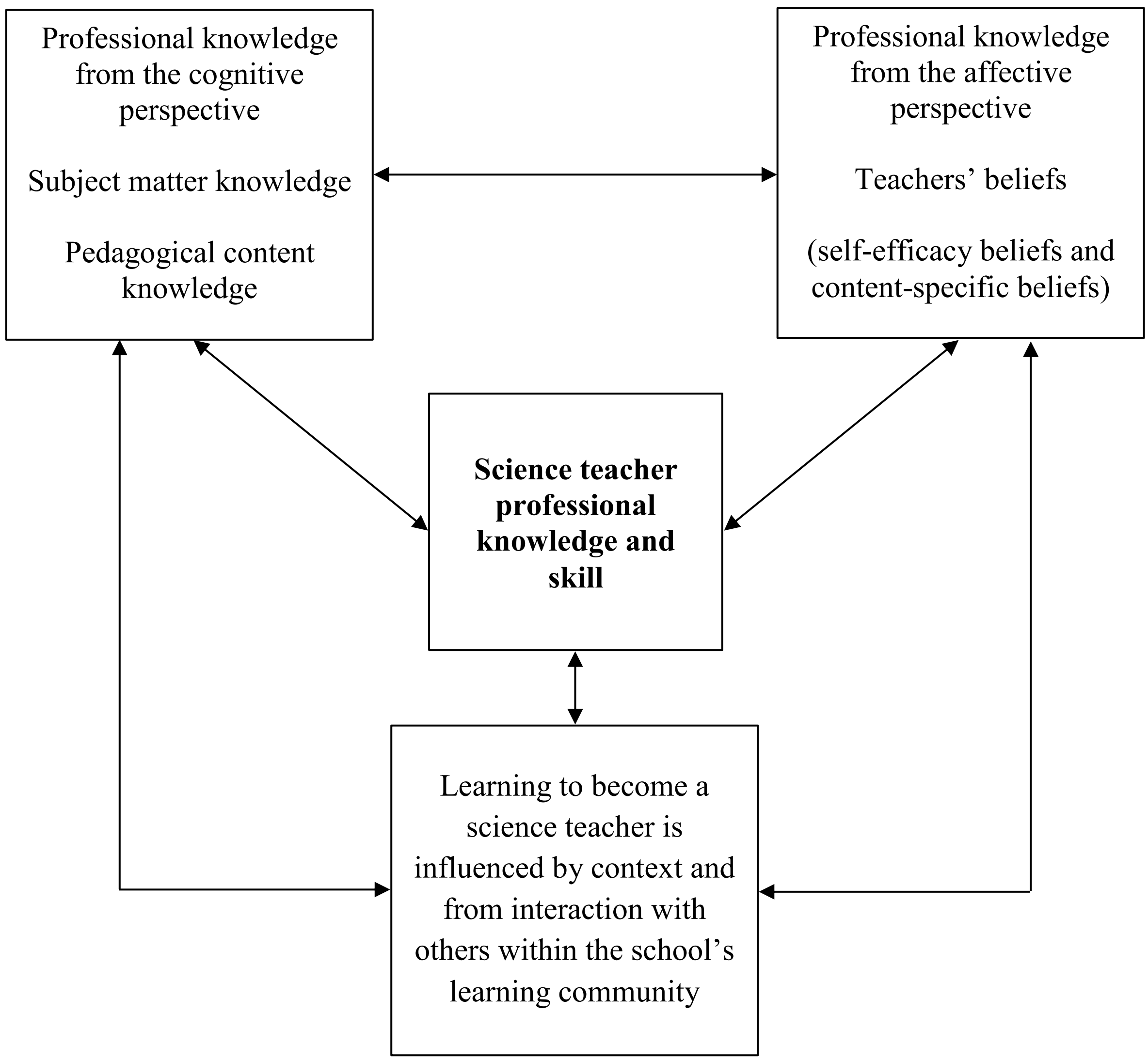

Figure 2.2: Factors shaping the teacher's professional knowledge base

On the other hand, the literature has shown that developing an identity as a science teacher is shaped by the teachers' personal histories and experiences, by interactions with others and by the context. It is also highly dependable on the subject being taught as illustrated in Figure 2.3. These factors in return influence one another as the teachers' personal histories and experiences developed as science learners can affect their motivation and disposition in teaching a particular subject (Avraamidou, 2016b). Professional identities are shaped by discourse that occurs in a particular context and this affects the teachers' beliefs and attitudes (Danielewicz, 2011) towards the subject being taught.

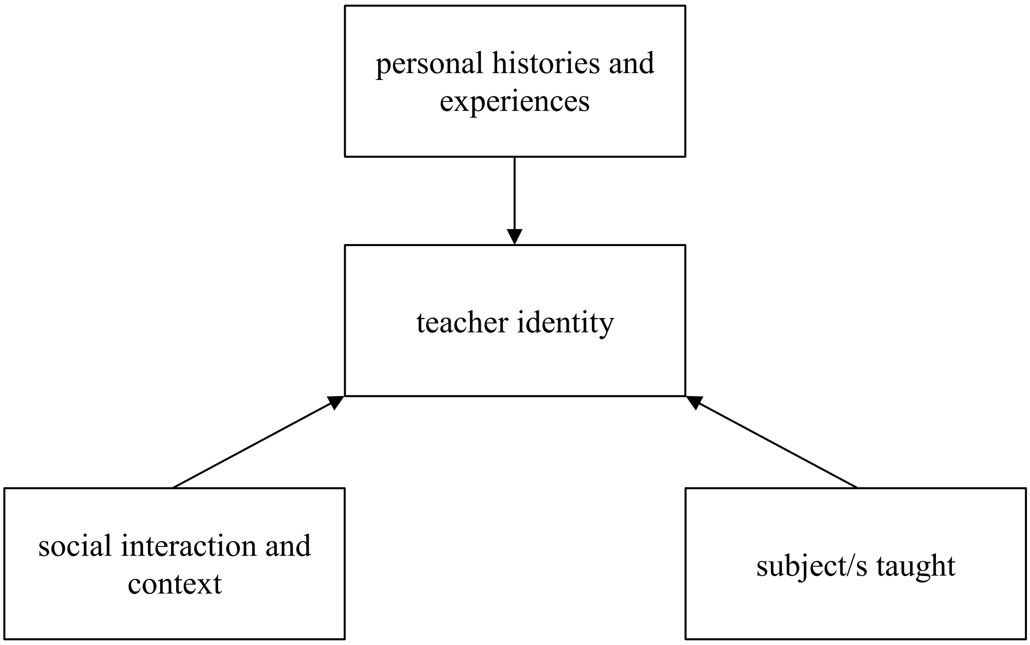

Figure 2.3: Factors shaping teacher identity

These two models have shown that similar factors influence the development of the teacher's professional knowledge base and the teacher's identity, but it seems that in literature these constructs are treated as separate entities. Kind and Taber (2005) argue that the "process of becoming an effective science teacher requires taking on a new professional identity and adapting to new specialist knowledge" (p. xv). This is a gradual process that starts at ITE and keeps on taking place throughout the years, thus science teachers keep learning to develop a professional knowledge base and this may impact their professional identity.

In this study I will use this theoretical framework to find how the teachers' professional knowledge base can impact the teaching of the different areas of science. Teachers need to make use of their professional knowledge base when teaching science, however it is highly unlikely that teachers have the same level of SMK, PCK and attitudes in different areas of science. This may imply that teachers will not teach the different science disciplines with the same passion and enthusiasm (Hobbs 2013a). Since Siskin (1994) argues that teachers derive their professional identity from the subject being taught, in this study I aim to find out whether the teachers' professional identity is affected when teaching outside specialism and whether their knowledge base affects the development of their professional identity.

The next chapter explores the phenomenon of teaching outside specialism and outlines that teachers are likely to face more challenges when teaching an unfamiliar area compared to when teaching their area of expertise.

Chapter 3

Teaching outside one's area of science specialism

3.1 Teaching outside one's area of science specialism

Science teachers have a wider responsibility because they can take the role of 'subject specialists' when teaching subject-specific disciplines studied at a degree level and/or 'generalists' teachers when teaching all science areas (see section 1.4). Kind and Taber (2005) argue that this creates a "professional dilemma" because science teachers are looked up to for their specialist skills yet they are expected to "teach as 'experts' throughout the whole science area" (p. 16).

In the previous chapter I argued that SMK, PCK, teachers' beliefs, contextual and social factors affect the development of the teachers' professional knowledge base. The question that I will try to address in this chapter is whether the professional knowledge and skills derived from teaching their specialist area can be transferred and generalised to teach all science domains. What is problematic is whether teachers have the adequate SMK, PCK and positive attitudes and beliefs to be able to teach effectively both within and outside their science specialism.

The major issue and concern related to teaching outside one's area of science specialism is that teachers may lack considerable content knowledge in particular areas (Childs & McNicholl, 2007; Kind, 2009a; McNicholl, Childs & Burns, 2013). Ingersoll (1998) claims that "teaching a subject in which one has little background or interest is challenging to say the least" and believes that it can be "very detrimental to the educational process" (p. 774). Even Luft, Hill, Weeks, Raven & Nixon (2013) report that teaching outside one's area of expertise should be a concern for those involved in policies. The Royal Society of Chemistry (RSC) advocates that subject specialists should teach primary school science and secondary school chemistry because students need to be inspired and engaged by teachers who have a "deeper understanding of the subject matter, the resultant increased confidence and the ability to improve attainment levels and attitudes to science" (RSC, 2014, p. 3). Bennett (1993) claims that adequate knowledge and understanding of the subject is required for the teacher to effectively diagnose the students' misconceptions, make appropriate curricular choices, plan suitable tasks and present quality explanations and demonstrations. When teachers possess a limited content background or lack understanding of fundamental concepts, they are more likely to promote inaccurate learning (Kind, 2014). In fact like Kind (2009b) I would argue that:

> Good SMK confers a sense of security, which supports a teacher in devising appropriate PCK. Where good SMK is absent, teachers tend to resort to more passive and less active instructional strategies and show less understanding of students' learning difficulties related to science (p. 191).

On similar lines Childs and McNicholl (2007) argue that when teachers teach outside their science specialism, "not only do science teachers have to learn what to teach (subject content knowledge, SCK) they also need to learn how to teach it (pedagogical content knowledge, PCK)" (p. 3). This means that first teachers need to know and understand the subject content that is to be learnt. Then they need to transform it into representations, activities, demonstrations and exercises to facilitate students' understanding.

One of the main arguments made in the previous chapter was that teachers develop expertise within a community of practice and with the help of experienced teachers they can move from, what Lave and Wenger (1991) describe as, moving from the periphery to the centre and from being a novice to being an expert. In Lave and Wenger's theories, the community of practice includes both novices and experts who interact with one another and learn from each other. When teaching outside specialism it is more likely that teachers will be learning content knowledge alongside their students while at the same time finding ways about how best to teach it (Kind 2009b). They are participating in a learning community in which they are trying to become experts at the same time with their students. Teachers also need to be able to transfer the knowledge learned from their specialist to their non-specialist area. However they struggle to achieve this since the content of each science discipline is widely different. Due to lack of content knowledge teachers may find it difficult to identify with the teaching of a less familiar area.

Hobbs (2013a) has in fact found that teachers can demonstrate lack of interest, passion and motivation when teaching an unfamiliar area and this will affect the development of their professional beliefs and teacher identity. Since science teachers may not identify with subject areas outside specialism they often claim that they do not feel confident to teach these areas and encounter a number of difficulties when teaching outside their science specialism. Within the Maltese context Gatt (2011) found that science teachers experienced different levels of confidence when teaching the different science topics within integrated science, particularly the physics specialist teachers who demonstrated lower levels of confidence in teaching biology and chemistry units.

International research shows that teachers experience various challenges and issues when planning lessons and teaching outside their area of expertise (Childs & McNicholl, 2007; Hashweh, 1987; Hobbs, 2013a; Kind, 2009a; Kind & Kind, 2011; Sanders et al., 1993). This research was carried out both with trainees and with experienced teachers in different science disciplines. Trainee teachers may encounter further challenges than experienced teachers since they are at their initial stages of developing both their SMK and PCK. With regard to their SMK, Lederman, Gess-Newsome and Latz (1994) found that pre-service teachers did not have well-formed or stable subject matter content. The SMK of trainee teachers generally includes lists of discrete topics studied at university or at college level that are often fragmented and disjointed with little indication of coherent themes. Their PCK is also still not well-developed. With teaching experience subject matter structures change producing a more integrated and interrelated network of topics and their PCK continues to evolve. Although experienced teachers have better PCK acquired through teaching their area of specialism, Childs and McNicholl (2007) and Sanders et al. (1993) found that experienced teachers still felt like novice teachers when teaching outside specialism. Sanders et al. (1993) explain that experienced teachers used their pedagogical knowledge to manage their classrooms and develop their lessons plans making up for their limitations when teaching outside their area of expertise. Classroom experience helped these teachers to adapt and find ways to overcome the difficulties experienced when teaching outside specialism.

The next section looks at the challenges faced by both trainee and experienced teachers when planning and teaching outside their area of specialism. At the same time teachers also make use of a variety of strategies to create positive learning environments for students even though they are teaching in an unfamiliar context.

3.2 Challenges faced by science teachers when teaching outside one's area of science specialism

3.2.1 Challenges encountered when planning lessons

Teachers encounter more uncertainties and struggles when planning lessons in their non-specialist area rather than when planning lessons in their area of expertise. As portrayed in Hashweh's (1987) study, subject specialists were more knowledgeable, held a wider and detailed knowledge about the topic being taught and were better able to link concepts to other disciplines. As a result they could create activities, if the textbooks did not provide any, or use different approaches to develop activities linked to their area of expertise. At times the subject specialists rejected the chapter outline and used modified or alternative activities that were more in line with their own conceptual scheme. This shows that teachers' own content knowledge and orientation to science teaching influences the planning and the organisation of subject content in preparation for teaching. Another study (Sanders et al., 1993) showed that when planning lessons within their subject area teachers could point out the important content students had to learn. Content was represented in a logical sequence and teachers had a better sense of time management in planning lessons. They were also more aware of the students' background knowledge and could predict potential problem areas.

Planning lessons outside area of expertise tends to be more laborious and time-consuming since teachers are not so familiar with the content and curricular knowledge. During lesson preparation teachers often realise that they have gaps in their understanding of content knowledge (McNicholl et al., 2013). Sanders et al. (1993) report that non-specialist teachers took more time to plan lessons and had difficulties in deciding the key concepts of a lesson. They were uncertain about the organisation of the unit, the linking of different content, the sequence of content and the duration of activities. In such circumstances teachers wrote down pages of notes, practiced procedures and worked out assignments before the lesson. Within the same study teachers tended to demonstrate more uncertainties and they frequently changed their plans when something was unsuccessful.

In their study Childs and McNicholl (2007) observe that outside their area of expertise, teachers did not have the necessary knowledge to make an informed choice to select the appropriate resources and activities from a multitude of resources provided in their schemes of work. In Hashweh's (1987) study non-specialist teachers closely followed the textbook to make up for their lack of content knowledge. This is also observed by Kind (2009a) whose research suggests that trainee teachers closely followed the scheme of work thus feeling secure that the core material was being covered. These trainee teachers consulted more resources to revise and relearn content, asked colleagues for help and conducted experiments before the lesson when preparing lessons outside specialism. The above studies show that planning lessons of unfamiliar topics is a more arduous and time-consuming task. The non-specialist teachers tend to be less creative and feel more secure sticking to the prescribed lesson plans and activities suggested in textbooks or schemes of work since they believe that they do not have enough content knowledge to develop their own plans and resources.

In studies by Childs and McNicholl (2007) and Kind (2009a), some teachers reported that it felt better to teach outside specialism, even though they faced a number of challenges. These teachers perceived that it was rather helpful to have limited SMK because they felt that they were more at par with the 'students' level.' They could understand how it felt to be learning science because they could understand and anticipate students' difficulties when teaching challenging concepts. An interesting observation reported by Kind (2009a) was that outside specialism trainees taught what they had learnt resulting in more focused lessons than within specialism.

3.2.2 Challenges encountered during teaching

Teachers find that teaching their non-specialist area can be challenging and demanding. Research (Childs & Mc Nicholl, 2007) shows that pedagogies used and the type of activities, examples and analogies tend to be limited. Classroom interaction tends to be restricted when considering the proportions of the teachers' versus students' talk. Teachers also face considerable difficulties in answering students' questions, in devising practical work and in identifying students' misconceptions. These difficulties, as explored below, can make teachers more apprehensive when teaching outside their science specialism.

3.2.2.1 Teaching styles and classroom interaction

Non-subject specialists tend to use a closed pedagogy, presenting the subject as a series of unrelated facts rather than focusing on conceptual understanding (RSC, 2014). Teachers tend to use authoritative and didactic approaches limiting students' talk and interaction by giving individual work and avoiding small group activities or class discussion. Sanders et al. (1993)

observed that teachers talk more and plan less risky activities. Teachers' questions tend to be closed and recall-based when teaching outside specialism whereas higher order questions that require application and synthesis of ideas are used in their area of expertise (Hashweh, 1987). Carlsen (1993) also notes that teachers talk for longer periods of time and ask low cognitive questions when teaching unfamiliar topics. On the contrary they ask higher order questions and give students more opportunities to speak when they are more knowledgeable about the topics being taught.

In a study with a non-science specialist Lee (1995) observes that lecturing methods were even used and the teacher maintained strict classroom order. For most of the time students were kept busy reading science content from the textbook and answering questions from an accompanying workbook whilst the teacher graded tests. No opportunities were provided for students to discuss and actively engage in learning science. Classroom interaction was restricted to avoid disclosing the teacher's knowledge uncertainties in science content and risk revealing her weak science teaching identity.

It appears that teaching approaches vary remarkably when teaching within or outside specialism. Sanders et al. (1993) confirm this by noting that lessons within specialism flow smoothly compared to lessons outside specialism where the latter are characterised by quick and frequent changes and at times both teachers and students end up confused. When teaching unfamiliar topics teachers are uncertain of some of the concepts, they look for exact words and precise definitions while at times consult the textbook for an answer. Within their area of expertise teachers talk less, involve students more and select riskier activities. These studies show that teachers' content knowledge affects the type of pedagogy used and the quality of classroom discourse; therefore there is an interconnection between the depth of teachers' content knowledge, classroom management and the selected teaching practices. These studies support the arguments made in the previous chapter that a teacher needs to have a good knowledge base in both SMK and PCK. Teachers with a limited SMK were more concerned and opted for traditional teaching strategies due to their poor self-efficacy beliefs. This implies that the perception of teaching capabilities seems to vary when teaching within or outside specialism.

3.2.2.2 Explanation of concepts and uses of analogies

Teachers with limited content knowledge can have a restricted repertoire of representations, explanations and analogies. Millar's (1988) work with non-specialist teachers teaching physics shows that teachers lack background knowledge, anecdotes or analogies that specialist teachers use to explain the subject. The non-specialists teachers are not as confident in expanding their explanations and feel uncertain about particular content even though they spend a longer time learning content. Likewise Childs and McNicholl (2007) report that teachers use limited activities, analogies and illustrations due to their lack of content knowledge, whereas those teachers with a sound and more sophisticated content knowledge come up with different ways of explaining concepts students are grappling with. This implies that subject specialists "are frequently more able to explain complex concepts effectively, answer detailed questions and teach beyond the textbook" (RSC, 2014, p. 4) since their PCK is flexible and further developed. Although trainee teachers would not have developed their PCK, Kind (2009a) observes that when trainee teachers noticed that their students did not understand a topic in their area of specialism they could explain concepts in different ways, but felt rather limited to do so when teaching outside specialism due to their poor knowledge background.

These situations imply that the possession of good and deep SMK affects the teachers' ability to create different representations, explanations and analogies to explain subject content, once again confirming that a sound background in content knowledge is a necessary foundation in the development of exemplary teaching practice as has been argued by Shulman (1987). As described previously, in the model of TPK&S (Gess-Newsome, 2015), content knowledge is one of five domains that make up the teachers' professional knowledge base and if this is lacking teachers encounter difficulties to transform content knowledge into adequate representations to help students learn science.

3.2.2.3 Answering students' questions

Another challenge faced by teachers when teaching their non-specialist area is answering students' questions. Teachers encounter these difficulties due to the lack of depth in content knowledge and confidence in that knowledge (Sanders et al., 1993). In many cases teachers could not answer students' questions and had to carry out research or seek help from colleagues to answer students' questions on the following day (Millar, 1988). Around a quarter of the trainee teachers in Kind's (2009a) study report that they became anxious and were not able to handle questions outside specialism.

In contrast, within their area of expertise teachers were more confident and could easily answer questions. They were able to further elaborate on students' ideas or questions and link these to new content (Sanders et al., 1993). Hence stark differences can be noted in the teachers' ability to handle questions within and outside specialism. This does not only depend on the level of SMK but also on the emotional reaction of the teacher. When teachers demonstrate anxiety to answer students' questions, students may doubt whether their teacher has an adequate knowledge base and this can impact the self-efficacy beliefs.

3.2.2.4 Practical work

Preparing and devising practical work is another area of concern for non-specialist teachers in different research studies (Childs & McNicholl, 2007; McNicholl, et al., 2013). These studies show that teachers do not know how to use practical work effectively to enhance student understanding. They also experience challenges in organising, setting and managing equipment and they lack the technical knowledge to use equipment safely and with skill. Teachers feel that doing laboratory work involves more pedagogical risks. Hence they become anxious when experiments fail to work properly and they have to explain unexpected results. In the SCORE's (2008) report about practical work, non-specialist teachers declare that they are confident to conduct practical work in their area of expertise but they lack the practical competence outside specialism. This is more common with teachers teaching the physical science subjects. Consequently, the report states that this lack of practical confidence would eventually "have a knock-on effect on reducing the number of pupils who enjoy these subjects, so reducing the pool of expertise further" (SCORE, 2008, p. 16).

In Volkmann and Anderson's (1998) study the teacher talks about the fear of conducting laboratory sessions, especially the fear of the unknown, when the outcomes of experiments are not predictable. Teachers may decide to do away with practical work since it requires more time to set up, conduct and take results (Harlen & Holroyd, 1997). It also puts more pressure on the teacher to explain what can go wrong. This sense of inadequacy causes dilemmas in their professional identity, as on the one hand teachers would like to make the teaching of a science subject understandable and fun and on the other hand they feel constrained by their lack of knowledge and examples of practical work that can be set up.

Their lack of experience and their personal history influences their competence in the science classroom.

3.2.2.5 Knowledge inaccuracies or misconceptions

Misconceptions in the different science domains are common among teachers and trainee teachers. Kind (2014) argues that trainee teachers with a Bachelor's degree in science may have weakness in understanding basic science concepts. They also have different levels of knowledge within the different science fields since they would not have studied all the science subjects at undergraduate level, for instance a teacher who is a biology specialist would not have studied chemistry or physics in the undergraduate course. Their understanding of these subjects is based on what they learned during their Advanced level classes or at secondary school. Indeed Kind (2014) found that many pre-service teachers had misconceptions in chemistry similar to 15-year-old students. Biologists had much weaker knowledge in chemistry topics than the physics and chemistry specialists. This can have serious consequences as in practice many biology specialists may have to teach chemical and physical concepts in the UK (Kind & Kind, 2011).

The teachers' knowledge inaccuracies or misconceptions in their non-specialist area can be passed on to their students and these misconceptions can perpetuate from one class to another. Teachers may not even be aware of particular students' misconceptions and fail to address them in the teaching process. Hashweh (1987) notes that misconceptions featured in the teachers' lesson plans. Moreover the non-specialists teachers failed to detect students' misconceptions and at times reinforced these incorrect ideas through using particular explanatory representations. On the other hand, within their area of expertise teachers dealt effectively with students' difficulties. They were more likely to uncover preconceptions and correct them. Passing on misconceptions or failing to identify them is a rather worrying situation. As Ball and McDiarmid (1989) contend:

> …when teachers possess inaccurate information or conceive knowledge in narrow ways, they may pass on these ideas to their students. They may fail to challenge students' misconceptions; they may use tests uncritically or may alter them inappropriately. Subtly teachers' conceptions of knowledge shape their practice – the kinds of questions they ask, the ideas they reinforce, the sort of tasks they assign (p. 2).

Besides encountering difficulties in dealing with misconceptions, Hashweh (1987) found that the less knowledgeable teachers in the area define scientific words in terms of the common sense meaning of the word, hence creating further knowledge inaccuracies. Identifying students' misconceptions is an important area in PCK and having an inadequate SMK limits one's ability to detect knowledge inaccuracies, thus these ideas can remain unchallenged and reinforced whilst teaching.

This section provided an overview of the challenges and issues that often arise in lessons outside specialism. Traditional teacher-centred approaches are more common and teachers feel less confident to teach particular areas. Childs and McNicholl (2007) contend that pedagogies used in teaching outside specialism are rather limited, dull and lack cognitive challenge. Lessons tend to be tightly controlled by the teacher with limited discussions and closed questions. Very often teachers follow the textbook more closely, use practical work in a limited way and emphasise rote learning (Carlsen, 1993; Sanders et al., 1993; Childs & McNicholl, 2007). Teachers struggle to make the subject interesting and lessons tend to be less inspiring.

The theoretical framework outlined in Chapter 2 forms the backdrop for, and is reflected in the different studies that confirm that teachers' knowledge base differs when teaching the various science disciplines. In view of this, teachers are often concerned that they possess a limited knowledge of the topic-specific professional knowledge leading to a restricted repertoire of teaching strategies, practical applications and curricular knowledge when teaching outside specialism (Hobbs, 2013a). This situation affects the teachers' self-efficacy beliefs. However teachers are also agents of their own development. Although they face a number of challenges, studies (Childs & McNicholl, 2007; Hobbs, 2013a; Kind, 2009a) show that teachers try to overcome the challenges by making use of different strategies to improve their practice as explained in the next section. This would eventually influence their self-efficacy and professional identity as they learn to teach the various science topics.

3.3 Overcoming challenges when teaching outside one's area of science specialism

Teachers often attempt to find ways to deal with teaching an unfamiliar area. When teachers switch from teaching their area of specialism to outside their field of expertise, they are 'crossing boundaries' where boundaries are defined "as the socio-cultural difference leading to discontinuity in action or interaction" (Akkerman & Bakker, 2011, p. 133). Between boundaries there is sameness and continuity as well as discontinuity. Boundary crossing involves a process where professionals move from a familiar field, in which they have the necessary knowledge and attitudes that inform their practice, to enter a new unfamiliar territory in which they feel unqualified due to insufficient content knowledge and ways of teaching the subject. Yet teachers can also experience continuity, as they use their pedagogical knowledge and knowledge of curriculum to organise their teaching in both areas. In crossing boundaries teachers can experience challenges or discontinuities in preparing and teaching a new subject because the new practices and perspectives required to teach the subject do not correspond with their own current practice. Akkerman and Bakker (2011) argue that learning does not only take place when one becomes an expert in a particular bounded domain but it also occurs when crossing boundaries as teachers learn to negotiate and combine components from different contexts to achieve hybrid situations.

Teachers deal with the challenges by making use of support mechanisms or 'boundary objects'. These 'boundary objects' can be "human or non-human and come in the form of artefacts (tools), discourses (as a common language), or processes that allow the co-ordination of actions" (Hobbs, 2013a, p. 287). Hobbs (2013b) argues that "boundary objects are central to professional identity development because they improve the likelihood of learning through the boundary crossing event" (p. 11). Boundary objects can help teachers experience boundary permeability when they learn to resolve their difficulties and feel more confident to teach outside specialism (Hobbs, 2013b).

A number of research studies (Childs & McNicholl, 2007; Harlen & Holroyd, 1997; Hobbs, 2012; 2013a; Kind, 2009a; McNicholl et al., 2013; Nixon & Luft, 2015) mention a range of strategies used to deal with the challenges and issues that arise when teaching unfamiliar topics. These include conducting research from books, Internet and other resources, consulting colleagues who are specialist in the area and repeated teaching experiences. Other teachers resort to use their knowledge from their area of specialism to understand and learn new content or stick to familiar practices to feel safe and secure. What is problematic and what needs to be further researched is whether these strategies are simple fix-it strategies that enable teachers to cope in the short term or whether these strategies support teachers in their learning, enabling them to expand their professional identity as science teachers.

3.3.1 Conducting research from books, Internet and other resources

Consulting textbooks and schemes of work when planning lessons is one of the common strategies used. The schemes of work in the English system provide a framework for the topics to be taught which include activities, practical work, examples of resources and teaching strategies. These resources are consulted more frequently when teachers are teaching outside specialism in order for them to enhance their SMK and PCK (Childs & McNicholl, 2007; McNicholl et al. 2013). Trainee teachers note that they use textbooks and the Internet as examples of sources for developing both content knowledge and teaching ideas or activities (Kind 2009a). In contrast Kind (2009a) notices that trainee teachers use fewer resources to prepare lessons within their area of specialism. When they do consult resources it is to gauge the students' level of knowledge rather than to revise the subject content.

3.3.2 Consultation with colleagues

Very often teachers seek support from colleagues to deal with difficulties arising in teaching unfamiliar areas. Childs and McNicholl (2007) report that support from colleagues, who are specialist in the area, is the most popular strategy used by teachers to address their weaknesses in SMK. Thus they learn both content knowledge and PCK from the colleagues in the workplace. In some cases experienced technicians are also consulted with regards to practical work (McNicholl et al., 2013). Science technicians can provide essential support to trainee and newly qualified teachers to familiarise themselves with school science practical work especially when non-specialist teaching has been increasing (Helliar & Harrison, 2011). Kind (2009a) also describes how trainee teachers seek the assistance and help of colleagues when planning their lessons outside their area of expertise.

Seeking advice from colleagues has manifold advantages: for instance, it facilitates the process for teachers to become part of a community of practice since this enables the transition from being a novice to acquiring further expertise. McNicholl et al. (2013) suggest that school subject departments are key places that can support and enhance teacher learning. Various interactions occur between teachers in team rooms or in places where teachers spend their time when not teaching. Within this safe community teachers ask their colleagues for assistance such as how to explain particular concepts and to suggest good teaching strategies. As argued by Hobbs (2013a), the knowledge, expertise and resources disseminated amongst colleagues help teachers build their content knowledge and develop strategies whilst gaining confidence and competence in teaching an unfamiliar subject.

When seeking support from colleagues PCK is developed as a result of social interaction. McNicholl and Childs (2010) argue that "PCK is the product of a social process" because teachers in their study often referred to PCK "as being shared, distributed and held across people, material artefacts and social settings" (p. 49). This is in line with the situated perspective of learning (Lave & Wenger, 1991). This shows that collegial support is necessary for boundary crossing. When teachers feel supported, they will be willing to be improve their practice, change their beliefs and expand their personal and professional teaching identity (Hobbs, 2013a).

3.3.3 Repeated teaching experiences

Repeated experience and success can increase confidence in teaching a subject area (Hobbs, 2013a). When teachers teach the same topics year after year, they become more knowledgeable about students' difficulties, questions and misconceptions because they develop curriculum knowledge, links and connections between and across different topics (McNicholl et al., 2013). Trainee teachers in another study (Finlayson, Lock, Soares, & Tebbutt, 1998) confirm that they would feel more confident if they had to teach the same topics again. As described by Hashweh (2005), teachers develop a repertoire of 'teacher pedagogical constructs' after repeatedly planning and teaching a topic, hence they improve their PCK with repeated learning experiences and gain further knowledge and confidence when teaching unfamiliar topics.

3.3.4 Using knowledge from the area of specialism

Teachers also tend to draw on ideas from their area of science specialism to understand the new content. In their study Nixon and Luft (2015) explain how teachers with a biology degree drew on ideas from biology when teaching chemical concepts. These teachers used their biology content, such as the process of osmosis and diffusion to explain the concept of chemical equilibrium. They also used their knowledge of crosscutting concepts across the science areas to connect topics and support their limited knowledge in chemistry.

3.3.5 Sticking to the familiar

Some teachers may find it more difficult to deal with the challenges arising when teaching outside specialism and use coping strategies to hide their uncertainties. For instance Harlen and Holroyd (1997) focus on the coping strategies used in science lessons by primary teachers, who are non-science specialists. Teachers were prescriptive and relied on worksheets where students followed step-by-step instructions and were kept busy and on task. In other situations, teachers tended to talk for most of the lesson, minimising students' talk and interaction mainly to avoid awkward questions. The lessons became very traditional, teacher-centred and there was very little attempt to include practical work or simple experiments as teachers feared that something could go wrong. In some cases teachers focused in more depth on the topics they felt more confident in and skimmed through topics that they felt less confident in. The main findings of Harlen and Holyrod's (1997) study suggest that when teaching outside specialism teachers tend to stick to familiar and traditional practices in order to hide their weaknesses and insecurities.

As described in the literature teachers can resort to using support mechanisms or boundary objects that enable them to cross boundaries when teaching their non-specialist area. Boundary objects, as Hobbs (2013a) argues, can be used as professional learning opportunities to improve the chance of a successful boundary crossing. They can provide opportunities for re-conceptualisation of practice and lead to the renegotiation of one's identity. What needs to be investigated further is whether using boundary objects would be sufficient to transform the teacher's identity, such as from being a specialist teacher to a generalist teacher. Transformations are generally slow processes because the teachers' beliefs and attitudes need to be addressed and confronted before claiming changes in teacher identity.

3.4 Developing an identity as a science teacher when teaching outside one's area of expertise

Teaching outside specialism affects one's professional identity in terms of how teachers engage with the subject and the way they see themselves in relation to the subject (Whannell & Hobbs, 2018). Whilst reviewing the literature I came across research about the identity development of primary science teachers (Avvramidou, 2014b) and for teachers teaching out-of-field (Hobbs, 2012; 2013a; 2013b; Whannell & Hobbs, 2018). The claims made by these researchers can apply to the current research because primary teachers and teachers teaching out-of-field share common characteristics with teachers teaching outside their science specialism. They all feel less confident to teach an area in which they are unqualified to do so due to their limited content knowledge and pedagogical expertise. Additionally these teachers very often do not tend to identify themselves with their non-specialist area.

As Hobbs (2013a) argues, when teachers use boundary objects to overcome the challenges arising from teaching an unfamiliar area they will be learning how to use their 'adaptive expertise', that is they apply their knowledge to deal with new situations. Adaptive expertise is critical not only to one's practice but also to one's professional identity since it "encompasses a range of cognitive, motivational and personality-related components as well as habits of mind and dispositions" (Hobbs, 2013a, p.288).

Hobbs (2013a) devised an adaptability scale for teachers teaching out-of-field as shown in Figure 3.1. In my view this scale can also be used with teachers teaching outside their science specialism. Hobbs (2012) speaks of two types of teacher commitment driving the teacher's practice; (1) the 'pedagogical perspective' where the teacher takes the responsibility of teaching students to help them learn, and (2) the 'personal perspective' where the teacher is committed and shows passion for the subject being taught. Studies (Childs & McNicholl, 2007; Kind, 2009a; McNicholl et al., 2013) show that committed teachers spend time preparing, finding resources and asking for help from their colleagues when they encounter difficulties in preparing and teaching outside specialism, hence these teachers are committed to their students' education from a pedagogical perspective.

just filling in	***making the most of it***	***pursuing an interest***
Teachers who are just filling in have a limited identity or no identity in relation to the subject due to negative experiences or a history of failure. They cannot relate to the subject, lack interest and can even lack knowledge of how to teach the subject.	These teachers tend to be committed to engage students in interesting contextualised learning experiences.	Teachers pursuing an interest have expanded their identity to being a teacher of the subject due to personal interest and high levels of self-efficacy stemming from positive interactions with the subject.

Figure 3.1: Adaptability scale devised by Hobbs (2013a, p. 291).

Hobbs (2013a) claims that the adaptability scale is dynamic and context-specific. Teachers can be placed on this adaptability scale according to their identity in relation to the subject. This will also depend on their level of commitment in terms of the pedagogical and personal imperative. Teachers who are willing to teach their non-specialist area and seek to improve their practice can be placed on the right-hand side of the adaptability scale and they are known to be 'pursuing an interest.' Teachers who are resistant to change and relate more to their subject specialism are placed on the left-hand side of the adaptability scale since they feel that they are 'just filling in' when teaching outside their area of expertise. Teachers can be seen to 'make the most of it' when their pedagogical commitment is stronger than their personal imperative.

The expansion of one's professional identity can occur through two important processes; by engaging in self-reflection and by being supported by colleagues. These will enable teachers to move forwards along the adaptability scale. Reflection is an important process whereby teachers can recollect their thoughts and practices to assess their worth and effectiveness. The process of reflection can shape the teachers' identity (Beauchamp & Thomas, 2009) because teachers get in touch with their sense of self and contemplate on how the self fits within the broader context involving others. In line with Gee (2000), Hobbs (2013a) notes that, "professional identity develops not just through participation but through interpretation or recognition of that participation by self or others" (pp. 291-292). Colleagues play a critical role in the development of one's identity. Acknowledging one's efforts when participating in discourse leads to building self-confidence and developing a more positive identity towards the subject.

This review of literature has shown that teaching outside one's area of science specialism presents various challenges during lesson preparation and delivery. As Hobbs (2013a) argues, crossing the boundary leads to a re-conceptualisation of practice and expansion of the teachers' identity. What is problematic and needs to be further researched is whether teachers change their identity or adapt their identity when teaching outside specialism. Teachers may even have a web of identities (Griffiths, 1995) where identities are constructed to suit the purpose of the individual but where they do not have control over the development of these identities as they are bound by circumstances. When Griffiths (1995) describes this web of identities she explains that the metaphor of the web:

> …can be thought of as fragments in a conglomeration, or as a unitary whole; though whether it is a whole, or which whole it is depends on the viewer as much as on its own constitution. (The web)… is intricate, entangled and interlaced, with each part connected to other parts (p. 2).

Teachers can experience different identities when teaching within and outside their science specialism. Hobbs (2013b) argues teachers experience a sense of a discontinuity in their identity when switching from teaching their subject specialism to teaching an unfamiliar area since they need to learn new subject knowledge and PCK. This can lead teachers to feel less comfortable and competent to teach across specialisations. The sense of identity needs to be problematised even further to find out whether science teachers view themselves as subject specialists or as generalist teachers or somewhere in between. The context and social interaction can change or adapt one's personal and professional identity; hence one needs to question how PD can shape the teachers' identity.

PD programmes can support teachers who teach outside their area of expertise by developing the teachers' professional knowledge base. Hobbs (2013a) argues that the way teachers perceive themselves as practitioners will reflect their willingness and ability to look out for PD programmes to improve their practice. The next chapter explores how PD programmes can be designed to support teachers teaching outside their science specialism by taking into account that teachers learn from a social and situative perspective.

Chapter 4

Continuing the learning journey: Overcoming the challenges through professional learning

4.1 Learning to teach is a lifelong process

Teachers learn all the time about teaching, thus learning about teaching is a lifelong process (Darling-Hammond & McLaughlin, 2011). Teachers learn through formal approaches when attending courses, workshops or conferences (Bullough, 2009; Postholm, 2012). They also learn informally for example from conversations and through sharing of knowledge and experience when interacting with other teachers in staff rooms, during departmental meetings or when meeting teachers outside school (Bransford, Brown & Cocking, 2000).

Teacher learning is a complex process, where according to Korthagen (2017) it involves the interaction of the cognitive, emotional and motivational dimensions. Learning is an active and constructive process that occurs both at an individual level and through social interaction. It is not a passive process of merely absorbing new information. Teachers learn by participating in the learning experience, hence it is influenced by the social and cultural contexts in which knowledge is acquired. In view of this teacher learning can be conceptualised as a "complex combination of the individual teacher's knowledge growth, the professional teacher practicing in a particular setting and the social teacher working collaboratively with others in that setting" (Simon & Campbell, 2012, p. 310).

Teachers keep on learning throughout their career by reflecting on their own practice, from social interaction with other teachers and from their interaction with their context. The need for ongoing professional learning is widely recognised as a means to enhance lifelong learning. Teachers generally undertake a number of PD courses with the aim of widening their professional knowledge base, developing their expertise whilst at the same time keeping abreast of the pedagogical trends and practices adopted within the educational system.

4.2 Professional development

There are various definitions of PD based on different perspectives. Starting with a broad definition, the Teaching and Learning International Survey (TALIS) states that "professional development is defined as activities that develop an individual's skills, knowledge, expertise and other characteristics as a teacher" (OECD, 2009, p. 49). On similar lines, Mitchell (2013) defines PD as the "process whereby an individual acquires or enhances the skills, knowledge and/or attitudes for improved practice" (p. 390). These definitions focus on the individual teacher acquiring skills, knowledge and new teaching methods with the aim of developing professional competency. They are based on cognitive models of learning and suggest that when teachers acquire new knowledge and skills in one setting they will transfer these skills and knowledge in the classroom (Kelly, 2006).

Other definitions of PD emphasise the social aspects of learning and focus on classroom practice. In the process teachers interact, examine their own classroom experiences and use each other as sounding boards to enhance students' learning. Day (1999) defines PD as follows:

> Professional development consists of all natural learning experiences and those conscious and planned activities which are intended to be of direct or indirect benefit to the individual, group or school and which contribute, through these, to the quality of education in the classroom. It is the process by which, alone and with others, teachers review, renew and extend their commitment as change agents to the moral purposes of teaching and by which they acquire and develop critically the knowledge, skills and emotional intelligence essential to good professional thinking, planning and practice with children, young people and colleagues through each phase of their teaching lives (p. 4).

The focus here is engaging in collaborative practice and becoming active learners where teachers observe, assess, reflect on teaching episodes and relate their prior knowledge to new experiences using the constructivist approach to learning. Effective PD entails a long-term process where teachers learn together over time by discussing issues and concerns within their teaching contexts (Luneta, 2012; Villegas-Reimers, 2003).

4.3 Professional development of teachers in Malta

Within the Maltese context PD refers to the "ongoing learning opportunities that all educators pursue in order to grow personally and collectively" (Bezzina & Camilleri, 2001, p. 158). There are two types of ongoing PD for teachers in Malta post completion of teachers' pre-service education (Bezzina 2002). Teachers can engage in 'professional education' by undertaking a postgraduate course either at diploma level or a Master's Degree at the University of Malta or at other foreign higher education institutions. Teachers can also undergo 'professional training' that aims to develop the teacher's knowledge and skills in particular areas related to their work.

4.3.1 In-service education and training courses

In-service Education and Training (INSET) courses were the most common form of PD in Malta, offered to all state and non-state school teachers from 1987 till 2018. The INSET was a three half-day course held either in July or in September, meaning either at the end or at the beginning of the scholastic year. They were generally one-shot courses without follow up sessions. Teachers in state schools were called to attend a compulsory course by their subject education officer. Teachers from non-state schools could attend any of the available courses on a voluntary basis. During the INSET days schools and colleges had the possibility of organising their own 'school-based' PD sessions to address the teachers' needs in their own particular context. INSET courses were attended by most teachers since the previous collective agreement signed between the Government authorities and the Malta Union of Teachers (MUT) stipulated that teachers had to attend an INSET course on a regular basis (Malta Union of Teachers, 2011). According to the latest agreement signed between the Government authorities and MUT, the INSET courses have been replaced by professional learning opportunities that are to be carried out during the scholastic year (Ministry of Education and Employment, 2017).

PD practices are shaped by the particular context of the educational system and are a product of the political, economic, social, cultural, historical, technical and professional aspects of the system (Bolam & McMahon, 2004). Malta, being a small state, has particular contextual factors such as the demographic scale, the isolation, the limited financial resources, human resources and their multiple roles, political factors and changes in population. All these influence the operation and management of the local education system (Farrugia, 1987).

Reform policies or restructuring changes have generally determined the INSET agenda and these courses were frequently used to introduce reforms in curriculum design, innovative pedagogical strategies or new resources (Azzopardi, 2014).

4.3.1.1 Traditional models of professional development

Kennedy (2005) describes nine models of PD where four of these are considered as traditional models. These include the 'training model', the 'award-bearing model', the 'deficit model' and the 'cascade model.' Locally the INSET courses generally had a training-focused perspective (Attard Tonna & Shanks, 2017). They were mainly designed on the 'training model' of PD (Kennedy, 2005) where the main focus was on the technical aspects of teaching which enforces the transmission of knowledge by promoting 'additive learning' (Thompson & Zueli, 1999). Teachers were expected to update their knowledge and skills by attending one-off sessions that were generally delivered by an external expert and away from the classroom, outside school hours. After the sessions teachers were expected to embrace and enact changes when they returned to their classes.

The 'training model' has often been criticised because short-term or one-off sessions are often fragmented (Borko, Jacobs & Koellner, 2010) and they are deemed to be ineffective due to a lack of personal connection and value (Bullough, 2009). Simon and Campbell (2012) argue that it is unlikely that these models will lead to changes in pedagogy due to their lack of connection with classroom practice and practical applications. Camburn (2010) further criticises these programmes because teachers are not provided with opportunities to try out activities, to reflect and to evaluate the new practices to make them their own. Generally teachers adopt a passive role and are given information and resources from an external presenter considered as the 'expert'. At times teachers have reported that they get overwhelmed with the amount of knowledge disseminated in the sessions since the main focus is on "adding new skills and knowledge without helping teachers to rethink and discard or transform thinking and beliefs" (Loucks-Horsley, Stiles, Mundry, Love & Hewson, 2010, p.70). Moreover there are no follow-up workshops where teachers can meet to discuss their experiences in implementing classroom changes. The content of the programme is predetermined mainly by the requirements of the educational policy of the day rather than on the personal needs of the teacher (Bishop & Denley, 2007; Smith, 2017). Indeed traditional models of PD do not take into consideration how teachers learn (Borko, 2004), thereby neglecting the social aspects of learning and the relation to classroom practice. Hence such courses generally fail to address the required needs of the teachers (Attard Tonna, Murphy & de Paor, 2018). Even locally the INSET has been widely criticised being a short-term course without follow-up support (Brincat, 2014). As Bezzina, Bezzina and Stanyer (2004) argue, the INSET courses often failed to actively involve teachers or take their needs into consideration, thus very often changes were not implemented in the educational system.

4.3.2 Other examples of professional development courses in Malta

In recent years, other forms of PD courses were carried out in a number of secondary schools in Malta. One example was the PRIMAS (Promoting Inquiry in Mathematics and Science) project whose aim was to support mathematics and science teachers to include inquiry-based learning strategies in their teaching contexts (Maaß & Doorman, 2013). In her study Brincat (2014) investigated the experience of a group of Maltese science teachers who participated in this two-year project. The PD sessions took place in a number of state schools and were led by a facilitator, where facilitators or multipliers were trained by a project team from the University of Malta. During the meetings facilitators used the resources developed for this project to help teachers use inquiry-based tasks. Teachers implemented such tasks and discussed their classroom experiences during the ongoing meetings. They also reflected on their lessons by writing journal entries.

Brincat (2014) observed that the teachers in her study found it more beneficial and effective to participate in an ongoing long-term professional learning opportunity because it provided the necessary support to familiarise themselves with and learn how to use inquiry-based learning in their classrooms. Without follow-up support teachers argued that they could have easily reverted to traditional practices. Teachers formed a learning community where they discussed, shared their ideas, difficulties, experiences and reflections. They appreciated that they learnt about various aspects of inquiry-based learning and that they gained a number of creative ideas and resources. Teachers recognised the importance of having knowledgeable leader who acted as a guide, provided constructive feedback, and encouraged and inspired them to try out different activities. In this PD experience teachers were given a voice and a more active role in their professional learning journey.

Professional learning experiences, such as the PRIMAS project, actively involve teachers in their learning since it takes into account the teachers' thinking and practices. It also emphasises the development of professional learning communities. Long-term PD is necessary for teachers to start implementing changes in their classroom because change involves questioning and reviewing of one's beliefs and practices. PD courses should not aim to increase competence and accountability but they should encourage teachers to assume professional responsibility for their own learning and development. This form of support is provided through transformative models of PD (Kennedy, 2005).

4.3.2.1 Transformative models of professional development

PD programmes need to be aligned with changes taking place in teaching and learning theories by fostering cross-disciplinary and collaborative approaches to learning. Eurydice (2015) recommends the uptake of more flexible approaches to PD by using "adult learning methods based on communities of practice, online learning and peer learning" (p. 55). From the nine models of PD, Kennedy (2005) gives other examples of PD models labelled as transitional or transformative as shown in Table 4.1.

Table 4.1: Spectrum of the continuous professional development models (Kennedy, 2005, p. 248)

Models of Continuous Professional Development	Purpose of model	
The training model The award-bearing model The deficit model The cascade model	Transmission	Increasing capacity for professional autonomy (↓)
The standards-based model The coaching/mentoring model The community of practice model	Transitional	
The action research model The transformative model	Transformative	

The 'transformative model' is a combination of a number of processes and conditions drawn from the other models outlined in Table 4.1. The combinations of these models need to support a transformative agenda and facilitate transformative practice. By using transformative models of PD teachers are given more autonomy in their learning and it reduces the position of power taken up by external experts in traditional models of PD.

The PRIMAS PD programme was built by using a combination of some of the models proposed by Kennedy (2005). This form of PD is more in line with the "transformative models, without denying that some transmission might be needed in the initial stages of the programme and that transitional models could be considered useful until teachers' confidence, beliefs and knowledge have grown enough" (PRIMAS, 2011, p. 39). Communities of practice nurtured in schools resulted in sites for creating new knowledge and transformative practices as teachers discussed, reflected on and exchanged their experiences after field testing their lessons. The PRIMAS model involved transformative learning rather than additive learning because teachers were engaged in rethinking and transforming their beliefs and practices as they learnt to adopt inquiry-based practices.

This section has reviewed two main types of PD in Malta that is the INSET and the PRIMAS project. What needs to be investigated further is how particular features of transformative models of PD can be utilised to develop a PD programme for non-specialist teachers to enable them to learn at the boundary and feel more confident to teach across specialisations.

4.4 Professional development that supports professional learning

The ultimate aim of PD is to bring about change in teachers' practices to address the students' learning goals and improve their achievement (Birman, Desimone, Porter & Garet, 2000; Guskey, 2002; Loucks-Horsely et al., 2010). PD is required to ensure that teachers have the necessary professional knowledge, skills and competence in teaching their subjects (Desimone, Porter, Garet, Yoon & Birman, 2002). In this case PD is viewed as a form of 'training' that is provided for teachers to acquire a set of predefined skills and knowledge that can be transferred to the classroom. Indeed Woolhouse and Cochrane (2009) argue that PD courses tend to be designed to develop the individual competences and skills in order to meet the needs of the economy and the country's policies, thus adopting a utilitarian paradigm.

Other researchers view PD as "teachers' learning, learning how to learn and transforming their knowledge into practice for the benefit of students' growth" (Avalos, 2011, p. 10). Stoll, Harris and Hansdcomb (2012) argue that "effective professional development is the process of professional learning" (p. 2). Here it is important to question whether PD and professional learning have the same meaning. For instance Fraser, Kennedy, Reid and McKinney (2007) distinguish between teacher professional learning and PD. According to their definition "teachers' professional learning can be taken to represent the processes, whether intuitive or deliberate, individual or social, that result in specific change in the professional knowledge, skills, attitudes, beliefs or actions of teachers " (Fraser et al., 2007, p. 157). On the other hand teacher PD refers to "broader changes that may take place over a longer period of time resulting in qualitative shifts in aspects of teachers' professionalism" (Fraser et al., 2007, p. 157).

Due to such divergent views, research about PD has been interrogated over time (Easton, 2008; Fullan, 2007; Smith, 2017; Webster-Wright, 2009). The main point of contention is whether PD truly supports and nurtures effective teacher professional learning. Smith (2017) contests this by presenting three important aspects about PD vis-à-vis meaningful teacher learning. These include the purpose of PD, the ownership of expert knowledge in teacher education and the role of the teacher in the learning process.

Primarily the provision of PD has often been associated with increasing teacher's competences to improve students' outcomes (Loucks-Horsley et al., 2010). As a result PD has been turned into a series of events that concentrate on the delivery of content and on developing new pedagogical strategies about particular curricular aspects. In view of this Smith (2017) argues that the complex nature of teacher learning has been reduced to a linear process, where the product of teacher learning is the means of improving teaching actions and student learning. Such a view is too simplistic and even problematic because changes in teacher practice do not arise from teachers merely attending PD programmes which are often decontextualized and do not take into account how teachers learn.

Secondly in PD courses the teachers' professional knowledge of practice is often ignored and not taken into consideration even though it is a valuable component of professional expertise. Teachers are generally given information from outside experts who seem to know what is important for teachers to learn (Smith, 2017), hence PD is very often associated with the transmission model of teaching in which knowledge is transferred and delivered from more knowledgeable others (Easton, 2008). When outside expertise is given more weight, it limits the process of teacher learning because from this perspective teachers are perceived to be 'knowledge-deficient professionals' (Webster-Wright, 2009) in need of updating and upskilling. Yet the transmission of this professional knowledge does not lead to changes in classroom practice (Fullan, 2007).

Thirdly the role of the teacher within the PD experience is crucial. Very often teachers are rendered as passive recipients. They are often disempowered because they are not given an active role in their learning process and their extensive contextual knowledge is often not recognised. PD that views learning as a dissemination exercise considers teachers as objects that need change and improvement. Throughout their career teachers are constantly constructing and developing their own professional knowledge base, as described in Chapter 2. Given the opportunity and appropriate circumstances teachers can generate professional knowledge through social interaction that will enable them to improve their practice. Teachers have the capacity to become active decision-makers about personal learning and actions. Such views place teachers and their context as central to their learning experience and this comprises the notion of professional learning (Smith, 2017).

On examining the concept of PD it has been found to have a number of limitations (Easton, 2008; Fullan, 2007; Webster-Wright, 2009) because it limits the view of teacher learning (Smith, 2017). Within this perspective, I tend to concur with Easton (2008) who claims that:

> … educators need to learn and that is why *professional learning* has replaced *professional development*. Developing is not enough. Educators must be knowledgeable and wise. They must know enough in order to change. They must change in order to get different results. They must become learners (p. 756).

In view of the above, a number of educators are advocating for a paradigm shift: moving from PD to professional learning that is from content delivery to ways of supporting teachers' learning. Based on the previous arguments, in this research study I chose to develop a PD programme that focuses on the concept of professional learning, where teachers are actively engaged in thinking, discussing, sharing and reflecting on their beliefs and practices in a supportive and collaborative setting. Teachers learn from implementing changes in their lessons when they are supported by colleagues. As suggested by Smith (2017) teachers will not only take an active role in their learning process but will be empowered to set their own personal and professional learning goals. In the process they negotiate and socially construct knowledge that is meaningful in their own context.

4.5 Designing professional learning opportunities

In designing professional learning opportunities it is important to give the proper attention to the process of teacher learning. The literature on this topic presents a number of important aspects that enhance teaching learning (Attard Tonna & Shanks, 2017; Postholm, 2012). From the socio-cultural perspective, learning is perceived as the construction of knowledge and understanding conducted through social interaction in a particular context (Postholm, 2012). The social context is a crucial aspect of learning and development as discussed in Chapter 2. Dunne (2002) recommends that professional learning is most relevant for teachers when it is "focused on teachers' real work, provides teachers with opportunities to make choices about their own learning, happens over time, and contributes to building a professional culture of collaborative learning" (p. 67). When teachers feel more involved in their learning they can affirm their strengths and become empowered to take further challenges and responsibility thereby increasing their self-efficacy (see Hawley & Valli, 1999). This will also influence how they view themselves as science teachers.

Drawing on ideas about teacher learning and on research carried out on PD and professional learning (Borko et al., 2010; Darling-Hammond & McLaughlin, 2011; Darling-Hammond & Richardson, 2009; Desimone, 2009; Garet, Porter, Desimone, Birman & Yoon, 2001; Gilbert, 2010; Guskey, 2003; Hawley & Valli, 1999; Loucks-Horsley, Stiles & Hewson, 1996; Loucks-Horsley et al., 2010; Postholm, 2012) the characteristics of effective PD that result in professional learning include:

- Providing teachers with opportunities to develop their content knowledge and PCK.
- Providing opportunities for teachers to critically reflect on practice to construct new knowledge, beliefs on their subject content, pedagogy and learners.
- Focussing on the context and include learning opportunities that are relevant to classroom practice.
- Including learning-centred professional learning experiences by using active learning strategies that foster inquiry, discussion, experimentation, problem-solving, collaboration and reflection.
- Developing a metacognitive attitude by which teachers become aware of their own practices. By processing one's experiences with the help of others, teachers can learn to develop new and deeper knowledge about their classroom interactions and practices.
- Encouraging the building of a culture of collaboration by promoting collegial interaction and relationships within a team of teachers in a community of learners.
- Providing long-term professional learning opportunities such that teachers have enough time to put their ideas into practice, reflect on the outcomes that can eventually transform their beliefs.

In other words, effective professional learning needs to be "intensive, ongoing and connected to practice" (Darling-Hammond, Wei, Andree, Richardson & Orphanos, 2009, p. 9). It also needs to be built within a collaborative approach by using active learning strategies that are anchored in context. Teachers become sources of knowledge for each other when "knowledge is constructed by and with practitioners for their use of their own context" (Darling-Hammond et al., 2011, p. 82) rather than being acquired from external agents as in traditional models of PD. The above characteristics, outlined in literature about teacher learning, provide the necessary foundations to design a professional learning framework to support teachers teaching outside their science specialism.

4.6 Professional learning framework for teachers teaching outside their science specialism

Part of my research involved the design of a PD programme for non-chemistry specialist teachers. I looked at the literature to develop my own theoretical perspective and tease out the principles that would guide the design of the programme. The readings that were most influential in the development of this framework emerged from the literature on teachers' professional knowledge (see Chapter 2) and aspects of professional learning that are discussed in this chapter. From the readings I only managed to find very few studies related to a PD programme for non-specialist teachers (Campbell, 2011; De Winter, 2011; Inglis, Mallaburn, Tynan, Clays & Jones, 2013; Jones, Harland, Mitchell, Springate & Straw, 2008; Mamlok-Naaman, Eilks, Bodner and Hofstein, 2018; Woolhouse & Cochrane, 2009; 2010). Woolhouse and Cochrane (2009, 2010) discuss the teachers' experiences of a PD programme known as 'Science Additional Specialism Programme' (SASP) in the UK that was aimed at science teachers who were teaching chemistry or physics but they had no qualification in the subject. This was a year-long course and focused on three aspects: enhancing the subject knowledge and subject-specific pedagogy, forming part of a supportive community and engaging in self-reflection about their own practices and PD. The experiences of this programme made teachers rethink and rewrite their own stories whilst developing their professional self.

The framework for the PD programme for non-specialist chemistry teachers devised for this study is based on the following critical features:

- It enhances the teachers' professional knowledge (drawing on Shulman, 1986; Gess-Newsome, 2015);

- It takes into account the affective-motivational facet, that is professional beliefs of the teachers (drawing on Pajares, 1992); and

- Learning is grounded in context that is in classroom practice and developed through social interaction through the formation of a community of learners (drawing on Greeno, 1997; Lave & Wenger, 1991).

Figure 4.1 shows the framework of this PD programme that leads to professional learning. The aim of this framework is to expand the teachers' knowledge base, to gain confidence in teaching outside their science specialism and to be able to cross boundaries. Using theory of boundary crossing (Akkerman & Bakker, 2011) the PD programme aims to enable teachers to learn as they interact with each other, reflect and support each other to overcome the discontinuities or challenges that arise in their context.

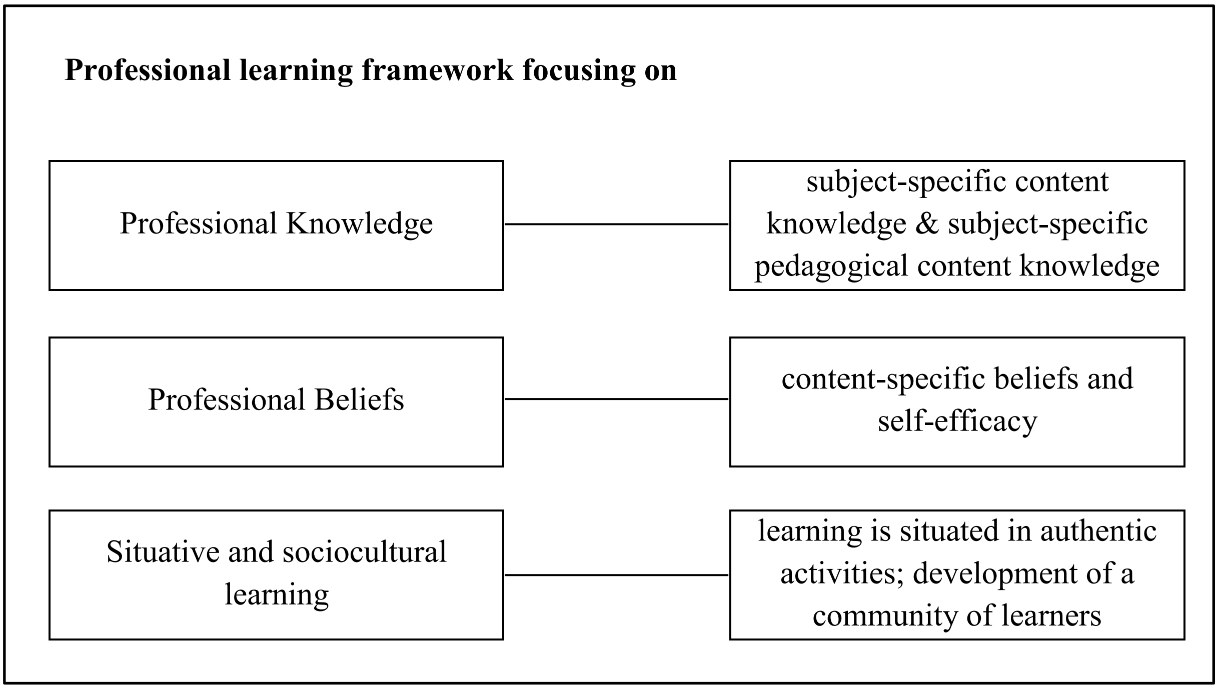

Figure 4.1: Professional learning framework for teachers teaching outside their science specialism

4.6.1 Professional learning focusing on professional knowledge

The teachers' knowledge base is one of the main aspects that need to be addressed in the PD programme (Desimone, 2009; Garet et al., 2001; Guskey, 2003; Loucks-Horsley et al., 1996; Loucks-Horsley et al., 2010). As explained in Chapter 2, both SMK and PCK are fundamental components of the teachers' knowledge base. From the literature in Chapter 3, it is evident that teachers encounter challenges when teaching their non-specialist area because they have gaps in their subject-specific content knowledge and insufficient curricular knowledge. In the studies reviewed teachers had limited ways of representing the subject matter, a restricted repertoire of explanations, analogies and stories that could be used to transform content into meaningful learning, implying that teachers had not yet developed subject-specific PCK in their non-specialist area.

It is important to enrich the teachers' SMK by deepening teachers' content knowledge and enhancing conceptual understanding. Teachers' PCK can be improved when they are empowered to develop instructional practices (Borko, 2004) that challenge students' misconceptions and assist them in their learning (Loucks-Horsley et al., 1996; Loucks-Horsley et al., 2010) and when they learn to use particular curricular materials or innovative teaching strategies (Gareth et al., 2001).

Gaining professional knowledge is not enough unless teachers are given the opportunity to reflect on their own learning and practice. Teachers need to be encouraged "to think about how they feel about their teaching in tandem with developing subject knowledge and pedagogy" (Woolhouse & Cochrane, 2009, p. 167). Sharing insights and reflections with other teachers can promote deeper reflection which can impact one's thoughts and practices. Like Woolhouse and Cochrane (2010), I would argue that critical reflection on practice can induce changes in one's self-perception.

4.6.2 Professional learning focusing on teachers' beliefs

Teachers' beliefs related to teaching their non-specialist area need to be addressed because they highly influence the way they approach the teaching of an unfamiliar subject. Teachers can show lack of motivation and enthusiasm when teaching their non-specialist area (Hobbs 2013a). As discussed in Chapter 2, teachers' beliefs are formed over time and they influence the professional judgments made about one's actions and decisions. Hence it is important for teachers to critically examine their own existing beliefs before they develop new ideas about science teaching and learning (Bryce, Wilmes & Bellino, 2016). Darling-Hammond and McLaughlin (2011) recommend teachers to be provided with opportunities to critically reflect on practice and to construct new knowledge and beliefs on their subject content, pedagogy and learners. Hence I would argue that teachers must be involved "both as learners and as teachers" and they need to face the "uncertainties that accompany each role" (Darling-Hammond & McLaughlin, 2011, p. 82). These uncertainties challenge the teachers' core beliefs.

Teachers tend to welcome new ideas and activities disseminated in PD programmes, but they often pick and choose such materials and techniques and incorporate them into their practice (Thompson & Zeuli, 1999). In this case the teacher's personal beliefs act as filters between knowledge and practice by leading them to select or reject knowledge which is consistent or inconsistent with one's personal beliefs, as presented in the model of TPK&S (Gess-Newsome, 2015) in section 2.2.4. However professional learning goes beyond gathering new teaching techniques. Wilson and Berne (1999) argue that teachers may not be aware that they need to change their views of knowledge, subject matter or students. In line with these researchers, I think that teachers need to be provided with time and space to articulate and clarify their beliefs about their teaching. It may become necessary to challenge the exposed deeply held beliefs about knowledge and typical practice. Thompson and Zueli (1999) recommend that professional learning experiences should create a sufficient amount of dissonance to challenge one's beliefs, knowledge and experiences to nurture conceptual change.

While as recommended by Bezzina (2002), it is useful for PD programmes to start from teachers' needs and interests, it is also important to challenge teachers' existing beliefs and personal practical knowledge. This can be very difficult since teachers very often feel that their practice has evolved through years of experience and that it is adequate to guide their decisions and experiences. A change in beliefs can lead to reconceptualisation of practice and an expansion in the teachers' professional identity thus enabling them to cross the boundary and feel more comfortable to teach an unfamiliar area.

4.6.3 Professional learning focusing on situated and socio-cultural learning

Darling-Hammond et al. (2009) argue that "the content of professional learning matters as much as the process by which it is transmitted" (p. 12). The delivery of the professional learning experiences needs to take into account how teachers learn. As Darling-Hammond and McLaughlin (2011) explain:

> Teachers learn by doing, reading, and reflecting (just as students do); by collaborating with other teachers, by looking closely at students and their work; and by sharing what they see. This kind of learning enables teachers to make the leap from theory to accomplished practice. In addition to a powerful base of theoretical knowledge, such learning requires settings that support teacher inquiry and collaboration and strategies grounded in teachers' questions and concerns. To understand deeply, teachers must learn about, see, and experience successful learning-centred and learner-centred teaching practices (p. 83).

This framework is based on the situated and socio-cultural learning theory. From the situative perspective learning occurs when one participates in the practice of teaching thus becoming more knowledgeable about teaching (Borko, 2004). Classrooms become powerful contexts for teacher learning (see Borko, 2004), thus teacher learning is grounded in their teaching practice (Putnam & Borko, 2000). Teachers are encouraged to engage with concrete tasks by being immersed into practices such as doing science, conducting investigations and inquiry activities and at the same time targeting the teaching and learning of specific content (Loucks-Horsley et. al., 1996; 2010). When teachers conduct the same learning activities as their students they came across potential questions or difficulties that students are likely to encounter and gain a better understanding to tackle these issues (Rogers et al., 2007). Teachers can experience these tasks as learners and make a better connection between their learning and classroom teaching (Borko et al., 2010.) From this perspective learning to teach becomes very much "intertwined with ongoing practice" (Putnam & Borko, 2000, p. 6).

This framework emphasises the sociocultural perspective of learning where knowledge about teaching is distributed amongst teachers and that learning occurs within social contexts via interaction with others, such as through the development of a community of learners rather than on an individual basis. It is important to break down barriers of teachers working in isolation and encourage them to work in collaboration and share effective practice. Professional learning experiences based on current sociocultural theories of learning aim to develop collaborative working cultures where teachers "work together, reflect on their practices, exchange ideas and share strategies" (Guskey, 2003, p.749). Professional learning can be developed through the setting up of communities of learners that enable teachers to sustain professional learning.

4.6.3.1 Teacher learning communities

Professional learning can be organised by setting up learning communities that bring teachers together to enable them to explore challenges, issues and share knowledge of practice. Over the recent years a number of terms have been used with reference to a group of teachers working together such as 'communities of practice' (Wenger, 1998), 'professional learning communities' (Stoll, Bolam, McMahon, Wallace & Thomas, 2006) and 'teacher learning communities' (Skerrett, 2010). They have common features such as developing a collaborative culture that enhances learning, discussion, sharing of their experiences and negotiating new meanings of knowledge situated in practice (see Vescio, Ross & Adams, 2008).

Wenger, McDermot and Snyder (2002) define 'communities of practice' as "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (p. 4). They describe three important characteristics that distinguish community of practice from other groups and communities which include: (1) a *domain* of knowledge that brings people together to guide their learning and provide meaning for their actions; (2) a *community* of people who engage in joint activities, discussions, share information, ask about their difficulties and assist each other in pursuing their interest in the domain and (3) a shared *practice* is developed through a collection of resources, tools, experiences, stories and methods of tackling recurrent problems (Wenger et al., 2002; Wenger & Wenger-Trayner, 2015).

The goal of a 'professional learning community' (PLC) is that teachers actively commit themselves to a common vision in analysing and reflecting on their professional practice such that it can lead to improve teaching practice and students' learning and achievement (Vescio et al., 2008). PLCs have five essential characteristics which include having shared values and vision, collective responsibility for student learning, reflective professional inquiry, collaboration and promoting group and individual learning (Stoll et al., 2006). PLCs are generally implemented within a school with the aim of "improving student learning by improving teaching practice" (Vescio et al., 2008, p. 82). Teachers often use samples of students' work and test scores and discuss together how students can enhance their achievement. Teachers work collaboratively to identify goals for improvement and develop strategies to improve their teaching practices (Hord, 2009). The main focus of a PLC is for teachers to "work together and engage in continual dialogue to examine their practice and student performance and to develop and implement more effective instructional practices" (Darling-Hammond & Richardson, 2009, p. 49). This is more in line with learning agendas that tend to focus on teachers' accountability and standardisation of instruction to improve students' learning outcomes.

On the other hand Skerrett (2010) opts to use the notion of 'teacher learning communities'. She argues that although communities of practice initially develop around shared practices, they do not automatically transform into learning communities unless they foster learning as a result of members' interaction. Teachers within a subject department can be referred to as a community of practice; however they can still work in isolation from each other especially if they do not dedicate time to design and discuss instructional and assessment strategies. Therefore it would be more appropriate to look into teacher learning communities that emphasise the notion of teacher learning (see NCTE, 2010). In teacher learning communities, teachers can bring issues and concerns that arise from classroom practice, identify common goals and develop ways of addressing them, thereby connecting pedagogical practice with content knowledge. This interaction leads to teacher learning and eventually encourages transformative teaching. Teacher learning communities encourage all participants, irrespective of years of teaching experience, to become contributors for learning within the group by encouraging collaborative culture (NCTE, 2010). Since a learning community is characterised by collaboration, collegial interaction and reflection on practice, learning communities can be defined as "those that continuously inquire into their practice, and, as a result, discover, create and negotiate new meanings that improve their practice" (Skerrett, 2010, p. 648).

In this thesis, I will use the term community of learners because one of the aims of the PD programme was to nurture a community of learners such that teachers can inquire about their practice, reflect individually and collectively and decide on the course of action about common challenges and problems encountered. Teachers bring to the learning community their own knowledge about their pedagogical practices, cultural and instructional contexts of their classrooms. Hence knowledge and skills are no longer considered to be the property of an individual member but are distributed among the members. As Putnam and Borko (2000) suggest:

> the notion of "distributed cognition" suggests that when diverse groups of teachers with different types of knowledge and expertise come together in discourse communities, community members can draw upon and incorporate each other's expertise to create rich conversations and new insights into teaching and learning (p. 8).

Participating in a community of learners can help break down barriers of isolation and foster a collegial approach to learning. Peer support can empower the teachers to deal with challenges associated with classroom practice (Woolhouse & Cochrane, 2009) and enable them to review their beliefs about teaching their non-specialist area and expand their professional identity.

4.7 Identifying the gap in literature

Following the review of literature, I have identified a number of gaps in the research that this study aims to address in the field of teaching outside specialism and professional learning.

When I embarked on this research study I was interested in exploring the experiences faced by science teachers teaching their non-specialist area. As I reviewed the literature, I found that teaching outside specialism is a common phenomenon in many countries and international literature has shown that many teachers experience a number of difficulties when teaching outside specialism (see Chapter 3). However there is a lack of research within the local context, particularly when science teachers are expected to teach both within and outside their science specialism when teaching integrated science in the first two years of secondary school. Gatt (2011) carried out a research study with science teachers in local secondary schools and found that they lack confidence to teach their non-specialist subjects. Nevertheless, no in-depth research has been carried out in this area. I was also interested in looking at chemistry since in Malta only around a quarter of science teachers have a degree qualification in chemistry (see Chapter 1), thus the majority of the science teachers are non-chemistry specialists. This implies that further research needs to be carried out within the local context to identify the challenges that non-chemistry specialists experience when teaching chemistry topics as part of the science syllabus. In fact, the first research question tries to address this gap in the literature by outlining the challenges that Maltese science teachers, who are non-chemistry specialists, encounter when teaching chemistry units as part of the integrated science curriculum.

As I continued to read the literature in order to understand how teachers approach the teaching of their non-specialist area, I began to realise the teachers' professional knowledge base influences the way teachers teach the different science disciplines whether they are teaching within or outside specialism. I used the literature related to teachers' professional base to develop a theoretical framework that guided this study. This theoretical framework suggests the teachers' knowledge base is affected by four main factors, that is the cognitive, affective, social and contextual factors. It has been found that challenges arising when teaching outside specialism depend on the teachers' knowledge base (Childs & McNicholl, 2007; Kind 2009a). Furthermore the challenges can also impact the teachers' identity, where this has been identified in the literature related to teaching out-of-field (Hobbs, 2013a; 2013b). However, there does not seem to be much research that tries to connect the aspects of teacher professional knowledge and teacher identity. This implies that further research needs to be carried out to find out how science teachers construct their knowledge base and negotiate their teaching identity as generalist science teachers. To address this gap in the literature, and answer my second research question it would be important to explore how science teachers, who are non-chemistry teachers, deal with the challenges when teaching chemistry units and to consider the implications on their professional knowledge base and teaching identity.

In this study I did not only want to explore the experiences of teachers and how they dealt with the challenges of teaching across specialisations. I was also interested in exploring how teachers could be supported in their professional learning. Various literature has been written about PD (see Chapter 4). However literature related to PD programmes designed for non-specialist chemistry teachers is rather scarce. A number of studies (Campbell, 2011; De Winter, 2011; Inglis, Mallaburn, Tynan, Clays & Jones, 2013; Jones et al., 2008; Mamlok-Naaman et al., 2018; Woolhouse & Cochrane, 2009; 2010) focus on the PD of non-science specialists. Only three of these research studies address the needs of non-specialist chemistry teachers. Jones et al. (2008) provide an evaluation for the 'Chemistry for non-specialist training programme' in UK. Mamlok-Naaman et al. (2018) describe a PD programme for non-specialist chemistry teachers in Israel. Woolhouse and Cochrane (2010) discuss the teachers' views of a PD programme in the UK in terms of how teachers improved their self-identity by developing their subject and pedagogical knowledge and reflective practices. This implies that to address this gap in knowledge it would be necessary to look at types of support structures that promote professional learning for teachers when teaching outside their area of expertise. This links to my third research question which tries to explore different ways of helping teachers gain confidence in teaching outside specialism.

This research, which will be developed through a qualitative case study, aims to address the gaps in the knowledge by providing evidence about the area of teaching outside specialism within the Maltese context and by looking into support structures that promote professional learning for science teachers teaching their non-specialist area.

Part III

Methodology

Overview

Part 3 gives an overview of the methodology used in the research study. In Chapter 5, I present the research framework by first discussing the ontological and epistemological assumptions related to the type and choice of methodology used. The study follows a qualitative methodology, where a case study approach is used to explore the teachers' narratives of their experiences when teaching outside their science specialism as they participated in a PD programme. The related ethical issues associated with carrying out this type of research are also analysed. Chapter 6 describes how I developed and implemented the year-long PD programme designed for this study. This is followed by a description of my entry into the field to look for potential participants. Then the research tools employed to collect data are discussed. A thematic analysis approach was used to analyse the data gathered to generate the main themes that emerge in this research study.

Chapter 5

The Research Framework

5.1 Philosophical underpinning of the research

The design of this research study involved constructing a plan and procedures in which several decisions had to be taken regarding the philosophical worldview assumptions, the strategies for inquiry and the methods of data collection and analysis (Creswell, 2014). Creswell (2013) argues that the researcher brings along their own history, values, assumptions, beliefs and perspectives into the research, thus making research a subjective process that cannot be value free (Bryman, 2012). On similar lines, Denzin and Lincoln (2005) suggest that research is "guided by the researcher's set of beliefs and feelings about the world and how it should be understood and studied" (p. 22). As a researcher embarking on a new research study, I was aware that my own beliefs and perspectives were influencing the development of the research design. My own personal views about the nature of reality (the ontological questions), the kind of knowledge I was aspiring to acquire (the epistemological questions) were all leading to my choice of methodology and the research tools that I decided to make use of in order to gain knowledge (see Denzin & Lincoln, 2005). Since the research process was a dynamic one that involved a number of decisions, like Creswell (2013) I believe that in order to make the research as trustworthy and authentic as possible I would need to make the philosophical beliefs and assumptions that guided my actions explicit and transparent. This reflexivity would provide insight to the reader with regard to the decision-making and choices that guided the design, implementation and outcomes of the research study.

5.2 Reflections on ontology, epistemology and methodology

5.2.1 Ontological considerations

Ontological assumptions question the nature of reality. Cohen, Manion and Morrison (2018) question whether reality is external to the individual or whether it is a product of individual consciousness created by one's own mind. They further question whether reality is objective in nature or a result of human understanding. The first perspective leads to objectivism which is an "ontological position that implies that social phenomena confront us as external facts that are beyond our reach or influence" (Bryman, 2012, p. 32). The second perspective leads to an ontological position that "asserts that social phenomena and their meanings are continually being accomplished by social actors" (Bryman, 2012, p. 33). Likewise Noonan (2008) argues that social reality is dynamic and "is the result of complex forms of human action and interaction" (p. 578). This implies that the researcher presents a constructed account of reality as well as a particular version of social reality (Bryman, 2012).

As I started to read the literature I came to understand that "reality is socially constructed" and "there is no single observable reality" (Merriam & Tisdell, 2016, p. 9). In any research process the participants have an active role in creating their particular reality that can be viewed from different perspectives (Bryman, 2012). As I embraced this ontological perspective – that there is no one true knowledge ready to be discovered but that there are multiple realities that are socially constructed (see Griffiths, 1998) within a specific context (Cohen et al., 2018) – I redefined my role as a researcher. Coming from a scientific background I was always inclined towards an experimental approach that looked for facts that could be discovered. However in this research, my role as a researcher was not to discover knowledge but to explore situations through the eyes of the participants and to represent their different views and perspectives as narratives of their multiple realities.

5.2.2 Epistemological considerations

Following this ontological position, the next questions that I asked were about epistemology and the nature of knowledge. In other words what counts as knowledge (Bryman, 2012), how knowledge claims can be justified (Creswell, 2013) and how knowledge is acquired and communicated to others (Cohen et al., 2018). According to Griffiths (1998) "epistemology encompasses a set of questions and issues about knowledge: what it is, how do we get it, how do we recognise it, how it relates to truth, how it is entangled with power" (p. 35). Cohen et al. (2018, p. 5) examine the different views of knowledge and claim that knowledge can be viewed as (1) "objective and tangible" or (2) as "personal, subjective and unique". Researchers who believe that knowledge is objective and tangible usually apply the methods of the "natural sciences to the study of social reality and beyond" (Bryman, 2012, p. 28). Those researchers who believe that knowledge is more personal and subjective usually follow the position taken by social constructivists who try to understand and give an interpretation of the world from the participants' perspective (Creswell, 2013).

My ontological position identifies research as value-laden and that facts cannot exist separately from values. From this position I would argue that all knowledge is constructed within a social context, what is described by Creswell (2013) as social constructivism. Within this paradigm, "subjective meanings are negotiated socially and historically" (Creswell, 2013, p. 25). Therefore my aim as a researcher was to bring out the participants' views of the situation and the interaction that takes place amongst all the participants of the research. Within this paradigm I also recognised that my own background and experiences are embedded within the interpretations given (Griffiths, 1998; Creswell, 2013). As argued by Maykut and Morehouse (1994) "if knowledge is constructed, then the knower cannot be separated from what is known" (p. 11). This implies that the researcher and the research process cannot be separated from the information that is gathered.

Epistemological assumptions also involve gaining an understanding of the relationship between the researcher and who is being researched. From a social constructivist point of view, the researcher aims to get as close as possible to the participants by spending time in the field in order to gain first-hand information and experiences arising from the individual participants, from the interaction with other persons and from their specific context in which they live and work (Creswell, 2013). This epistemological standpoint meant that in my research design I had to think of ways in which I could gain access to the participants' way of thinking and involve myself in their day-to-day processes in the science classroom by developing an ongoing dialogue with the participants. This would enable me to interpret the teachers' actions and their social world from their point of view (Bryman, 2012).

In other words the epistemological assumptions that guided the research process were based on the point of view that:

1. Knowledge is co-constructed and can never be independent of the knower.
2. Knowledge is embedded within a social context and can never be value free.
3. Knowledge is complex and multidirectional.
4. Knowledge emerges from an intimate relationship between the participants of the research including the researcher.

Based on these assumptions the scope of my research was to understand how teachers teaching outside their science specialism created and gave meaning to their context since social reality is based on multiple perspectives and realities.

5.2.3 Methodological considerations

Ontological assumptions give rise to epistemological questions that lead to a particular methodology. Griffiths (1998) contends that methodology "refers to the theory of getting knowledge, particularly in research contexts" (p. 35). Furthermore methodology "provides a rationale for the way in which a researcher goes about getting knowledge" (Griffiths, 1998, p. 35). Both Griffiths (1998) and Cohen et al. (2018) argue that research methods involve more than a technical exercise of collecting data. Griffiths (1998) argues that methodology provides the reasons for using the different techniques in relation to the type of knowledge that is collected or constructed. Cohen et al. (2018) suggest that one's views about the nature of reality and knowledge have direct implications on the methodology. In other words, the contrasting ontologies and epistemologies determine the methodological approach one adopts, that is either an objectivist or positivistic approach to research or an interpretative approach.

Since my ontological and epistemological beliefs acknowledge that there are multiple realities and that knowledge is socially constructed, I chose to approach this research study using a qualitative dimension by focusing on the subjective experience of individuals. Like Griffiths (1998), I believe that people have agency and cannot be regarded as passive subjects of the research. Individuals "react to the situations…. (that is) … they can and do construct interpretations of events, and they can and so use such interpretations as reasons to act in particular ways" (Griffiths, 1998, p. 26). This situation applies for both the researcher and the participants in the research where both construct their own meanings for the events in which they participate. In view of all these thoughts this research study used a qualitative approach to draw out the different views, interpretations and knowledge provided by the teachers when teaching outside their science specialism as they gave explanations for their interpretation of events and experiences.

Qualitative approaches to research design follow particular characteristics (Hatch, 2002; Maykut & Moorehouse, 1994; Merriam & Tisdell, 2016). They are exploratory in nature, have a descriptive focus and are generally inductive. Qualitative approaches have an emergent design, are flexible and evolve with time as the research study can change in its course. Data are collected in the natural setting since the researcher is interested in understanding experiences, actions and behaviours in a particular context (Hatch, 2002). Spending time in the field helps the researcher to indwell, where Maykut and Moorehouse (1994) refer to indwelling as "being open with the persons under investigation, walking a mile in the other person's shoes, or understanding the person's point of view from an empathic rather than a sympathetic position" (p. 25). This will help the researcher to acquire both explicit and tacit knowledge about the phenomenon being studied. Therefore the aim of this research study was to gain a deeper understanding of particular experiences from the participants' perspectives, how participant teachers ascribed meanings to their experiences, how they constructed their realities and interpreted their experiences when teaching outside their science specialism and when participating in PD programme designed for non-specialist chemistry teachers.

5.3 Reflections on my role as a researcher

In a qualitative study the researcher is the primary instrument of collecting and analysing data (Hatch, 2002; Maykut & Moorehouse, 1994; Merriam & Tisdell, 2016). This has advantages, as the researcher can expand understandings, clarify and check for accuracy of interpretation and explore anticipated answers. There can also be disadvantages since the researcher's biases can affect the interpretation of results. This implied that as a researcher I had to engage in reflexive thinking to identify and make visible my subjectivities to find out how these may have impacted the collection and interpretation of data.

5.3.1 The insider-outsider status within the research field

Ontological and epistemological views influence how the researcher goes about collecting data. In this study since knowledge is seen to be constructed both by the individual and by the researcher it was necessary to reflect on my position as a researcher with regard to the insider and outsider status within the research. As Sherry (2008) argues:

> …being an insider or outsider may affect the way in which the researcher enters the field, the obligations that the researcher has to research participants, the ongoing nature of contact with research participants, and the level of trust demonstrated by research participants (p. 433).

Being an insider implies that the researcher is actually part of the research process, participates in the research and has a certain amount of inside knowledge by virtue of being familiar with the research context. An insider researcher also shares a common identity, language and experiences with the participants. As an insider, the researcher may have established particular relationships with the research participants who tend to accept, trust, and be more open and willing to share information with an insider researcher (Dwyer & Buckle, 2009). On the other hand, an outsider comes from an outside setting to investigate a particular situation.

Objectivity and authenticity can be questioned in a project carried out by an insider researcher. Additionally, insider researchers can face dilemmas within the research process because they can become aware of particular sensitive issues that cannot be disclosed publicly (Sherry, 2008). On the other hand, there are arguments in favour of having an outsider researcher collecting objective data, if reality is perceived as objective and external to the individual. The outsider researcher may be more able to see through and understand the complexity of the situation since the researcher is more distant from the research participants and not immersed in their experience. Like Dwyer and Buckle (2009) I would argue that being an insider does not make one "a better or worse researcher; it just makes (one) a different type of researcher," (p. 56) since one has more depth and breadth of knowledge of the research setting and is more aware of the established cultural practices within the field of study. In this case the subjectivity of the researcher needs to be acknowledged. If subjectivity is not recognised Dwyer and Buckle (2009), argue that:

> …the researcher's perceptions might be clouded by his or her personal experience and that as a member of the group he or she will have difficulty in separating it from that of the participants. This might result in an interview that is shaped and guided by the core aspects of the researcher's experiences and not the participants. Furthermore, its undue influence might affect the analysis, leading to an emphasis on shared factors between the researcher and the participants and a de-emphasis on factors that are discrepant, or vice versa (p. 58).

My position within this research study lies along the insider-outsider continuum. Being a teacher researcher and at the same time a science teacher I am very familiar with the school setting and with the teaching of integrated science, thus having an insider's perspective. However the participants in this study are non-specialist chemistry teachers whereas I am a chemistry specialist teacher. My experience, attitudes towards the subject and knowledge of teaching chemistry can be very different from the participants' perspective and situations; hence I am also an outsider researcher. Whether the researcher has an insider or outsider status or as in my case, occupies a space in between in relation to the research field it is necessary for the researcher to be "open, authentic, honest, deeply interested in the experience of one's research participants, and committed to accurately and adequately represent the experience" (Dwyer & Buckle, 2009, p. 59).

In view of this as a researcher I needed to engage in critical self-reflection about my subjectivity to find out how my personal bias and background experiences could influence the interpretations given to the situation being investigated. Moreover my insider status could influence the type of personal relationship and trust created with the research participants. Consequently, as Sherry (2008) recommends, as a researcher I needed to be aware of common or similar experiences shared with the participants as well as the differences between the researcher and the participants because these similarities and differences may affect the nature of the data collected.

5.4 Selecting the research design

This study uses a qualitative approach as a strategy for inquiry because "qualitative research is based on the belief that knowledge is constructed by people in an ongoing fashion as they engage in and make meaning of an activity, experience, or phenomenon" (Merriam & Tisdell, 2016, p. 23). According to Creswell (2014), the main aim of qualitative research is to explore and understand the meaning individuals assign to a particular problem. In this regard qualitative research tools were chosen since I wanted to gain an in-depth perspective of how teachers were living their personal and professional story as science teachers and the challenges they were experiencing when teaching outside specialism. A case study approach was chosen to understand the teachers' lived experiences when teaching outside their science specialism in their own particular contexts.

5.4.1 The case study

A case study approach is used to investigate in depth a particular phenomenon within its real-life context (Yin, 2009). Case studies are used to search for meaning and understanding by "providing an in-depth account of events, relationships, experiences or process occurring in that particular instance" (Denscombe, 2014, p. 54). In case studies an inductive investigative strategy is used where the researcher collects data from the field which is combined and ordered into themes, categories and/or concepts to derive theory about specific aspects of practice (Merriam & Tisdell, 2016). Denscombe (2014) explains that "the point of a case study is to analyse the situation and to arrive at certain concepts, propositions or hypotheses that might explain what is happening, and why, in the particular setting that has been investigated" (p. 61). Merriam and Tisdell (2016) describe a case study as an "in-depth description and analysis of a bounded system" (p. 37). The researcher focuses on a unit of study or a case as a bounded system where to be bounded means that the phenomenon must be identified within a specific context (Ary, Jacobs, Razavieh & Sorsensen, 2010).

One of the strengths of a case study is that it is anchored in a real-life context and people are observed in their own environment. Cohen et al. (2018) argue that "contexts are unique and dynamic, hence case studies investigate and report the real-life, complex dynamic and unfolding interactions of events, human relationships and other factors in a unique instance" (p. 376). In fact Yin (2009) defines a case study as "an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between the phenomenon and the context are not clearly evident" (p. 18). Hence the case study is set within a context and the phenomenon cannot be separated from the context. The case study approach enables one to understand the meanings and ideas of people in actual situations and how their behaviour can change in a particular context (Ary et al., 2010). Yin (2009) also states that case study research is an encompassing research method which covers the design, data collection techniques and particular approaches to data analysis.

Case studies are appropriate when asking the ‘how’ and ‘why’ questions about a particular event in which the researcher has no control over it (Yin, 2009). Case studies can focus on understanding the dynamics present in a particular situation by looking at the “relationships and social processes within social settings” (Denscombe, 2014, p. 55). This can lead to an explanatory case study (Yin, 2009), which generally follows an interpretative tradition of research. The aim of using a case study is to investigate an issue in depth in order to understand the whole case in the totality of the context. Both past and present actions, emotions and thoughts can be probed so the researcher can gain an insight and explain particular behaviours (Ary et al., 2010).

The outcomes of a case study are specific to the situation being studied and cannot be generalised. Patton (2002) argues that extrapolations can be made rather generalisations. “An extrapolation connotes that one has gone beyond the narrow confines of the data to think about other applications of the findings” (Patton, 2002, p. 584). Extrapolations are modest speculations in which it is possible to think about the applicability of the findings to other comparable situations. The case study approach provides a holistic view of what goes on by providing sufficient detail and a rich description of the contexts and narratives of the participants and their activities that the researcher has learnt about (Merriam & Tisdell, 2016). Moreover a case study shows how different aspects or facets to the situation are interlinked. Case studies can also provide an explanation of the complexity of the situation especially when participants may have different views of a particular reality. In case studies there are many variables operating in a single case, which requires more than one tool for data collection (Cohen et al., 2018). One of the strengths of the case study, as outlined by Denscombe (2014), is that the case study approach allows the researcher to use a variety of sources of evidence and ways of collecting data to gain a holistic view and capture the complex reality under study. Having multiple data collection methods is necessary for data triangulation in order to strengthen the research findings and conclusions (Denscombe 2014; Yin, 2009).

This case study aims to portray what it feels like to be in a particular situation and to catch a closer glimpse of the reality and experiences of the participant teachers in a given situation (see Cohen at al., 2018). This research can be presented as a case study, a bounded system, since it was carried out with a particular group of Maltese science teachers who are non-chemistry specialists. It provides an in-depth account of the teachers’ lived experiences, and their thoughts and reflections when teaching chemistry to young secondary school students as their non-specialist area. It explores why teachers are encountering a number of dilemmas and challenges and how they develop particular strategies to overcome the challenges encountered. In this research study the participant teachers agreed to participate in a PD programme that was developed to target their needs when teaching outside specialism. It provides rich descriptions when it narrates the teachers' experiences in the PD programme and how these influenced the teacher's professional growth and their teaching identity.

5.5 Ethical considerations

A qualitative research design must address important ethical considerations. As a researcher I was aware that ethical issues pervade all stages of the research journey since qualitative research involves the collaboration and participation of research participants when they share their personal experiences (Hatch 2002). Cohen et al. (2018) mention a number of ethical issues that need to be taken into consideration when conducting research. Following their suggestions I made sure to first gain access and acceptance in the research field by asking permission from gatekeepers, where in this case I sought permission from the Directorates of Education to conduct research with science teachers and obtained ethical clearance from the university. Later on I obtained permission from heads of schools to visit the participant teachers in their respective schools.

At the beginning of the study whenever I met potential participant teachers I was always honest and open about what the study entailed, how the data would be collected for the purpose of the study and the role of participants in the research (Denscombe, 2014). I assured them that participation in this research study was voluntary and they could opt out of the research at any point without justification. I also ensured that potential participants received enough information to make an informed decision because as Cohen et al. (2018, p. 122) state, informed consent involves four aspects. This includes (1) competence, where participants make a decision given the relevant information; (2) voluntarism where participants are given the right to freely choose to accept or decline participation in the study; (3) giving full information about the research project and (4) comprehension where participants fully understand the nature of the research study.

Ethical considerations also imply that the researcher has to maintain privacy, confidentiality, anonymity and protect the interests of the participants by preventing harm. I protected the participants' identities in this research study by keeping their anonymity and avoiding the identification of participants from the information provided (Cohen et al., 2018).

Pseudonyms are used in the write-up not to reveal the participants' identities. Like Ary et al. (2010), I felt that it was my moral responsibility to keep confidentiality and to maintain trust. Information shared by the individual teachers during the one-to-one interviews was kept confidential. None of this information was divulged during the discussions that took place in the community of learners and it was up to the individual teachers to share sensitive issues with other teachers. Teachers were also assured of confidentiality in the final publication. When teachers wanted to discuss particular sensitive issues, as per their request I immediately reassured them that this sensitive information was not going to be audio recorded and was kept off the record. The teachers' requests were respected in order to gain trust and maintain a good rapport, thus respecting the relationship between the participants and the researcher.

The welfare of the teachers participating in the research was one of my utmost concerns. As Denscombe (2014) states the participants' interests were protected by safeguarding their interests and protecting them from any physical, personal or psychological harm. I had obligations and commitments to the participant teachers and aimed to strike a balance between seeking to understand the teachers' thoughts and behaviours and making the participants feel comfortable by safeguarding their welfare during the research. Bogdan and Biklen (2007) advise that participants should not be "exposed to risks that are greater than the gains they might derive" (p. 48). Participants have to be protected by minimising any foreseeable risks and getting the maximum benefits from the research.

Participant teachers can feel that they have given more than they have actually gained (see Bogdan & Biklen, 2007). Reciprocity is important as both participants and researcher should benefit from the research process. Cohen et al. (2018) put forward the following question: "what will this research do for the participants and the wider community, not just for the researcher?" (p. 128). This question prompted me to seriously reflect on the benefits that the teachers had to gain out of this research study. The PD programme was designed to enhance the teachers' content knowledge and use different pedagogies to teach chemistry through the resources given. The workshops, focused on the specific learning needs of the teachers. Hence the PD programme was designed in such a way that the participants would gain maximum benefits both on a personal and on an educational level.

The next chapter describes the research process starting with how the yearlong PD programme was developed and implemented. It discusses my entry into the field as I looked for potential participants to participate in the study. I also describe the research tools used to collect data when I met the teachers on a one-to-one basis and in the PD sessions.

Chapter 6

The Research Process

6.1 Starting the research process

My previous experiences and encounters with non-specialist chemistry teachers and my role as head of department, as described in section 1.5, inspired me to embark on this project. As part of this research study I wanted to develop supportive structures by designing a PD programme for non-chemistry specialists to help teachers increase their confidence and competence to teach chemistry topics to Year 7 and 8 students. The PD programme was a yearlong programme starting during a summer workshop and continuing through a number of workshops held during the next scholastic year. This chapter describes the preparatory phase of this study which involved designing the first part of the PD programme and my entry into the field. The teachers voluntarily consented to participate in the study and take part in the PD programme. The second part of the PD was developed with ongoing collaboration and discussion with the participant teachers. During the same year I also meet the participant teachers on a personal level and conducted interviews and class observations. Table 6.1 presents a timeline of the research study.

Table 6.1: Timeline of the research study

Timeline	Stages in research study
June 2013 – July 2014	Preparation of PD programme Seeking of potential participants for research study
July 2014	First part of PD programme: INSET sessions
October – November 2014	Meeting individual teachers
December 2014	Second part of the PD programme Workshop 1: Getting together, working together
January – February 2015	Meeting individual teachers
February 2015	Workshop 2: Getting together, working together
May 2015	Workshop 3: Getting together, working together
May 2015	Meeting individual teachers
June 2015	Final meeting with individual teachers
June 2015	Closure of PD programme
May – June 2016	Meeting individual teachers a year after PD programme

6.2 Designing a professional development programme for non-specialist chemistry teachers

This was the first time that a long-term PD programme was being developed for non-specialist chemistry teachers within the local context. Hence I resorted to gain a personal experience by participating in a PD programme targeted for non-specialist chemistry teachers in the UK in preparation for this project. I also engaged in reading literature about professional learning, professional development, teachers' knowledge base and teaching outside specialism to draw out the essential principles and the professional learning framework upon which I could construct the PD programme. By using the knowledge gained from the PD experience and the literature I embarked on the process of developing a PD programme for the science teachers by adapting and designing tasks that were in line with the integrated science syllabus for Maltese students.

6.2.1 The preparatory phase

6.2.1.1 A personal experience of a professional development course for non-specialist chemistry teachers

In preparation for this project I wanted to personally experience a PD programme designed for non-specialist chemistry teachers. I decided to enrol in a course entitled "Teaching Chemistry for the Non-Specialists" organised by the RSC in the UK. The aim of this course is "to raise confidence and expertise of non-specialist teaching chemistry in UK secondary schools" (Jones et al., 2008, p. 1). The programme covered important chemistry concepts, provided hands-on experiences of practical work and teacher demonstrations targeted for older secondary school students (ages 14 to 16). The course, held at the Science Learning Centre in Bristol was split in two parts and I attended both the June and November sessions in 2013. Prior to attending this course I informed the course leader that I wanted to develop a similar programme for Maltese non-chemistry specialist teachers who were teaching science to younger secondary school students (ages 11 to 13); thereby I used an overt approach about my objectives for attending this course.

The main strength of this course was that we were mainly engaged in conducting practical work for three out of the four days. A number of experiments were set up and we moved from one station to another conducting experiments by following instructions from a given laboratory manual (RSC, 2010). The group trainer supported us by posing questions and discussed links between different concepts in chemistry. I had never experienced such sessions in Malta and I came across new versions of experiments even though I was a chemistry specialist. From this experience I expanded my own PCK in teaching chemistry. The PD experience gained abroad inspired me to include practical sessions within the PD programme that I had to devise for the Maltese teachers. When reflecting on this experience I thought that:

> *We never had lab sessions as part of professional development courses in Malta. It would really be interesting and a more engaging learning activity to set up laboratory work for non-chemistry specialists in Malta. Maybe this can help them overcome their fears. Risk assessments need to be introduced and emphasised.*
>
> (Journal Entry: November 2013)

This experience also helped me to reflect on how I could prepare worksheets required during the laboratory sessions, hence I thought that:

> *Worksheets need to be prepared for the lab sessions in which the procedure of the experiment is given. A number of questions can be set for teachers to review the chemistry content related to each experiment. Teachers will take an active role by conducting the experiments and by thinking about how they can use them in their lessons. They can learn at their own pace as they move from one experiment to another.* (Journal Entry: November 2013)

The personal experience gained from this PD programme provided significant innovative insights and examples that I could use and adapt to design the PD programme for Maltese non-specialist chemistry teachers. I decided to include practical work so that teachers could revise or learn new content knowledge and at the same time learn how to explain concepts related to the experiments. Tackling experiments was one the challenges identified in Chapter 3 (Childs & McNicholl, 2007). Hence I thought that the laboratory sessions would help teachers gain confidence in handling apparatus, conducting experiments, observing results and drawing conclusions. I felt that it was highly beneficial to attend this PD experience in the preparatory phase of the research study because I gained new insights into how I could design a PD programme for Maltese non-specialist chemistry teachers.

6.2.1.2 Drawing on the literature

At the same time I was also engaged in reading literature about teacher learning, professional learning and characteristics of PD programmes. These readings were providing the underpinning philosophy related to teacher learning both at an individual and at a collective level as described in Chapters 2 and 4. The characteristics of effective PD that led to professional learning as drawn from literature (section 4.5) were highly influential in developing the PD programme for non-chemistry specialists.

Besides reading literature about professional learning and development I was also reading literature about teaching outside one's area of expertise and the factors that shape the teachers' knowledge base. As indicated in the theoretical framework in Figure 2.2, the cognitive, affective, contextual and social factors shape the teacher learning and consequently the teachers' knowledge base. By combining the insights gained from the literature as well as my personal experience of a PD programme for non-specialist chemistry teachers, I started formulating initial ideas and a possible structure for designing a long-term PD programme. I resolved that the PD programme had to focus on the three main goals as outlined in the framework for professional learning for non-chemistry specialists (see section 4.6). It needed to enhance the teachers' professional knowledge, transform the teachers' beliefs, engage teachers in context-based learning activities and promote a collaborative culture where teachers can learn together, reflect and develop their knowledge base. In designing this PD programme, that was specifically drawn for this study, I believed that both the content and delivery of these sessions were critical to enhance professional learning (Darling-Hammond et al., 2009). This was an original PD programme and the sessions and resources prepared targeted the teaching of the chemistry topics within the local curriculum.

6.3 Outline of the professional development programme

The PD programme was a two tiered programme that started during a summer workshop, locally known as the INSET in July 2014 and developed in follow-up workshops over a whole scholastic year when teachers were teaching science. A workshop was held once a term when teachers were teaching or about to teach a chemistry topic as part of the integrated science syllabus. As suggested by Putnam and Borko (2000), the use of multiple contexts of learning can be more successful when summer workshops, which introduce theoretical ideas, are combined with ongoing support throughout the year as teachers enact and apply newly learnt ideas into their practice. Table 6.2 gives an outline of the timeframe of the PD programme.

Table 6.2: Timeframe of the PD programme for non-specialist chemistry teachers

PD Programme for non-specialist chemistry teachers			
First part	**Second part**		
During INSET days (12 hours) July 2014	Workshop 1: (4.5 hours) December 2014	Workshop 2: (4.5 hours) February 2015	Workshop 3: (4.5 hours) May 2015

6.3.1 The first part of the professional development programme

The professional learning experience started in July 2014 during a three half-day summer course, known as the INSET. I decided to commence the professional learning journey at the INSET for two main reasons. Within the local school calendar, INSET days were allocated as PD days, therefore I resorted to use existing structures within the local context to launch the project. Secondly interested teachers generally opted to voluntarily attend INSET courses, meaning that they wanted to enhance their knowledge and gain ideas in teaching chemistry to improve their practice.

The aim of the first part was to familiarise the teachers with the teaching of chemistry. The programme of the INSET was designed before meeting the participant teachers. Table 6.3 gives an outline of the first part of the PD programme. A detailed description of the programme and activities is found in Appendix 2.

Table 6.3: Outline of the first part of the PD programme

First part of the PD Programme: INSET		
7th July 2014	8th July 2014	9th July 2014
▪ Introduction of participants ▪ Explanation of research study ▪ Teaching and learning scientific concepts: Using assessment probes to elicit and challenge students' misconceptions ▪ Case study discussion: Teaching chemistry topics ▪ Reflections on Day 1	▪ Introduction: Experiments and investigations in science ▪ Laboratory session: conducting various hands-on experiments and investigations ▪ Reflections on Day 2	▪ Lecture demonstration: The chemistry of the atmosphere ▪ Some updates regarding e-content and the integrated science syllabus ▪ Reflection and group discussion: Transferring experiences to classroom practice ▪ Evaluation of the experience

The programme of the INSET was based on the framework that promotes teacher learning in section 4.6. Table 6.4 illustrates how the programme of the INSET was based on the three core features of the professional learning programme.

Table 6.4: The INSET programme based on the three core features of the framework for professional learning for non-chemistry specialists

Core features of PD programme	First phase of the PD programme (summer INSET sessions)
professional knowledge (content specific SMK & PCK)	In the session *'teaching and learning scientific concepts'* teachers worked on activities in which they prepared activities to challenge students' misconceptions. In the '*laboratory session'* teachers conducted a number experiments and investigations. During the *'lecture demonstration*' teachers learnt about the properties of gases in air and their reactions. The purpose of these activities was twofold: for the teachers to revise and consolidate their SMK and to learn about different ways of teaching and explaining particular chemistry topics.
professional beliefs (content specific beliefs and self-efficacy)	The aim of the session: '*case study discussion: teaching chemistry topics'* was to expose the teachers' beliefs related to their content-specific beliefs about chemistry and their self-efficacy beliefs to find out how they were feeling when teaching chemistry topics.
situated & sociocultural learning (learning is situated in authentic activities; development of a community of learners)	The teachers were engaged in collaborative work. They discussed and learned from each other and from a chemistry specialist during the laboratory session. They conducted activities that could be used to teach different aspects of the chemistry topics based on the local integrated science syllabus.

In targeting the teachers' professional knowledge (that is subject-specific SMK and PCK), as shown in Table 6.4, the sessions focused on the common challenges that teachers experience when teaching an unfamiliar area (see Chapter 3), such as dealing with students' misconceptions, conducting experiments and providing explanations of chemistry concepts.

Since PCK as originally defined by Shulman (1986) comprises 'knowledge of representations or instructional strategies' and 'knowledge of students' subject matter learning difficulties', one of the sessions focused on identifying students' misconceptions in chemistry and discussing ways how to challenge them. A pedagogical tool, known as assessment probes (Keeley, Eberle, & Farrin, 2005) was introduced. This tool can be used to elicit the students' prior knowledge at the beginning of a lesson. Examples of these assessment probes were used to check teachers' understanding of chemistry concepts. The teachers then worked in groups and devised classroom activities to challenge the misconceptions presented in each probe.

Based on the personal experience gained from attending the PD programme abroad, one of the sessions focused on gaining laboratory experience so that teachers could become more familiar with examples of chemistry experiments suitable for young students. Teachers were engaged as learners by conducting similar activities that students would do in class (Loucks-Horsley et al., 2010). The aim of the practical session was for the teachers to develop their practical skills and confidence in preparing and conducting experiments, as well as revise their content knowledge. The experiments presented challenged the common belief that chemistry is an abstract subject because simple reactions were carried out by using chemicals and materials commonly used in everyday life, hence encouraging teachers to gain positive experiences of the subject. The non-specialists teachers worked in groups and each group was assisted by a chemistry specialist teacher who prompted them with questions and provided support in case of difficulties. The participant teachers had the opportunity to examine their background knowledge, develop scientific understanding and discuss how different experiments could be used to help students comprehend chemistry concepts, thus building both their SMK and PCK about chemistry-related concepts.

Teachers also had a lecture demonstration about gases in the air, where properties and reactions of different gases were illustrated and discussed through a number of experiments. Resources, such as examples of assessment probes to elicit students' misconceptions and a manual of chemistry experiments, were designed based on the curriculum materials used in Year 7 and 8. These resources were intended to help teachers widen their repertoire of representations and activities in chemistry. Examples of these resource booklets are found in Appendix 2.

Besides targeting the teachers' professional base (teachers' SMK and PCK), one of the sessions was particularly intended to expose the teachers' beliefs and their perception of chemistry teaching, thus targeting the second goal of the professional learning framework as indicated in Table 6.4. I was aware that teachers attending the INSET had their own preconceptions about chemistry teaching and these initial beliefs and understandings had to be made explicit. By using a case study describing the experience of a non-specialist chemistry teacher, participant teachers were prompted to share their own beliefs, feelings and experiences about teaching chemistry topics. These discussions provided the first insights of the teachers' feelings and challenges they came across when teaching their non-specialist area.

As proposed by the situative and sociocultural learning theories, learning is a social process and it is situated in a given context (Putnam & Borko, 2000). In targeting the third goal of the professional learning framework, as shown in Table 6.4, teachers worked on various hands-on engaging activities that could easily be implemented in their classrooms, thus learning was situated in context. Teachers also worked together in groups thus encouraging collaborative practices and sharing of ideas. The programme was designed to emphasise the process of creating and negotiating knowledge through the active participation and interaction of the teachers, rather than imparting knowledge and rendering teachers as passive acquirers of information (O'Sullivan & Deglau, 2006).

6.3.2 The second part of the professional development programme

The second part of the PD programme was carried out in the next scholastic year. It was also developed at the same time that I was meeting the teachers on an individual basis, conducting the research and collecting data. The science syllabus is devised in such a way that one or two chemistry units are done per term. Biology and physics units are also taught in the same term. The workshops were held once a term, close to when teachers were teaching or about to teach chemistry topics. All the workshops were called "Getting together, working together" because I wanted to foster a sense of collegiality that would eventually lead to the formation of a community of learners. I hoped that collegial support would help to reduce the teachers' anxiety when teaching chemistry topics.

Hogan et al. (2007) explain that there are three main types of PD, those that focus on the needs of the educational system, those that focus on the needs of the school and those that focus on the needs of the individual teacher. Generally the short courses, as explained in Chapter 4, target the needs of the educational system and adopt traditional delivery formats. In this case the aim of this PD programme was to address the individual needs of the teachers and use a participatory approach to professional learning.

The planning and the design of the two phases of the PD programme differed from one another. The content of the first phase of the programme was designed prior to meeting the teachers. Activities were developed for teachers to familiarise themselves with the teaching of chemistry and to support them to overcome the challenges outlined in literature when teaching outside specialism (see Chapter 3). The second part of the programme focused more on their specific needs. Since it took place during the scholastic year teachers had the opportunity to implement what they were learning in practice. Hence the second phase of the PD programme had an emergent and flexible design. Stoll et al. (2012) recommend that professional learning needs to be based on the assessment of individual needs. As I was meeting teachers to collect their experiences in teaching chemistry topics I was also asking them to identify their own personal learning needs and concerns about their teaching and professional development. During the interviews I was also collecting feedback about the previous PD sessions and suggestions for the coming sessions. Besides, at the end of the workshop I was also asking teachers to suggest activities for the next workshop.

I decided to base the second part of the programme on what the teachers wanted to learn, so that it would truly address the challenges and issues that teachers were coming across in their daily practices. In this phase teachers were given the opportunity to identify their own starting points in learning and to focus on issues that were important to them (Cordingely, Bell, Rundell, & Evans, 2003). As a result the tasks were developed according to the teachers' interests and their needs as learners (Bransford et al., 2000). In other words the second phase of the PD programme was developed through an ongoing consultation with the participant teachers because, as Darling-Hammond and McLaughlin (2011) suggest, the programme must be "responsive to the specific and changing needs of teachers" to allow the "teachers to share what they know and what they want to learn and to connect their learning to the contexts of their teaching" (p. 84).

In this process the participant teachers had to be introspective and engage in self-evaluation about their own professional learning. Bishop and Denley (2007) suggest that teachers need to have a high degree of self-awareness to truly identify their learning needs and decide about the next phase of their professional learning. As Hobbs (2013a) recommends "a range of support mechanisms over a period of time that is negotiated or initiated by the teacher and offered at the teacher's point of need" is "more likely to lead to real professional learning and identity development" (p. 287). Since the second phase was carried during the scholastic year teachers also had the opportunity to implement what they were learning in their classrooms. In contrast to other PD programmes that teachers were accustomed to, this experience was constructed from a bottom-up rather than a top-down approach because teachers were involved in shaping the learning agenda by giving them more ownership in their learning and at the same they had the opportunity to test their own ideas in practice. Table 6.5 provides an outline of the second part of the PD programme.

Table 6.5: Outline of the second part of the PD programme

Second part of the PD Programme: Workshops		
Getting together, working together 1 3rd December 2014	*Getting together, working together 2* 12th February 2015	*Getting together, working together 3* 5th May 2015
▪ Welcome: Getting to know each other ▪ Looking at teachers' requests and objectives of the day. ▪ Brainstorming task about the use of starter activities in science lessons ▪ Laboratory session: Conducting starter experiments ▪ Lesson planning ▪ Case study: Teachers reflecting about their teaching, collaborative work and the professional development experience at INSET ▪ Reflection on the day's activity and planning of the next workshop	▪ Introductory activity: Human knot reflection on the teachers' feelings as they try to overcome challenges in teaching outside specialism ▪ Sharing the objectives of the day ▪ Sharing of lesson plans and reflections ▪ Inquiry-based activities – Predict Observe Explain (POE) activities ▪ Lesson planning using POE activities; sharing of lesson plans ▪ Reflection on the day's activity and planning of the next workshop	▪ Introductory activity: Snakes and ladders: personal reflection on changes within one's classroom practice ▪ Sharing the objectives of the day ▪ Sharing of lesson plans and reflections ▪ Topic planning and sharing of work ▪ Planning an investigation ▪ Reflection on the day and on the professional learning experience

Appendix 2 describes in detail how I constructed the programme for each workshop. The introduction includes a personal reflection explaining how each session was constructed from the teachers' feedback and from salient points found in the literature. Although different teachers proposed different suggestions, in general they all wanted to widen their professional knowledge by acquiring and reviewing their content knowledge and gaining further pedagogical ideas and ways of planning and developing engaging lessons in chemistry, thus they all wanted to widen their SMK and PCK. Teachers wanted to use inquiry-based methodologies, such as the use of the 5 E approach as applied to chemistry topics. They also wanted to learn how they could use simple investigations in their lessons. This implied that the teachers' requests were mainly focusing on targeting the first criteria of the framework in section 4.6, that is the teachers' professional knowledge. Resource booklets were also prepared for each workshop session depending on the aim of the session. Samples of these resources are found in Appendix 2.

The PD programme was designed on a developmental approach where initially the researcher facilitated a number of sessions but this progressively decreased as teachers were encouraged to lead the sessions. Along the year the teachers gained more responsibility for their own learning since from the second workshop teachers started sharing their lessons plans and resources whilst critically reflecting on their work. The sharing of teachers' lesson plan was an opportunity, as Luehmann (2007) argues, for teachers to develop confidence with their new identities within their professional practice. Putnam and Borko (2000) recommend that teachers bring their experiences and share their instructional practice. As Ball and Cohen (1999) argue:

> … the opportunity to engage in such conversation can provide a means for teachers to represent and clarify their understandings, using their own and others' experiences to develop ideas, learn about practices and gain a more solid sense of themselves as contributing members of a profession, as participants in the improvement of teaching and learning and their profession, and as intellectuals (p. 17).

When teachers share their work they do not only provide further ideas about how a lesson can be developed but they also participate in systematic pedagogical thinking and reflection. Teachers were provided with a set of reflective questions before the session (see Appendix 2). Every teacher engaged in critical self-evaluation prior to the session by examining the lesson plan, identifying the challenging issues and discussing ways to approach them. They had to think of ways of improving their lessons. The aim of this activity was to encourage self-reflection on their practice and to deepen the "teachers' understanding of the processes of teaching and learning and of the students they teach" (Darling-Hammond & Mc Laughlin, 2011, p. 82). At the same time it was an opportunity for teachers to learn from one another, to widen their knowledge base and encourage contribution from the other members, thereby constructing new knowledge within the community of learners. This exercise did not only expose the teachers' beliefs about their teaching and learning but it encouraged them to reconsider their own beliefs, hence targeting the second criteria of the framework in section 4.6. Engagement and discussion of practice in context targeted the third criteria the framework. Table 6.6 shows how the programme of the three workshops was also based on the three core features of the professional learning programme.

Table 6.6: The programme of the workshops based on the three core features of the framework for professional learning for non-chemistry specialists

Core features of PD programme	Second phase of the PD programme: Workshops
professional knowledge (content specific SMK & PCK)	In the sessions *'conducting starter experiments' and 'predict-observe explain activities'* teachers worked on inquiry-based activities and developed lesson plans. During another two sessions teachers shared their lessons plans. In another session teachers worked on topic planning. From these activities the teachers enhanced their SMK. The discussions related to lesson planning enabled the teachers to develop their 'personal PCK'. Sharing their lesson plans enabled the teachers to reflect on how they were using their PCK in practice, hence explaining and developing their 'PCK and skill.'
professional beliefs (content specific beliefs and self-efficacy)	In the *'case study: teachers reflecting about their teaching, collaborative work and professional development experience at INSET'* teachers had the opportunity to reflect on how they were feeling when teaching outside specialism and on their experiences in the previous PD session. When sharing their lesson plans and reflecting on practice, the teachers were articulating and reflecting on their beliefs about teaching and learning. The outcomes arising from implementing changes in one's lessons also shaped their beliefs and affected their self-efficacy. At the end of the programme using the *'snakes and ladders activity'* teachers were asked to reflect on how their beliefs and personal view of themselves had changed throughout this programme.
situated & sociocultural learning (learning is situated in authentic activities; development of a community of learners)	Teachers were engaged as learners as they actively participated in different activities. Within the community of learners teachers generated and negotiated knowledge when they constructed lesson plans based on inquiry-based practices and when they shared their own lesson plans. In the sessions, the teachers worked on several examples of activities that were part of the science syllabus thus adding relevance to their professional practice.

6.4 The implementation phase

The implementation phase started with finding potential participants who could take part in this research study. Participation in the long-term PD programme was voluntary and teachers could opt out of the research process at any time. At the beginning of the study I had to gain the necessary permissions to enter the field.

6.4.1 Entering the field and gaining access

As a first step I started looking into how I could gain access into the field. My role as a teacher and as a head of department provided me with the necessary knowledge of how I could gain access into the field, since as an insider I am quite conversant with school life and procedures. As a researcher I abided by ethical guidelines and followed the required procedures to gain permission to access the field of study. I first sought to obtain permission to conduct research with science teachers from the Directorate for Quality and Standards in Education and from the Secretariat for Catholic Education to work with teachers from state schools and church schools respectively. After permissions were granted from both sectors, I applied to obtain ethics clearance both from the Faculty of Education and from the University of Malta. Once ethics clearance was obtained I could start seeking participants for this study.

6.4.2 Finding participants to take part in the research study

A call for applications for a voluntary INSET course was published on the INSET catalogue in April 2014 inviting science teachers from state and non-state schools who are non-chemistry specialists to participate in a PD programme for non-chemistry specialists (see Appendix 3). The call for applications was the first attempt at trying to find teachers to participate in this study. Since this was a voluntary course I was apprehensive in terms of the number of teachers applying for this course. Although the course was open to all teachers from all sectors, I learnt that teachers from state schools could not attend since they were called to attend a compulsory course related to a European project. This news was very disheartening. Bogdan and Biklen (2007) recommend that researchers need to be persistent in trying to get access. I tried to contact and speak to different persons within the Directorate of Education however none of the science teachers from state schools could make it to the INSET due this prior commitment.

Whilst the INSET call of applications was open, science teachers in church schools were called for a seminar in May 2014 organised by the Secretariat for Catholic Education. I thought that this would be a good opportunity to start approaching potential participants. I asked permission from the organiser and at the beginning of this seminar I was given a time slot to speak about the research study. I invited teachers to attend and explained that the INSET course was part of a long-term PD programme for non-chemistry specialists. By participating in the INSET teachers could opt to participate in a research study. However the teachers could still come to the INSET and not participate in the study. As Hatch (2002) recommends, one of the basic ethical considerations that I adhered to from the very start was a "full disclosure of research intentions and a clear message that participation is voluntary" (p. 67) since these two elements are essential for genuine consent. Teachers were free to accept or not to accept to participate and at any stage they could opt out of the research study without providing any justification.

Meeting and talking with teachers was a necessary step to get them interested in participating in the study. Besides the introductory meeting, informal meetings were held with some teachers prior to the course to explain the aims of the research and the participants' involvement in the programme. Interested teachers could "enter the research project voluntarily, understanding the nature of the study and the dangers and obligations that are involved" (Bogdan & Biklen, 2007, p. 48). Whilst negotiating entry among potential participants I was providing information about the scope and nature of the study, the structure of the PD programme, the research tools to be employed, the methods of collecting data, the dissemination of data and the role of participants in the research. By being open and truthful I hoped to gain the participants' trust and respect. As Bogdan and Biklen (2007) suggest it was important to make my interests known and to seek co-operation from potential participants. I also discussed the benefits that could be derived from participating in the PD programme. I ensured that the participants received enough information to make an informed decision about their participation in the study. An information sheet and a consent form were given to interested teachers (see Appendix 4) and they were given time to think about whether they would like to participate in this research study.

6.4.3 Teachers participating in the professional development programme

Twenty-six teachers applied to attend the INSET course. Although the INSET course was aimed at chemistry non-specialist teachers, a number of teachers who were chemistry specialists and at the same time teaching science decided to apply. These teachers did not qualify to participate in this study. From these twenty-six teachers, ten science teachers voluntarily accepted to participate in the research study and signed the consent form. Both researcher and participants kept a signed copy. In order to resolve this situation I decided to divide the group into two such that the chemistry specialist teachers and those who did not opt to take part in the study worked separately from the ten participant teachers during the various sessions. This also facilitated the process of data collection.

Although ten science teachers participated in the first part of the PD programme, two of these teachers did not follow the second phase of the PD programme. One of the teachers was not teaching science in the next scholastic year and the other teacher withdrew from the study due to personal reasons. All data gathered from these two teachers during the first phase of the PD programme were not used in the data analysis, respecting the right of the participants to opt out of the study. Consequently eight teachers teaching in boys' or in girls' church schools with different years of teaching experience voluntarily participated in the second phase of the PD programme.

Once the eight teachers were identified, permission from the Secretariat for Catholic Education was again sought to gain access and visit these teachers in their respective schools (see Appendix 4). I then negotiated entry with the gatekeepers of the different schools that is, I informed each head of school that the science teacher was participating in a research study. Interviews and class observations were to be carried out and teachers had to choose a suitable date and time when I could go and observe a chemistry lesson. I always asked permission from the head of school to conduct interviews and class observations. Building a good rapport and seeking cooperation with the heads of school was important throughout the study and I assured them that this study would create minimal disruptions. The next section discusses the research tools used to collect data and it also describes how the data were analysed to outline the emerging themes of the findings.

6.5 Data collection methods

In a qualitative research study multiple research tools are chosen to capture the participants' experiences, actions and behaviours because "no one single method can grasp all the subtle variations in ongoing human experiences" (Denzin & Lincoln, 2005, p. 21). This research study used a wide range of interconnected interpretive methods to portray a holistic picture of the teachers' narratives and experiences when teaching chemistry as their non-specialist area. Data collection methods included a questionnaire, classroom observations, individual and focus group interviews and keeping a researchers' reflective journal. These methods were used to triangulate the data and generate a rich data source to create a powerful narrative. The participant teachers and I as the researcher worked together in a collaborative relationship in using the different methods of data collection (Connelly & Cladinin, 1990). Table 6.7 indicates the research tools that were used to collect data during the PD sessions and when meeting the individual teachers at their school.

Table 6.7: Data collection methods used during the research study

Timeline	PD Sessions	Meeting teachers at school	Data collection methods
June 2013 – July 2014	Preparatory phase of the study		▪ Researcher's journal
July 2014	INSET		▪ Questionnaire (Q) ▪ Focus group interviews (FG.1, FG.2) ▪ Researcher's journal
October-November 2014		Introductory meeting with teacher at school	▪ Interview (I.1)
October 2014 to February 2015		Meeting teachers to conduct lesson observation and follow-up interview	▪ Lesson observation (O.1) ▪ Interview (I.2)
Dec 2014	Workshop 1		▪ Researcher's journal
Feb 2015	Workshop 2		▪ Researcher's journal
May 2015	Workshop 3		▪ Researcher's journal
		Meeting teachers to conduct lesson observation and follow-up interview	▪ Lesson observation (O.2) ▪ Interview (I.3)
June 2015	Closure of the PD programme		▪ Focus group interview (FG.3)
		Final meeting with individual teachers	▪ Interview (I.4)
May – June 2016		Meeting individual teachers a year after the PD programme	▪ Interview (I.5)

6.5.1 Questionnaire

In this research study a questionnaire was designed to generate the teacher's profile at the beginning of the study. Although questionnaires are generally associated with collecting data from a large number of respondents, they can also be used with small groups of people in order to gather the participants' views, attitudes, preferences, feelings and beliefs about a particular situation. By using a questionnaire the respondents answer a set of identical questions ensuring consistency (Denscombe, 2014). Questions need to be unambiguous, simple and straightforward and have clear instructions, since the researcher is not in a position to probe further to understand how respondents interpret the questions asked (May, 2011). Questionnaires are generally piloted to check for accuracy in wording, interpretation of questions and instructions as well as for the time taken by the respondents to answer (Bell, 2010). The questionnaire was piloted with six science teachers teaching integrated science at my school prior to the research study. Amendments were carried out and a copy of the final version of the questionnaire is found in Appendix 5.

The questionnaire was used to gain factual information about the participants' background as well as the first insights of the challenges that teachers encounter when teaching outside their area of expertise and the strategies used to face such challenges. It was divided into three parts. The first part gathered information about the participant's background, that is qualifications, years of teaching experience, background in chemistry. The second part consisted of a number of open and closed questions. In answering closed questions respondents selected an answer from a given range of responses, hence comparison between answers could be drawn between the different participants. In answering open questions respondents provided a more detailed view of their opinions since they were expressing their ideas in their own words (Denscombe, 2014). In the second section teachers were asked about their attitudes, beliefs, challenges and behaviours when teaching within and outside subject specialism. Teachers had to indicate their level of confidence in teaching different topics within the science curriculum. A set of ten paired statements were constructed about teaching within and outside specialism (see Appendix 5). The third part of the questionnaire investigated the strategies adopted by teachers when teaching within and outside specialism.

In constructing the second part of the questionnaire I based the questions on existing instruments retrieved from literature. Riggs and Enochs (1990) created a 'science teaching efficacy belief instrument' (STEBI) for primary teachers to be able to explore the teacher's beliefs about science teaching and learning at primary level. Kind (2009a) devised a similar instrument based on the STEBI and adapted it to assess the teachers' personal characteristics when teaching within and outside specialism. It includes a set of four paired statements, based on a Likert-scale that focus on the teachers' attitudes towards the different subject areas, their general levels of confidence, their ability to handle questions and their preference for teaching a subject within and outside area of expertise. The statements are paired as according to Kind (2009a) it enables examination of inconsistencies in the response patterns.

I used these ideas and extended them by devising ten paired statements to explore the personal characteristics of the teachers and challenges encountered when teaching within and outside specialism as outlined in Chapter 3. These statements not only assessed the teacher's level of confidence, area of preference, attitude and handling of questions as in Kind's (2009a) study. They also addressed further aspects such as the ability to set up and conduct experiments, the ability to explain concepts and simplify ideas, the ability to link various concepts, the identification of misconceptions, and the ability to devise activities when teaching within and outside specialism. Another statement explored whether teaching experience helped the teacher to gain confidence in teaching outside their area of expertise. The five-point Likert scale was used with the following response categories: 'strongly agree', 'agree', 'uncertain', 'disagree', and 'strongly disagree'.

The third part of the questionnaire aimed to explore the range of strategies used whilst planning and developing lessons in their specialist and non-specialist areas. Teachers had to tick how frequently they use these strategies by marking whether each strategy was 'generally used', 'often used', 'occasionally used' and 'not used at all'. This part of the questionnaire was also based on the questionnaire devised by Kind (2009a) where she asked the pre-service teachers to rank how often they used similar strategies to develop their subject knowledge.

The disadvantage of using questionnaires is that the researcher cannot check the truthfulness of the given responses especially when incongruent responses have been given, thus other research tools would be required to verify the disparity between data. Hence I used the data derived from each questionnaire during the first one-to-one interviews to gain an understanding of how each teacher feels when teaching outside specialism compared to when teaching within specialism. The insights gained from the follow-up interview were helpful to clear any ambiguous answers given by the teachers in the questionnaire and to gain further information about the participants' background and experiences as a generalist teacher and as a subject specialist.

6.5.2 Observations

Observations are a direct method of collecting data by gathering first-hand evidence in real-life situations in a particular context (Denscombe, 2014) in order to understand the situation being studied from the participants' perspectives (Hatch, 2002). In this study classroom observations were conducted along the year when teachers were teaching a chemistry topic in order to obtain a first-hand account of the teachers' experiences, behaviours and activities in their natural setting. The time of observation varied because lessons ranged from forty minutes to an hour or one hour and twenty minutes long. An average of two observations were carried out with each participant teacher. The initial set of lesson observations took place between October 2014 to February 2015, that is either prior to workshop 1 or after depending on the order of the science topics in the teacher's scheme of work. The last set of observations took place after the third workshop that is in May 2015.

Observations can be structured, semi-structured, or unstructured (Cohen et al., 2018). In this research study I opted to use unstructured observations as a means of gathering open-ended information through observing people and their behaviour at the research site (Creswell, 2013) rather than using structured observation with predetermined categories. Time spent in the field conducting unstructured observations was helpful to acquire insights and experiences of the teaching and learning processes in order to gain an insider's point of view of the classroom culture (Denscombe, 2014). This research tool was chosen in line with my ontological and epistemological perspectives to capture the multiple versions of reality as experienced and constructed by the participant teachers. These observations produced a rich and detailed description of the situation illustrating the complexity and interconnectedness of the social world being investigated (Denscombe, 2014). As a result knowledge could then be framed within the context in which it was generated.

Maykut and Morehouse (1994) recommend that in an emergent research design the observer should start with a broad focus of inquiry. During my initial observations I wanted to familiarise myself with the classroom context to obtain a holistic overview of the situation and learn about teaching outside one's area of science specialism. After conducting initial observations with different teachers I found that I started to focus on a number of observations that caught my attention such as the development of lessons, the explanation of particular terms and concepts, the emergence of misconceptions, the interaction between the teacher and students, the teacher's actions, decisions and behaviour and the way the teacher handled and answered the students' questions. I was also interested in observing lessons that included a teacher's demonstration of an experiment or students' experiments. I recorded any critical incidents or significant events taking place during the lessons since as Cohen et al. (2018) argue, these can provide important insights related to the person or situation. Observing the non-verbal behaviour (Cohen et al., 2018) such as the teacher's reactions, facial expressions and body language throughout the lessons was important as this could indicate the teacher's level of confidence and knowledge in teaching a particular topic.

In this process I reflected on my role as an observer and decided to take on the role of a non-participant observer by observing the classroom as an outsider to the group (Creswell, 2013). As Denscombe (2014) suggests, I tried preserve "the naturalness of the setting" (p. 210) by minimising disruption and thus I chose to sit in a place where I would not interfere with the lesson or students. As posited by Maykut and Morehouse (1994), I tried to avoid interaction and limit the engagement with the teacher and students by assuming an unobtrusive presence. I was aware and conscious that the teachers may react or behave differently when I was in the classroom. This is known as the 'observer effect' (Denscombe, 2014) where teachers can feel anxious, act defensively, disguise normal practice or try to behave differently in ways they think that the researcher wants to observe. I was concerned about this because the researcher in the role of the observer affects what is being observed and thus "the interdependency between the observer and the observed may bring about changes in both parties' behaviours" (Merriam & Tisdell, 2016, p. 147).

I acknowledge that it was difficult to maintain the non-participant observer role since the teachers knew that I am a chemistry teacher. In some cases I noticed that when teachers obtained anomalous experimental results they often looked at me to provide them with possible suggestions or interpretations since I was considered to be 'the expert' in the subject. At that point it was very difficult to avoid any interaction and I was caught trying to balance the tension between engagement and detachment (see Merriam & Tisdell, 2016). Eventually teachers found their own way of coping with such difficulties. They either re-cleaned the apparatus and repeated the experiment or changed some chemicals and conducted new tests. Time spent on site was beneficial to gain the teacher's trust and establish a better rapport as well as to minimise the 'observer effect' since the participants got used to me as a researcher and acted naturally in their own setting (Denscombe, 2014).

During the PD sessions I took on the role of a participant observer (Creswell, 2013) where I was simultaneously observing the participant teachers and at the same time taking part or facilitating some of the activities. As a participant observer I was listening, observing, asking and trying to understand the participants' reactions and views (Bell, 2010). As Creswell (2013) notes, by taking the role of the participant observer the researcher assumes the role of the insider whilst engaging in the activities. When teachers led the PD sessions, then I took on the role of a non-participant observer. Thus my role constantly shifted between trying to be a non-participant observer to provide time and space for teachers to voice their ideas to a participant observer when I was more involved in explaining or facilitating the PD session.

At this point it is important to problematise the role of an observer since this can be described as "subjective, biased, impressionistic, idiosyncratic and lacking in precision" (Cohen et al., 2018, p. 554). Researchers do not observe and record events in a simple, mechanistic straightforward manner. Denscombe (2014) argues that in practice there is always an "element of interpretation with the mind acting as an intermediary between 'the world out there' and the way it is experienced by the individual" (p. 207). Hence observations carry the risk of bias since what we observe is determined by our own perceptions, interests, experiences, emotions, personal factors and judgements. Mack, Woodsong, MacQueen, Guest & Namey (2005) propose reporting objective observations to reduce personal bias. Yet this can be rather difficult as the researcher is the main instrument of data collection and subjectivity cannot be excluded. To reduce this bias, Creswell (2013) recommends writing field notes by describing events, activities and people during observation sessions and then writing reflective field notes that consist of the researcher's thoughts, hunches, ideas and reflections based on the observations. Following these suggestions I kept notes describing the lesson flow, behaviours and interactions of students and teachers in the lesson. After the lessons I expanded and recorded reflective field notes that represented an active reconstruction of classroom events (Connelly & Cladinin, 1990).

Since observations are a subjective exercise where the researcher's perceptions might influence the observations recorded (Denscombe, 2014) I decided to conduct a follow-up interview after each class observation such that the interviews could help me understand the interpretation of the experience from the participants' point of view, where this is known as subjective understanding (see Seidman, 2013). After collecting data from class observation I asked the teachers to give their own interpretations of the lesson and of any critical incidents taking place. Such interviews are known as 'anchored interviews' since interview questions are derived from what was observed (Merriam & Tisdell, 2016). Data emerging from these interviews provided a more faithful interpretation of the observations recorded since the teacher's views, beliefs and experiences could be made more explicit. Interpretation of observation was not solely based on the researcher's perception of the situation but supported by the participants' views and interpretation of their reality.

6.5.3 In-depth interviewing

Interviews are a means of creating in-depth conversations with the participants (Maykut & Morehouse, 1994) by revealing their thoughts, feelings, experiences, opinions, values aspirations and attitudes (Denscombe, 2014; May, 2011). They also helped to build a good rapport and an atmosphere of trust between the researcher and participants. Considering the ontological and epistemological standpoints taken in this study, in-depth interviewing was chosen as a research tool to access one's perception of reality, ways of thinking, construction of meaning from experiences and interpretation of events. Like Seidman (2013), I was interested to listen to each participant recounting his/ her story as a means of understanding one's lived experience.

Interviews were conducted at different phases of the study as shown in Table 6.8. In-depth interviews in the current study provided profound insights into the teachers' concerns when teaching outside specialism, their experiences of the PD programme and their impact on their personal and professional identity. They were also carried out to validate the data collected by other instruments such as questionnaire and class observations. Each interview lasted around forty minutes to one hour. It was audio recorded and later transcribed verbatim. Interviews were held either in English or in Maltese. To ensure translation reliability when Maltese texts were translated into English I asked a colleague to translate the texts back into Maltese and any modifications were made. The interviews schedules are found in Appendix 6.

There are three common types of interviews; structured, semi-structured and unstructured (Braun & Clarke, 2013; Denscombe, 2014; Merriam & Tisdell, 2016). In a structured interview the researcher asks a series of predetermined questions without deviating from the interview schedule or prompting the participant to give further views. This format standardises the data collection process (Denscombe, 2014) such that responses can be compared (see May, 2011). Opting for this type of interview can be somewhat limiting since it does not allow the researcher to access the participants' perspectives and understanding of their context. This type of interview also assumes that researcher and participant share a common language since the questions posed will be interpreted by the participants and researcher in the same way (Merriam & Tisdell, 2016).

Table 6.8: Interviews held with participant teachers

Period	**Interviews**	**During the interview teachers:**
October – November 2014	Introductory meeting with individual teachers (I.1)	discussed their experiences as non-chemistry specialists and their reflections on the first phase of the PD programme. Data gathered from the questionnaire were discussed to sort any anomalous answers suggested a way forward in their learning journey so that the workshop sessions would target their learning needs
October 2014 – February 2015 May 2015	Interviews held after classroom observations along the scholastic year (I.2, I.3)	discussed and reflected on their lesson and on their experiences as non-specialist teachers reflected on how the PD could be shaping their practices suggested areas that needed to be targeted in the next PD session
June 2015	Final interview with individual teachers (I.4)	narrated their story as science teachers and reflected on the PD experience
June 2016	An interview held a year after the PD programme (I.5)	engaged in a retrospective reflective analysis of their participation in the PD programme and its effect on their teaching

In a semi-structured interview a list of questions or issues to be discussed are prepared prior to the interview. The interviewer has more flexibility in terms of the order in which the questions are posed and is free to probe beyond the given answers in seeking clarification and elaboration of the topic or issue being discussed. Through the semi-structured interview the interviewer and interviewee enter into a dialogue (May, 2011). The interviewee is given time and space to talk about a topic, develop ideas, give personal views and answers using their own words on issues being raised by the researcher. This permits the interviewer to understand how the interviewee generates meaning in social life.

The unstructured interview allows the interviewee to talk openly about a particular subject or issue from their own point of view. The role of the interviewer is to start the ball rolling by introducing a theme or topic and then allow the interviewee to develop their ideas and thoughts (Denscombe, 2014). The researcher still has a clear focus of inquiry in mind. Maykut and Morehouse (1994) argue that the researcher asks tactfully and listens actively to understand important aspects about the setting and the experiences of the participants in that setting. They point out that the questions are not written in advance but the researcher "asks questions pertinent to the study as opportunities arise, then listens closely to people's responses for clues as to what question to ask next, or whether it is important to probe for additional information" (Maykut & Morehouse, 1994, pp. 81-82).

In this research study I opted to use semi-structured interviews where I constructed open-ended questions based on either classroom observations, or on the responses of the questionnaire, or on previous PD meetings, or on a combination of these, to develop the conversation. Following Braun and Clarke's (2013) suggestion, semi-structured interviews were used to capture a range and diversity of responses using the participants' own words and expressions. Participants could provide in-depth and detailed responses and discuss any issues that were important to them. At times interviews can shift between semi-structured and the unstructured type where the researcher introduces a topic and gives space to the interviewees 'to speak their mind' and develop their thoughts (Denscombe, 2014). This happened more often during interviews after the lesson observations where the questions raised by the interviewer led to further questions and new areas which, as described by Merriam and Tisdell (2016), provided fresh insights and new information about the research study.

As Seidman (2013) recommends, during the one-to-one interviews I listened actively and attentively to gauge the interviewees' feelings both from their verbal and non-verbal behaviour. Tone of voice, body language and facial expressions of participants can provide further information related to the feelings and emotions experienced by the participants whilst relating their stories. Bell (2010) argues that one of the major advantages of using interviews is adaptability since the interviewer can follow ideas, probe answers and investigate feelings and motives to enable the participant to develop and clarify their answers. Probes were used to encourage teachers to open up and expand their ideas and explanations to explore their understanding and perspectives at a deeper level (Braun & Clarke, 2013). They were also used when the teacher's initial answers were limited or lacking detail and/or needed further clarification. During the interviews I made sure that I was correctly understanding and interpreting the participants' perspectives. At different points of the interview I asked further questions to ensure understanding or paraphrased the teachers' explanations and asked them to confirm whether I was accurately understanding and interpreting their thoughts and ideas. This technique was used as a means of checking and concluding discussions at different parts of interview before exploring further aspects.

I constantly reflected on the interviewer-interviewee relationship created during the interviews. Seidman (2013) argues that the interviewing relationship is a "reflection of the personalities of the participant and the interviewer and the ways they interact" (p. 97). I was concerned that the personal identity of the researcher such as age, gender, ethnic origin and particularly the occupational status can affect how much the participants are willing to share information with the researcher (Denscombe, 2014). My personality and background as a chemistry teacher and as a head of department could have easily influenced what the participants said or wanted me to know during the interview. Developing rapport is crucial in an interview setting, however Seidman (2013) recommends that rapport needs to be balanced since too much or too little can still lead to distortion in what the participant reconstructs in an interview. In this research process I tried as much as possible to build trust and develop a good and balanced rapport with the participant teachers that was marked by respect, interest, attention, honesty and being genuine. This helped the teachers to talk more freely and openly when they related their personal stories and challenges especially in the final interviews.

6.5.4 Focus group interviews

Focus group interviews are used to explore a specific theme or topic in more depth (Bryman, 2012) by exploring the attitudes, perceptions, feelings and ideas about a specific topic (Denscombe, 2014). Focus group interviews have three distinctive features that distinguish them from other types of interviews. According to Denscombe (2014) these include:

1. a focus is given to the session since the group of participants have similar knowledge and discuss common experiences;
2. the role of the researcher is to facilitate the group interaction rather than lead the discussion and
3. "emphasis is placed on group dynamics and interaction within the group as a means of eliciting information" (Denscombe, 2014, p. 189).

Social interaction is crucial in a focus group interview (Braun & Clarke, 2013) as participants are explicitly encouraged to talk to one another and discuss the topic within the group (May, 2011). In focus group interviews participants can raise questions and challenge each other, thus providing a more detailed account and type of data that were not collected through individual in-depth interviews. The interaction can reveal the reasons behind the views and opinions of the different group members. Discussion within the focus group can either lead to a consensus of shared viewpoints or expose significant differences with regard to opinions and feelings by the different group members. As Denscombe (2014) argues both types of discussions are valuable to the researcher since they provide an insight into the participants' views and why they hold particular points of view.

The focus group interview as a research tool provided valuable in-depth information in this study since it illustrated how participants think about an issue or a particular situation, whilst giving their reasoning and explanation of why they hold particular views and beliefs (see Bell, 2010). Moreover, like Bryman (2012), I chose to use focus group interviews since as a researcher I was interested in noting the group dynamics, in particular how participants listened and responded to each other, and how they built, reviewed or refined their views and perspectives as they constructed meaning from the interactions taking place.

Three focus group interviews were held at different stages of the study. The first focus group interview (FG.1), held on the first day of the INSET, was used to gather the participants in a focused discussion to explore the feelings and challenges related to teaching outside specialism. It also explored the teachers' experiences and ways of tackling different chemistry topics that are perceived to be easy or more difficult to teach. The second focus group interview (FG.2), held at the end of the three-day INSET, gauged the teachers' feelings and learning experiences after the INSET. The last focus group interview (FG.3) was held at the end of the year as a means of concluding the PD experience. The aim behind it was to find out how the participant teachers felt whilst working together when they engaged in dialogue, constructed and negotiated meaning among one another. They were also asked to comment and reflect on whether they felt that they had formed a community of learners.

I designed an interview guide that included open-ended questions and a variety of issues that could be discussed (see Appendix 6), however the development of a focus group interview was quite fluid. As a researcher I followed the arguments created during the discussion, as well as the group dynamics and how the different participants influenced each other's thoughts and reactions. All the participants were encouraged to express their views and opinions and I posed questions and prompts to open the conversation and promote further interaction between members that led to further elaboration of ideas and opinions. As suggested by Denscombe (2014) it was important to establish a climate of trust. In fact as a researcher or moderator my aim was to create an atmosphere where participants would feel at ease and sufficiently comfortable to express themselves freely, also ensuring that the matters discussed were kept confidential within the group and were not disclosed outside the group.

Braun and Clarke (2013) regard focus groups discussions as a means of empowering individuals since from the discussions participants can realise that they are experiencing common difficulties and therefore not as different from other participants. Data gathered from focus group discussion can also be used to show how the perspectives and views of the teachers may change along the research study. In focus group interviews data are socially constructed as a result of the group interaction. Therefore, as Merriam and Tisdell (2016) argue a constructive perspective underlies this data collection procedure.

6.5.5 Reflective Journal

A reflective journal can help the researcher to log the experiences, decisions, observations, casual conversations, insights, beginning of understanding, hunches, concerns, feelings and emotions that the researcher goes through in a research study (Maykut & Morehouse, 1994). The journal entries provide a retrospective account of how the experiences gathered by the researcher are seen from the researchers' point of view. The interpretation of events are "filtered through the writer's past experiences, own identity, own aspirations and own personality" (Descombe, 2014, p. 228).

During the research study I kept a journal in which I included all my thoughts, questions, ideas, reflections, concerns, decisions and feelings throughout this journey. Whilst reading the literature, I kept a note of the most striking aspects that enabled me to understand concepts, theories and formulate further ideas. As a researcher I was deeply involved in capturing the teachers' lived experiences to find out how they were experiencing the phenomenon of teaching outside their science specialism. Although I was quite familiar with the different school contexts, as a researcher I did not share a common identity with the participant teachers since we had different backgrounds with regard to subject content, PCK and beliefs about teaching chemistry. Writing and reflecting on these different perspectives was important to try and capture these particular realities or set of different realities as experienced by the different teachers.

Journal writing, as described by Creswell (2014), helped me to ponder and make explicit my own subjectivity, my background, values, biases and experiences and how these could affect the collection and interpretation of the data. The journal entries encouraged me to be more reflexive, to critically reflect on the knowledge that was being co-constructed by and with the participants in this particular context. They also provided an understanding of the important experiences, ideas, concepts and themes in the data which were used to interpret the constructed knowledge during the analysis phase (Maykut & Morehouse, 1994).

6.5.6. Methodological Triangulation

Multiple methods of data collection could provide a more comprehensive picture of the results than a single approach could do on its own. Due to the complexity of the study, I felt the need to use more than one method of data collection in order to explore the different research questions. Triangulation was carried out to compare and cross-check data collected from different sources (Merriam & Tisdell, 2016) so as to increase the confidence in the research findings and provide information from different rigorous approaches. Table 6.9 shows the triangulation of data sources used to answer the research questions.

Table 6.9: Triangulation of data sources used to answer the research questions

Research questions	Research tools
Outlining the challenges that teachers faced when teaching outside specialism	▪ Questionnaire ▪ Focus group interview during INSET (FG.1) ▪ Interviews (I.1, I.2, I.3, I.4, I.5) ▪ Lesson observations (O.2, O.3)
Strategies used to deal with challenges	▪ Questionnaire ▪ Focus group interview during INSET (FG.1) ▪ Interviews (I.1, I.2, I.3, I.4, I.5) ▪ Lesson observations (O.2, O.3)
Professional development: type of support structures required	▪ Focus group interview during INSET (FG.2) ▪ Interviews (I.1, I.2, I.3, I.4, I.5) ▪ Closure of the PD programme (FG.3) ▪ Researcher’s journal

6.6 Data Analysis

Whilst analysing data I engaged in a process of making sense of the data (Hatch, 2002; Merriam & Tisdell, 2016) by trying to organise and explain the data. In other words, I sought to examine the meaning of participant words and actions (Maykut & Morehouse, 1994) by noting patterns, regularities and themes. As Merriam and Tisdell (2016) argue, this involved

> … consolidating, reducing and interpreting what people have said and what the researcher has seen and read – it is the process of making meaning. Data analysis is a complex procedure that involves moving back and forth between concrete bits of data and abstract concepts, between inductive and deductive reasoning, between description and interpretation (p. 202).

Since qualitative research is emergent, both Hatch (2002) and Merriam and Tisdell (2016) recommend to analyse data during the collection stage in order to provide a direction for the subsequent collection of data. In this manner the researcher can collect more focused data that addresses the problem at hand and avoids collecting repetitive data. Bogdan and Biklen (2007) also recommend such a strategy in order to plan the data collection sessions based on previous observations. Hence I started carrying out an informal analysis during the data collection period. Whilst reading the transcripts I started writing down comments and observations to summarise the most salient points emerging from the interviews. Whenever I did not manage to work on the transcript due to time constraints I went back and listened to the original recordings to conduct this exercise. I was using the participants' words and descriptions to capture as much as possible their feelings and experiences of their realities. This process generated points of interest in the data and further questions that were asked in the next interview; hence the previously collected data were used to inform the next data collection procedure. In the next set of interviews I still remained open to gathering new findings which had not emerged in previous meetings. Since this exercise was taking place after every interview I started building a teacher's profile and with time I started noticing changes in attitudes and/or practice. Previous examination of data was especially important in preparation for the last interview where participants were asked to relate their stories and their journey of professional development and identity as science teachers.

I decided to transcribe the data myself even though it was a very laborious process. First of all I wanted the data collected to remain confidential as promised in the information letter. Secondly as Merriam and Tisdell (2016) suggest, transcribing one's own interviews "is another means of generating insights and hunches about what is going on in your data" (p.

200). Whilst transcribing the data I started thinking about categories and themes leading to a rudimentary analysis of the data.

The next step was to start analysing the data, where Hatch (2002) explains that analysis means "organising and interrogating data in ways that allow researchers to see patterns, identify themes, discover relationships, develop explanations, make interpretations, mount critiques or generate theories. It often involves synthesis, evaluation, interpretations, categorisation, hypothesising, comparison and pattern finding" (p. 148). I used thematic analysis to analyse the data since my intention was to identify, analyse and report patterns of themes within the data (Braun & Clarke, 2006). I followed the guidelines outlined by Braun and Clarke (2006) when conducting thematic analysis which include (1) familiarising oneself with the data, (2) generating initial codes, (3) searching for themes (4) reviewing themes, (5) defining and naming themes and (6) writing the report.

The first step was to immerse myself in the data by reading through the various transcripts. I listened again to audio recordings to capture the participants' tone of voice and feelings and get impressions of meanings. Whilst reading the transcripts I split the teachers' conversations in sections or 'units of data' (Bogdan & Biklen, 2007) whenever the teacher mentioned a particular issue or topic or piece of information. A code or phrase was assigned to each section which summarised the salient aspect of the conversation. Clarke and Braun (2014) denote that coding is an "analytic process that captures both semantic (surface) meaning within the data and latent (underlying) meaning" (p. 1948). A notation made up of letters and numbers was given to create a reference system indicating the teacher's pseudonym and when it was said. Frequently the codes were derived from the participants' words to capture their thoughts and meanings (Saldana, 2009), thus remaining truthful to the participants' realities. An example of how the data was coded is found in Appendix 7. Coding was done manually creating several tables using word documents. A list of codes was generated after coding all the interviews and observations collected for one of the participant teachers. This list was used to code new data collected from the other teachers. It was an iterative process as the list was frequently amended when coding new transcripts and new codes were also added. By the end of this exercise I had eight data sets, one for each teacher. The last data set included the data gathered during the PD sessions, that is data from the three focus group interviews and my personal journal entries written after each PD sessions. The last set of data was also coded in the similar manner as the previous data sets.

The next task was to compare the codes and look for patterns in the data such as similarities, differences and causality (Saldana, 2009). Similar or related codes were grouped into categories. Category construction is highly inductive (Merriam & Tisdell, 2016). When searching for patterns of meaning in the data, general statements about the phenomenon being investigated can be made. Merriam and Tisdell (2016) do not distinguish between the terms 'category' and 'theme' and in this thesis the term 'theme' is used. Following Clarke and Braun (2014) themes were "analytically constructed from coding… (to) capture broader patterns of meaning within the data" (p. 1948). I started by first comparing the codes and grouped similar ones into themes for each data set. The themes generated during this process included teachers' background, teaching science, challenges when teaching outside specialism, strategies used to deal with the challenges, professional development, community of learners and improvements.

The next step involved revising the themes (Braun & Clarke, 2006). I started comparing the data for each theme from the nine data sets and looked for connections within each theme. This was done by copying the coded data from the nine sets of each theme on a document and looking for relationships within the theme. Sub-themes were then be derived once all the data of a particular theme were compiled together. However, this was not a straight forward process as some units of data had to be moved from one theme to another or into different sub-themes. To facilitate this process I proceeded to draw mind maps for each theme to find relationships between elements within a theme. Mind maps were also revised and refined to check coherency within the theme. A sample of the mind map is found in Appendix 7. Table 6.10 shows the main themes and their sub-themes derived after constructing several tables of data for each theme and drawing mind maps. I was aware that data analysis was not going to be a linear process but one which was recursive and it involved moving back and forth between the data and the themes, but this process was necessary to refine the trend of thoughts within the themes.

Table 6.10: Themes and sub-themes derived from the data

Themes	**Sub-theme**
Teaching Science	type of teacher (specialists vs generalists)
	teaching within specialism
	teaching outside specialism
	views re integrated science
Challenges when teaching outside specialism	challenges encountered when planning lessons
	challenges encountered when teaching
Strategies to deal with challenges	proactive strategies
	coping strategies
Professional development	reasons for participating in PD
	PD design
	characteristics of PD
	teachers' experiences of the PD
Community of learners	formation of a community of learners
	defining a community of learners
	learning through discussions and sharing of ideas
	reflections
	impact on self-efficacy
Improvements	improvements in the chemistry lessons
	changes in the teacher's perception

During the process of data analysis, I was again aware of my own biases and preconceptions since these influenced the data analysis process. Data analysis relies heavily on interpretation. Bryman (2012) calls it a 'double interpretation' since the researcher provides an interpretation of the participants' interpretations of their world. With this in mind I tried to be as reflexive as possible where in my reflections and interpretations I constantly identified my biases, values and background in order to ensure greater authenticity and transparency during the data analysis and in the writing up of the research.

6.7 Validity and reliability in qualitative research

Ensuring validity and reliability means that the research has been conducted in an ethical manner. Validity and reliability in qualitative research cannot be judged using the same criteria as in quantitative research. It is rather difficult to replicate a qualitative research study because the outcomes depend on and are influenced by the social context, the individual participants and by the researcher (Denscombe, 2014). However there are other means to show that these criteria can hold in qualitative research. Merriam and Tisdell (2016) speak of trustworthiness, rigour and authenticity in interpretative qualitative research rather than validity and reliability. These criteria are more in line with the ontological and epistemological views of qualitative research. Other terms such as 'credibility' and 'dependability' are applied in qualitative research and substitute terms like 'validity' and 'reliability' that originate in quantitative studies (Lincoln & Guba, 1985 as cited in Denscome, 2014).

Validity or credibility can be demonstrated by finding ways to show that the data are accurate, appropriate and capture reality. However reality in constructivist qualitative research is not a fixed entity waiting to be discovered, but it is multidimensional, constantly changing and constructed by how participants experience and make meaning of their own reality. Researchers being the primary instrument of data collection and analysis have a key role in interpreting the participants' reality based on the participants' perspective. Thus the qualitative researcher "can never capture an objective 'truth' or 'reality'" (Merriam and Tisdell, 2016, p. 244). Denscombe (2014) and Merriam and Tisdell (2016) suggest a number of strategies to ensure credibility. Following their suggestions these strategies were followed to increase the credibility of the work presented. These included:

- 'respondent validation' or 'member check' where transcripts were sent to participants for verification and to check for misinterpretation,

- spending a long time in the field to generate grounded data,

- triangulation of different data sources such observations, interviews and reflections recorded along the data collection period, used to compare and cross-check data to provide an accurate picture of the situation; and

- being reflexive by reflecting on how my background, values and biases affecting the research process and how the research study had shaped my own knowledge from an interpretive constructivist framework.

Triangulation of data and engaging in reflexive thinking also increase the dependability or reliability of the data. Since human behaviour is constantly changing and highly contextual, it is difficult to produce the same reality. However, I wanted to ensure that "the results are consistent with the data collected" (Merriam & Tisdell, 2016, p. 251). Hence recording entries in my reflective journal related to decision-making processes, the methods used, the data collection exercise, the derivation of themes and the analytic procedures used to arrive at particular conclusions increased the dependability of the study.

6.8 Reflections on the research process

This research process involved various stages that started by entering into the field and seeking potential participants, designing and implementing the PD programme and collecting the teachers' experiences when teaching outside specialism and during their professional learning journey. With this study I had a dual role of a researcher and a designer of the PD programme. As a researcher I always viewed the participants as collaborators to the research process. I wanted to make the participant teachers feel at ease and comfortable to share their personal stories and experiences. My aim was to establish a relationship of trust and good rapport based on transparency to make the research process more authentic and keep teachers away from harm and distress. I also wanted teachers to benefit from the research process by gaining various resources to enhance their teaching. Teachers also became co-researchers in this project (Maykut & Morehouse, 1994) because they had the opportunity to reflect on their own practices, experiment with new ideas and discuss their experiences within the learning community.

As a designer of the PD programme I aimed to develop a programme that would enhance the teachers' SMK, PCK and their beliefs and attitudes towards the subject. In this programme teachers took an active role in the learning by working in collaboration on materials that could be used in their classes. I wanted to give voice to the teachers by giving them the opportunity to set their learning goals. Hence as Hawley and Valli (1999) suggest teachers determined the learning agenda of the second phase of the programme. Thus my role as the PD designer of the programme became more of a facilitator in supporting teachers to address their needs and accompanying them on their learning journey.

Part IV

Research findings

Overview

Part IV describes the research findings of this study by representing the teachers' journey and their views about teaching outside their science specialism in as authentic a way as possible. The first chapter of this section (Chapter 7) introduces the participant teachers, their backgrounds, experiences and their view of themselves as teachers of integrated science and teachers of their specialist areas. This is then followed by two major themes that answer the first two research questions, namely the challenges faced by the teachers as they taught outside their area of expertise and the support mechanisms they used to overcome the challenges. Chapter 8 presents the lived experiences of the teachers and the tensions that they faced as they juggled their multiple identities when they taught the different science disciplines. Chapter 9 then looks at the strategies that teachers used to be able to cross the boundary between teaching their specialist and non-specialist area. The last two chapters then delve into the professional learning experience where Chapter 10 describes the teachers' experiences during the PD programme. Finally Chapter 11 provides closure to the narratives by describing the teacher's learning journey and how this impacted their identity as science teachers.

Chapter 7

The science teachers in the professional learning journey

7.1 Introducing the participant teachers

I met the participant teachers at the beginning of their professional learning journey during the INSET sessions. It was also at this point that the teachers came together as a group and started to get to know one another. Initially ten science teachers accepted to take part in this research study. However two of the teachers opted out after the first phase of the PD programme and eight teachers participated in the second phase of the programme. Out of these eight participants seven were female and one male. Laura, Sarah, Daniela, Amy and Robert were teaching in a boys' church school while Christine, Maria and Karen were teaching in a girls' church school. They were all teaching integrated science to Year 7 and/or Year 8 students. Six out of the eight teachers were also teaching their specialist subject, that is biology or physics, to older students. Laura and Daniela were school colleagues, as were Robert and Sarah. The teachers had different years of teaching experience. Sarah, Amy, Robert, Karen, Maria and Laura were early career teachers having from one to five years of teaching experience, while Christine and Daniela were middle career teachers having between six to fifteen years of teaching experience.

The participants had different backgrounds in chemistry. Christine, Robert and Maria had never studied chemistry, not even at secondary school. They studied physics as their main compulsory science subject at secondary school and Christine studied biology at Advanced Level. Laura and Karen obtained their Secondary Education Certificate in chemistry and continued to study chemistry at Intermediate level during their post-secondary education. Sarah, Daniela and Amy had the highest qualifications in that they had obtained a pass in chemistry in their Matriculation Certificate (Advanced Level). Table 7.1 provides a profile of the eight participant teachers.

Table 7.1: Profile of participant teachers in the research study

Teacher	Qualification	Subjects	Teaching in	Subjects taught	Teaching experience	Chemistry background
Amy	B.Ed. (Hons.)	biology & science	boys' church school	integrated science, biology	less than 5 years	Advanced Level
Daniela	B.Ed. (Hons.)	biology & EMY[6]	boys' church school	integrated science, biology	more than 10 years	Advanced Level
Sarah	B.Ed. (Hons.)	biology & science	boys' church school	integrated science, biology	less than 5 years	Advanced Level
Laura	B.Ed. (Hons.)	biology & science	boys' church school	integrated science, biology	5 years	Intermediate Level
Karen	B.Sc. (Hons.) M.Sc. PGCE	mathematics & physics	girls' church school	integrated science, primary science	less than 5 years	Intermediate Level
Christine	B.Ed. (Hons.)	personal & social development	girls' church school	integrated science, biology	between 5 and 10 years	never studied chemistry
Maria	B.Eng. (Hons.) PGCE	science	girls' church school	integrated science	less than 5 years	never studied chemistry
Robert	B.Ed. (Hons.)	physics & science	boys' church school	integrated science, physics	less than 5 years	never studied chemistry

In Chapter 1, teaching outside one's area of science specialism is defined as teaching a subject in which the teachers do not have a degree level or an Advanced Level in the subject (Childs & McNicholl, 2007). In this study, three teachers had an Advanced Level qualification in chemistry. They did not consider themselves to be subject specialists in chemistry and opted to participate in the study because they believed that they did not have enough competence and confidence to teach chemistry units. Amy and Sarah were early career teachers and wanted to learn about different teaching approaches. Daniela had never taught integrated science to younger students. She felt like a novice teacher and wanted to participate in the PD

[6] EMY: Early and Middle Years

programme to refresh her content knowledge and gain further ideas to teach chemistry. This implies that within this study, 'teaching outside one's area of science specialism' means that teachers are teaching a subject in which they do not have degree qualification.

7.2 Teachers' perception of themselves as science teachers

During my initial encounters with the participants, especially during the first interview when discussing their profile outlined in the questionnaire, the teachers' perception of themselves as science teachers started to take shape. Their narratives provided interesting and important insights related to how they felt when teaching a subject outside their area of expertise. Their stories gave a glimpse into their sense of self that was influenced by their background experiences as young learners. Each participant teacher told a personal story of how they viewed themselves as teachers of science.

7.2.1 Amy

Amy did not initially aspire to become a teacher but wanted to specialise as a midwife. She later changed her mind and went into teaching because she "*wanted to go into something familiar.*" After her field placement Amy felt that she had made the right decision when she completely fell in *"in love with this work."* By this time, she felt *"very strongly about teaching."* She worked hard and was very considerate of her students' needs. She explained, "*teaching is really a rewarding experience because I can share my love of biology with others is what I appreciate most."*

Amy graduated with a B.Ed. (Hons.) degree specialising in biology and science and felt more confident teaching biology. She could relate more *"fun facts"* in biology due to her wider knowledge in the subject and admits that *"students like these little snippets."* She felt rather limited when it came to relating similar examples in chemistry and physics. Amy got rather nervous and *"out of her comfort zone"* when teaching chemistry due to her prior school experience. In fact chemistry was not Amy's favourite subject and her dislike of chemistry started at post-secondary school. When interviewed she described how:

> *I started to dislike chemistry at sixth form. In first year I failed a test. The first time I failed a test in chemistry, in energetics, I will never forget it… it completely threw me because I was not expecting it… I thought I had studied it and I had panicked.*

From then onwards she "*completely lost faith"* in the subject and never managed to gain back enough confidence in chemistry. She confessed, *"I have never liked chemistry. Because I failed in one test, one time, that was it! I lost confidence and that is how it started and from there I have never fully recovered."* Although Amy did not feel confident in chemistry topics, surprisingly she admitted that she enjoyed teaching it due to the number of experiments that could be carried out. Yet she encountered a number of challenges related to practical work, like explaining chemical reactions and unexpected experimental results. Amy viewed herself as a biology teacher but she did not mind teaching outside specialism. However she only felt able to teach chemistry and physics till Year 8 and not at higher levels.

7.2.2 Daniela

Daniela graduated with a B.Ed. (Hons.) degree specialising in biology. She had been teaching biology to older students for more than ten years and consequently described herself as a biology specialist. Since this was her first year of teaching integrated science she felt "*like a new teacher in science.*" However she was *"enjoying teaching science*" and acknowledged that she was:

> *…not feeling the same as I do when I teach older students… that is the feeling that we will not manage to finish. There is less pressure. I can spend time playing around with things; I can experiment more and give time to observe.*

As a student Daniela was not so confident in chemistry and used to feel *"hopeless in the organic part of O Level and A Level chemistry."* However, she related that she *"was not afraid of the inorganic and the physical part of chemistry.*" At the beginning of her teaching career Daniela taught some chemistry and physics units to Year 9 students. She recalled that when she started teaching she needed to conduct research in all subject areas. Daniela did not mind teaching outside specialism yet she emphasised that preparation is required to feel knowledgeable in all areas of science. She pointed out that:

> *I do not mind teaching topics outside my specialism: I teach these subjects but it requires a lot of preparation… especially those areas that I did not teach when I taught in Year 9. If it were biology I know it inside out, whereas in the other areas I wouldn't like to be unprepared.*

Daniela felt rather apprehensive it having been her first time teaching chemistry. In spite of these concerns Daniela liked teaching chemistry, at times even more than the other science subjects because she liked *"to do many hands-on experiments*" with her students.

7.2.3 Sarah

Sarah always wanted to become a teacher and did not regret taking this decision. Initially she "*did not know what to choose, whether biology or chemistry*" for her teaching degree. Sarah liked both subjects but she "*always preferred biology"* and in fact she opted to further her studies in biology. She stated that:

> *I always wanted to become a teacher and science was my best subject. I never had teachers who inspired me nor were role models at secondary level except for the biology teacher. I think that the biology teacher helped me and motivated me to choose my career. I would like to keep on teaching science because it is more fun for Year 7 and 8 students. I try to pass on my enthusiasm to the students so maybe they will opt for science subjects.*

Sarah preferred to teach her subject specialism but did not mind teaching outside her specialism. She loved to teach both biology and science and argued: "*I would not say that I am only a biology teacher. I like science as much as biology. If the headmaster asks me to choose between the two I would be confused because I like both of them."*

Sarah believed that she had a good background in chemistry and felt comfortable teaching it. She argued, *"I was never afraid of chemistry topics because I always liked chemistry, so I don't think it was an issue."* She felt *"more confident in teaching chemistry topics in science especially due to the hands-on activities."* In our conversations I found out that Sarah lacked self-esteem and at times it affected her confidence to teach science and biology. Being an early career teacher she wanted to gain more self-confidence and learn about different pedagogical approaches in chemistry even though she felt that she had a good background in the subject.

7.2.4 Laura

Laura graduated with a B.Ed. (Hons.) degree specialising in biology and science. She considered herself to be a biology teacher since she had been teaching the subject for the past five years when we met. Her experience in teaching science was relatively new, since this was her second year of teaching the subject when she was interviewed. She felt very confident teaching biology topics because as stated during an interview, *"I teach biology for O Level so for me it is easy to do it again with the younger students."* Laura believed that a science teacher should teach all the subject areas at Year 7 and 8 to give a holistic picture of science. For this reason she admitted that she did not mind teaching outside specialism. However, when it came to teaching chemistry Laura felt very differently. In the previous scholastic year, there had been times where she felt "*very insecure and out of [her] comfort zone*" in chemistry. She described her knowledge of chemistry as:

> *...still very weak because my foundations aren't good and it will be very difficult for me to feel confident because if you don't have a good basis… it is like a language, if you don't know the alphabet you cannot learn how to spell…. That is how I feel about chemistry!*

Laura attributed her lack of knowledge in chemistry to the way in which she learned and was taught chemistry as a secondary school student. She explained how, "*at school my teacher was not good… even practicals, most of them used to be demonstrations. We never used to do any practicals ourselves. I did not have the practical experience with regard to chemistry."* Even after post-secondary school Laura felt that she did not manage to grasp the most basic concepts in chemistry. She did well in her Intermediate chemistry examination because she learned everything by rote. In reality no deep learning was taking place, because as Laura explained:

> *I don't have a good foundation in chemistry. Alright I have an A in my Intermediate, but it's because I studied. I had to do the resit to get an A… and because I studied practically everything by heart... not because I understood the basics. I still don't understand them…. Things like valencies, how to write chemical equations…I studied them, but I still don't know exactly what is going on. I know how to balance equations because I had to learn that because of biology as well.*

Laura had carried this sense of insecurity into her chemistry lessons. Due to her own negative experiences with chemistry and practical work as a student, Laura described herself as having very limited knowledge about activities and experiments. She felt constantly on edge when doing chemistry experiments because she believed that she cannot explain what is happening in chemical reactions.

7.2.5 Karen

Karen graduated with a B.Sc. (Hons.) degree specialising in mathematics and physics and then read for a PGCE in science. Karen "*always used to like chemistry*" as a young student and sees it "*as interesting and very actual.*" She felt confident to teach a range of topics from the different science disciplines. She claimed to be a generalist teacher rather than a subject specialist and did not mind teaching outside specialism. She managed to teach chemistry topics quite well due to her background in chemistry. However she admitted that she would not feel so capable of teaching chemistry to older students and "*would struggle to teach chemistry at O Level.*"

Karen's insecurities and uncertainties revolved more around her teaching skills. She was concerned that her lessons were too traditional and involved a lot of teacher talk. Her first year of teaching was very challenging and she explained that:

> *Personally what I found most difficult was that as soon as I started teaching I had four different years in primary and one year in secondary so I had to prepare five schemes of work at one go… as well as lessons plans. I wanted to use an inquiry based approach but I had to prepare notes, resources… it was too much!*

Karen found it challenging to teach abstract concepts both within and outside specialism. For instance she explained that students found it very difficult to understand the concept of nuclear energy because it was "*abstract*" and they had never seen a nuclear power station. She argued that although these concepts were within her area of specialism, at times she found it difficult to adapt to the students' level. She explained, "*I do not like teaching abstract things. I find it more difficult to teach abstract concepts rather than teaching outside specialism.*" Since Karen was an early career teacher she encountered more issues related with her teaching rather than teaching outside specialism.

7.2.6 Christine

Christine always wanted to become a biology teacher but could not do so because she had no qualifications in chemistry. She still went into teaching and graduated with a B.Ed. (Hons.) specialising in personal, social and career development (PSCD). She started teaching PSCD together with science. When the opportunity to teach biology came up at her school she switched to teaching biology and science. Christine admitted that initially she encountered some challenges to teach biology, however she managed to overcome these due to her motivation and support from colleagues. She stated that:

> *I always wanted to teach biology but I did not have chemistry so they did not let me go for biology. At first it was difficult because I had last done biology when I was at Sixth Form but if you like biology you will manage. Then the resources, the other teachers were helpful.*

Christine had to learn chemistry when she started teaching science. She did not study chemistry at secondary school, thus she lacked confidence due to her limited background. Christine recalled that she used to feel very hesitant in her initial teaching years and would read the chemistry lesson plan several times before going into class. She found tremendous support from her colleague who was a chemistry specialist. They worked in close collaboration, preparing and using the same schemes of work, lesson plans, resources and assessment tasks. Christine preferred to "*work with other teachers rather than working alone"* both when teaching science and biology because she could discuss her practice and concerns with other colleagues. She felt that she gained confidence due to her teaching experience and did not feel like a novice teacher when teaching outside specialism.

Christine considered herself to be a biology teacher and felt more confident teaching biology topics because she enjoyed them more. She did not mind teaching the other subject areas and claimed that she was "*still capable of teaching chemistry and physics topics even though they [were] not [her] areas."* She carried out prior preparation and research to ensure that she was passing on the correct information to her students. In our conversations, Christine pointed out that:

> *I prefer teaching within specialism however in science you need to teach physics and chemistry topics as well. I don't mind them, but I am more comfortable with biology. I still do some research. I want to do the lesson well and I want to know that what I am saying is correct. Since you have to teach the three areas you need to adapt.*

7.2.7 Maria

Maria never studied chemistry at secondary and post-secondary level. She initially graduated as an engineer and worked in the industry for a number of years. Then she decided to read for a PGCE and graduated as a science teacher. When studying to become an engineer she regretted that she had not studied chemistry at an earlier age and asserted, "*chemistry is a subject I lack… and I always say, whoever is into engineering should have chemistry, because at university I felt the need for chemistry and I regret never having done it.*"

Maria was most confident and comfortable teaching physics topics due to her "*background in physics and engineering*" because the topics *"are easier to understand and can be easily related to everyday life.*" She considered herself to be a physics specialist and acknowledged, *"physics is my forte."* When teaching physics she felt that she could *"get easily through it."* Speaking further, she asserted, *"I explain it and I have enthusiasm.*" Although she preferred to teach topics within her subject specialism, she did not mind teaching topics outside specialism. She thought that *"chemistry is such a beautiful subject and students adore it"* especially when they carried out laboratory activities. However Maria was aware that she could influence the students' perception in chemistry because she thought that "*if you are weak in that area, you will make students fear the subject."*

Maria felt very insecure when teaching chemistry due to her weak background, thus she admitted, *"I keep it vague, since I do not know the details."* Very often she got "*stuck"* because she had "*no background in the subject."* For Maria teaching chemistry was more challenging because as she explained, *"with lack of deeper knowledge it is difficult to adapt for students;"* hence Maria faced a considerable number of difficulties both when preparing and when teaching chemistry units.

7.2.8 Robert

Robert graduated with a B.Ed. (Hons.) degree specialising in physics and science. He was most confident teaching physics topics because as he explained, "*these are topics that I am most familiar with."* Robert was very apprehensive and became very concerned when teaching chemistry because he did not study the subject as a young student. He felt rather insecure and explained that he could not give the same type of lesson in chemistry as in physics. Consequently when he went for his chemistry lesson, he wondered and asked himself: *"Will I manage to succeed today?"* Since Robert lacked a background in chemistry he felt that he was "*just a bit ahead of the students"* and explained, *"I am learning chemistry with the students."* He was enjoying learning chemistry and doing experiments because it was "*practical, involves a number of hands on activities and students are learning about different materials from an activity. They are learning through first-hand experience."*

Robert mentioned a number of difficulties that arose in his chemistry lesson ranging from giving adequate explanations, tackling students' questions and practical work. In the previous scholastic year Robert had tried to avoid teaching chemistry and taught physics after the teachers at his school adopted a modular approach to teach science. In the year we met they had done away with the modular system and each teacher was teaching all the subject areas. Although Robert considered himself a physics specialist he did not mind teaching outside specialism as long as he carried out research to feel confident and knowledgeable enough to teach the area. He suggested that, *"the fact that I teach science subjects (means) I don't mind doing research and getting to know new things. I prefer physics obviously, otherwise I would not have chosen it but I don't mind going into other areas."*

7.3 Personal view of self when teaching science

The previous narratives provide the first insights of the teachers' own perceptions as science teachers. From the results of the questionnaire (see Appendix 8) and when listening to the teachers' conversations it was strikingly evident that teachers felt completely different when teaching the different science disciplines. A recurring theme throughout their narratives is the disparity and discontinuity shown in the levels of knowledge, confidence, behaviour and attitudes when teaching different areas of science. Six out of the eight teachers felt less confident in chemistry because of their past experiences of the subject and/or because of their inadequate knowledge base. These teachers had specialised in one subject area in their undergraduate studies, yet in science they had to tackle new content knowledge and pedagogy in subject areas they were less familiar with. As described by Hobbs (2013b) subject-specialist teachers "have conceptualised learning and teaching within the field of their specialist area, but are required to take on new knowledge, and find ways to translate or transform what they already know in another subject" (p. 7). Similarly the teachers in the current study were moving between different practices and domains of knowledge which triggered feelings of apprehension and insecurity.

When the participant teachers were teaching both their subject specialism and outside specialism, as Beijaard et al. (2004) states, they developed multiple identities according to the context they were teaching in. This affected the way they perceived themselves as science teachers because as the initial narratives indicate, most of the teachers were experiencing a different sense of self when teaching within and outside specialism. This led teachers to experience tensions between their multiple identities, because on the one hand they felt competent and secure to teach their subject area but experienced anxiety and frustration when teaching outside specialism. The teachers' multiple identities affected the way they perceived themselves when they claimed to be generalist or subject specialist teachers. In this study the teachers can be divided into two groups where Sarah and Karen perceived themselves as generalist teachers and Amy, Christine, Daniela, Laura, Maria and Robert viewed themselves as specialists teachers based on their subject specialism.

7.3.1 Perception of self as a generalist science teacher

A generalist teacher is one who feels comfortable teaching all science areas and shows no preference in teaching the different subjects (Kind, 2009a). As explained in Chapter 2, having deep content knowledge or what is referred to as SMK is one of the fundamental components needed for teaching. Furthermore the teachers' beliefs and orientation towards the subject shapes the type of affinity developed towards the subject. Karen and Sarah perceived themselves as generalist science teachers because they did not mind teaching chemistry even though it was not their area of expertise. They studied chemistry at post-secondary school and had positive experiences as young students. Sarah and Karen were not afraid to teach chemistry because they both liked the subject. Compared to the other teachers, Sarah and Karen spoke of fewer challenges in teaching chemistry; hence they experienced fewer disruptions between their multiple identities as science teachers.

Sarah and Karen were still early career teachers and they felt that they had a lot to learn to feel like expert teachers. As beginner teachers they had, what Feiman-Nemser (2003) describes as "legitimate learning needs that cannot be grasped in advance or outside the contexts of teaching" (p. 26). They were still building their repertoire of teaching activities and at times they felt insecure in terms of whether they were transforming content knowledge into appropriate activities, tapping the best resources, giving adequate explanations or answering students' questions. Sarah stated that since she is "*still starting [her] teaching career, every bit of help will be needed.*" Karen wanted to "*gain confidence in teaching chemistry based* *science topics and in planning inquiry-based learning activities or investigations."* She wanted *"to gain more ideas and resources"* to improve her teaching. Although Sarah and Karen referred to themselves as generalist teachers they still decided to join the PD programme because wanted to improve their practice and develop PCK.

7.3.2 Perception of self as a subject specialist teacher

Maria, Robert, Christine, Amy, Laura and Daniela felt more confident teaching their subject of specialism and claimed to be either biology or physics specialists. When teachers consider themselves as subject specialist they are expressing their attitudes and practices related to their subject. Moreover, they are defining their identity, which is related to what they know, what they feel more competent in, what they value and how they would like others to see them. In this case these teachers constructed their own teaching identity as subject specialists because they believed that they had (1) strong foundation of SMK and subject-specific PCK, (2) positive perceptions and attitudes towards their subject specialism and (3) some of the teachers had been teaching their area of specialism for a number of years. As Siskin (1994) argues they derived their professional identity from teaching their subject specialism because teaching their subject area influenced both their actions and attitudes.

The participant teachers felt more secure and knowledgeable in their area of specialism. Due to their well-developed subject-specific PCK they felt more capable to take decisions about the lesson organisation and could modify their lessons according to students' needs. Daniela believed that she knew "*biology inside out"* due to her teaching experience. Robert's strong affiliations and confidence in teaching his subject area are clearly evident when he describes himself as a physics teacher.

> *... in my specialist area, I can go into class, I can bring examples, I can give a lesson and do an experiment…. In physics it's OK. I go into class 'happy go lucky'. I am so familiar with the subject that I do not really need the teaching file.*

This strong identity in relation to subject specialism is a result of, what Whannell and Hobbs (2018) describe as, "a history of being thoroughly committed to the discipline" (p. 37). It also develops from being successful learners of the subject as young students. In fact Robert related that for his undergraduate degree he opted for physics because he found it easier than mathematics. He said, *"I chose physics because in maths I made an effort and in physics I almost made no effort and got the same mark, so I went for physics."*

Teaching experience helps teachers to gain confidence in teaching their subject area which in turn reinforces their self-perception as subject specialists and increases the sense of self-efficacy. In view of this Laura explained that, *"in biology I have got used to the experiments now…. I feel comfortable now, I know what to expect and I know why things don't work sometimes, it is pretty plain sailing now."* Whannell and Hobbs (2018) state that with time subject specialist teachers become more proficient in teaching their area of specialism. This was the main reason why Laura and Daniela perceived themselves as biology specialists because they had been teaching biology, to 14- to 16-year-old students, for several years thus gaining confidence and competence in their area of expertise. When these teachers switched to teaching science they felt they had reverted back to being novice teachers. In fact Daniela commented, *"I don't have experience in teaching science, so yes I am feeling like a new teacher."* Laura expressed that she felt like a novice teacher teaching science because *"everything was new and [she] did not feel that comfortable when teaching chemistry."* Moreover Laura felt that teaching science was different from teaching biology because:

> *Science in reality is very different from biology. You need to work more to make it fun …. You need to think of ways of making particular concepts interesting and may be a bit less abstract so that students are able to relate or understand what is happening.*

In other words when teaching science, Daniela and Laura felt they had to start afresh by revising their content knowledge and looking for interesting and engaging resources. This episode illustrates that for Daniela and Laura teaching biology was not the same as teaching science because they had to learn how to develop subject-specific PCK in science. When teaching a new subject both Daniela and Laura felt that they had to take on new identities and start thinking of themselves as science teachers rather than biology teachers. Kind and Taber (2005) point out that "time is required to make the mental shift to a new identity" (p. 16). Indeed in their narratives they still maintained that they perceived themselves as biology specialists, showing they had stronger ties with biology than with the other science subjects.

7.3.3 Teachers' attitudes towards teaching chemistry

From their initial profile the teachers demonstrated that they had different attitudes when teaching within and outside specialism. Table 7.2 shows the results of four of the paired statements of the questionnaire related to area of preference, level of confidence, attitudes and effect of work experience. Results of the questionnaire are found in Appendix 8.

Table 7.2: Results of four of paired statements from questionnaire

	Paired statements	Strongly agree/ agree	Strongly Disagree/ Disagree	Undecided
preference	prefer to teach topics within specialism	Amy, Christine, Daniela, Laura, Maria, Robert, Sarah	Karen	0
	do not mind teaching topics outside specialism	Amy, Karen, Maria, Sarah	Laura, Daniela	Christine, Robert
confidence	more confident teaching within specialism	Amy, Christine, Daniela, Laura, Maria, Robert, Sarah	Karen	0
	less confident when teaching outside specialism	Amy, Christine, Daniela, Laura, Maria, Robert, Sarah	0	Karen
learning new subject	enjoy learning new subject knowledge outside specialism	Amy, Christine, Daniela, Karen, Maria, Robert, Sarah	0	Laura
	continually seeking better ways to teach topics within non-specialist area	Amy, Christine, Daniela, Karen, Laura, Maria, Robert, Sarah	0	0
teaching experience	increase in confidence due to teaching experience when teaching outside specialism	Amy, Christine, Karen	Laura	Daniela, Maria, Robert, Sarah
	still feel like a novice teacher when teaching outside subject specialism	Daniela, Karen, Laura, Sarah	Christine	Amy, Maria, Robert

From the responses in the questionnaire held at the beginning of the INSET all teachers preferred to teach their subject specialism with the exception of Karen. Initially four out of eight teachers mentioned that they did not mind teaching outside specialism, two were undecided and another two preferred teaching their area of specialism as seen in Table 7.2. By their first interview held after the INSET, the teachers clarified their position and stated that they did not mind teaching outside specialism. Robert stated that he did not mind teaching outside specialism because he liked to learn new ideas. Laura, Christine and Daniela explained that one teacher should be responsible to teach all areas in science. However they acknowledged that more preparation and research was required to teach outside specialism. In view of this Christine explained that:

> *I don't think it is beneficial for the students to have three teachers for the same subject.... I think that at Year 7 and 8 there are no difficult topics, so a biology teacher is capable of teaching the other subjects as long as she makes her own research.*

Table 7.2 shows that teachers felt more confident teaching their area of specialism and lacked confidence in teaching outside specialism with the exception of Karen. As stated by Amy *"the more you know the content the more confident you can be."* Here Amy voices the general opinion of the teachers in the study. Their lack of confidence developed from their beliefs that they did not have the necessary knowledge to teach chemistry, especially the three teachers who did not study chemistry at secondary school. For instance Robert perceived lesson preparation as *"mainly by trial and error"* because he was still looking for chemistry experiments and activities that were suitable for his students. These three teachers felt only just a bit ahead of their students and this created further uncertainty because they could not foresee how the topic could be developed.

Besides having a weaker background, their own personal experiences of learning or not learning chemistry at school affected their perception and attitude towards chemistry. In the case of Laura and Amy, their negative school experiences influenced their level of confidence and both felt uncomfortable and out of their comfort zone teaching chemistry. For the other teachers who lacked a background in chemistry they feared their students would sense that they had an insufficient background in the area and they could be judged to be incompetent teachers. Maria and Christine also believed that they could impart their poor beliefs and attitudes in their chemistry lessons. In view of this Christine related that:

> *I would not want to give a bad impression of chemistry. Probably I was not doing that but I was afraid that since I had difficulties in teaching the subject the students would realise that their teacher is not comfortable teaching the subject ... you can transmit the idea that chemistry is a difficult subject in a subtle way. Students in Year 8 start asking whether the topic is related to biology, chemistry or physics since they would be choosing their subjects. I am afraid that because of the way I teach I am giving an impression that chemistry is a bit difficult.*

Since most of the teachers were early career teachers it was rather difficult for them to feel confident in teaching outside specialism due to their limited teaching experience (see Table 7.2). Christine felt that teaching experience had shaped the way she approached teaching outside specialism. Although Laura and Daniela had more teaching experience they still felt like novice teachers since they had just started teaching science. The insecurities about the teaching of chemistry arising from a weaker knowledge base, from negative beliefs towards the subject and from limited teaching experience gave rise to a fragmented sense of identity.

These teachers were experiencing various challenges and issues when teaching their non-specialist area.

On the other hand the findings also suggest that the teachers were motivated to learn new material and seek ways to improve their practice (see Table 7.2). This implies that the teachers did not have rigid identities but they were flexible enough to adapt to new situations. Beijaard et al. (2004) argue that professional identity is not fixed but is an ongoing process of becoming. Teachers wanted to reconcile the tensions created between their multiple identities and gain more competence to teach outside specialism when teaching integrated science.

The next chapter provides an in-depth discussion of the challenges and issues that participant teachers met in their day-to-day experiences and it explains why such difficulties arose when they taught chemistry as their non-specialist area.

Chapter 8

Challenges experienced when planning and teaching chemistry lessons

One of the main aims of this research study was to explore the challenges faced by science teachers when teaching chemistry topics. This chapter identifies the issues and challenges encountered by the participant teachers thereby answering the first research question. Whilst reading the interview data, their questionnaires, my own field note observations and reflective journal, it was becoming evident that teachers were experiencing difficulties both when preparing and teaching chemistry lessons. Table 8.1 shows the results of six of the paired statements questionnaire that related with the challenges that teachers were experiencing when teaching outside specialism at the beginning of the study.

Their narrated experiences were suggesting that their levels of confidence and self-efficacy were compromised by their limited knowledge base and poor attitudes towards chemistry. This gave rise to underlying tensions and feelings of inadequacy that was manifested in their lesson preparation and delivery. In fact Whannell and Hobbs (2018) argue that the challenges imposed when teaching outside specialism can truly test one's professional identity leading teachers to question their capacity to teach and their competence as science teachers.

Table 8.1: Results of six of paired statements from questionnaire

	Paired statements	Strongly agree/ agree	Strongly Disagree/ Disagree	Undecided
planning lessons	feel more confident in planning lessons and creating activities within specialism	Christine, Daniela, Karen, Laura, Maria, Robert, Sarah	0	Amy
	find it more challenging to come up with activities when planning lessons outside specialism	Amy, Daniela, Karen, Laura, Maria, Robert, Sarah	Christine	0
explanations	find it difficult to explain concepts outside specialism	Laura, Maria	Robert	Amy, Christine, Daniela, Karen, Sarah
	find it challenging to simplify complex ideas in non-specialist area	Christine, Karen, Maria, Robert, Sarah	Daniela	Amy, Laura
linking concepts	more able to relate different aspects of subject knowledge within specialism	Christine, Daniela, Karen, Laura, Maria Robert, Sarah	0	Amy
	find it more challenging to draw up the potential links between topics outside specialism	Christine, Daniela, Laura, Maria, Robert, Sarah	0	Amy, Karen
misconceptions	able to anticipate and identify easily students' misconceptions within specialism	Amy, Christine, Daniela, Karen, Laura, Maria, Robert, Sarah	0	0
	find it difficult to identify students' misconceptions outside specialism	Amy, Christine, Daniela, Laura, Maria, Robert, Sarah	0	Karen
questions	more confident in answering students' questions within specialism	Amy, Christine, Daniela, Karen, Laura, Maria, Robert, Sarah	0	0
	not so confident in answering questions outside specialism	Amy, Christine, Laura, Maria, Robert	Daniela	Karen, Sarah
experiments	find it challenging to set up and explain a practical experiment outside specialism	Christine, Karen Laura, Maria, Sarah	Robert	Amy, Daniela
	find it difficult to explain why science experiments fail to work outside specialism	Amy, Christine, Laura, Sarah	Karen, Maria	Daniela, Robert

8.1 Challenges when preparing lesson plans

From their narratives and results of the questionnaire (Table 8.1) it was evident that participant teachers were encountering challenges from the very first moment they were about to teach chemistry topics. Data from the questionnaire shows that seven teachers found it more challenging to come up with activities when planning lessons outside specialism compared to within specialism. This meant that lesson planning outside their area of expertise was perceived to be more demanding than within specialism. All teachers mentioned that they took longer to plan chemistry lessons for different reasons.

Robert encountered a series of difficulties in lesson planning. Most of the time he felt lost and mulled over questions like "*from where I am going to start?... How will I continue?... How will I put it all together?*" Robert struggled with lesson planning because he had to learn the content knowledge before he was about to teach it. In this situation Robert confessed that that he was "*learning chemistry with the students*" and "*also experiencing the wow factor with the students*." He admitted, *"the first thing that I tell the students is that in chemistry I am learning with you, we are in the same boat."* His decisions and ways of designing a lesson plan are mainly influenced by his interests and his learning styles. He described his approach to lesson planning as follows:

> *... the first thing that I look for are experiments. I will look up an activity that captures the students' attention. If I get hooked by an experiment, then students will have the same reaction and I will show it to them.*
>
> *I did not have any knowledge of chemistry and it is now that I am studying chemistry in order to be able to explain to the students…. When I conduct research I look for an explanation which is at the very basic level, making sure that first I can understand it myself and then use this explanation to explain it to the students…. I will explain it to students in the same way that I understood it. My level of knowledge is very similar to that of the students and I look up information which is explained at their level. If the subject is within my area of specialism then undoubtedly I go beyond their level.*

Robert's arguments confirm the assertion put forward by Childs and McNicholl (2007) that teachers first need to learn new SMK and then they need to learn how to teach this content when teaching unfamiliar areas. Within this context, teachers frequently act as learners and start identifying gaps in their knowledge and understanding (McNicholl et al., 2013). I noticed that this was more common with teachers who had not studied chemistry at secondary school because they all had to conduct extensive research to learn new content knowledge. Maria experienced a similar situation to Robert and explained that:

> *Lesson planning takes me longer because I go online a lot, use books and do some background reading, so that I know what I am preparing. I would prepare a lesson for the other topics in a day or two, but it would take me twice the time preparing for a chemistry lesson because I want to have a background.*

Although Maria took longer to plan chemistry lessons she still felt insecure about her work. She stated, *"when I prepare lessons I feel that at times I skim through things because I am weak."* On the other hand, the other teachers with a background in chemistry read content knowledge for revision purposes. This meant that for teachers without a background lesson preparation turned out to be a more time consuming exercise.

Other common challenges mentioned by the participant teachers included difficulties associated with selecting the appropriate resources and developing a sequence of activities. Daniela said that she spent considerable time looking up resources but then she was not able to use them all. Karen and Sarah explained that there were many available resources but first these had to be adapted to their students' needs. Even Maria had difficulties in selecting the most suitable activities because she did not know the level of detail she had to go into. She said that:

> *When I have to plan a lesson I panic! I have too many things (to use). I don't know how to use them all. First of all I ask 'how much detail do I need to go into?' Because in my mind I am very logical, everything has to be a building block and my lessons are all done like that, starting from the simple concept and building on it. I have to picture it …at times I get lost in many things.*

From the teachers' narratives it was evident that the level of SMK, which included both the content and level of organisation of that content, was impacting their development of PCK and these two components were affecting the process of lesson planning. In line with other research findings (Childs & McNicholl, 2007; Sander et al., 1993), participant teachers had difficulties selecting suitable and effective activities that promoted students' learning because they lacked the background knowledge to make informed decisions. Moreover, like in Sanders et al. (1993) the participant teachers had problems in deciding the key concepts and in constructing a sequence of appropriate activities in their lessons. These issues influenced the approach taken during lesson planning. In fact Robert mentioned that he adopted a different approach when planning lessons in different subjects. When preparing a physics lesson he did not revise basic content knowledge but spent more time looking for resources. He stated that:

I will prepare the lesson plan. The next day I reshuffle the order of the lesson plan… I do this experiment instead of this one; I change things around because I find better ideas… I know that it is going to work because I have already experienced it...Or I have resources prepared from the previous year.

Robert revised and refined his physics lesson plans a number of times and was able to conduct modifications to improve his work. However he was not able to revise or amend his chemistry lesson plans and stated that *"after preparing the lesson plan in chemistry, it will not be changed."* Within his area of specialism Robert showed more flexibility in planning lessons since he had a deeper SMK and more elaborate PCK. On the other hand, outside his area of expertise lesson plans had a fixed structure because his limited knowledge in the area constrained his ability to adapt and change his work. Hashweh (1987) reports a similar difference in lesson planning. He describes how within their specialist areas teachers could reject a chapter outline expand or enrich the activities and devise their own ways of developing lessons but they could not think of other alternatives when planning lessons outside their subject specialism.

When content knowledge is inadequate further problems can arise in lesson preparation. Robert and Laura mentioned that they have difficulties in conducting an effective research. Despite having a multitude of resources that can be retrieved from the Internet, both explained that they lacked knowledge of the appropriate key terms that could be used to conduct an effective Internet research. They preferred to ask their colleagues for some lesson ideas. In contrast, when these teachers prepared lessons within their subject specialism they were more knowledgeable of the technical words they could use. In view of this Laura explained:

If I was teaching science and I was doing a reaction, I would not know how to go about googling it. I would not know the words to use to gain my answer. In that case it would be easier to talk to my colleague for example. But in biology I would know how to word it in such a way that I would be able to obtain an answer. I think apart from subject knowledge there are also the words that you use in the subject and how you use them to gain information …. and when you don't have the words or the technicalities that you would need to find an answer, it's easier to ask someone.

For Robert a teacher needed to be more knowledgeable to retrieve the best resources from Internet. He felt that he did not have the required knowledge to judge whether the retrieved chemistry experiments were of the appropriate level. In contrast he did not experience any difficulties in selecting physics experiments. However in chemistry he lacked the terminology needed to find the appropriate resources and thus he argued that:

> *There are experiments that you are not aware of. If you look them up on the Internet you have to input specific words in order to find them. There are experiments that can be done in the topic of sound like Rubens' tube and patterns formed on a vibrating generator. You have to input particular key words on YouTube to find these experiments.*

Feeling constrained in conducting effective research again illustrates that teachers had an inadequate knowledge base. These teachers also showed that they lack 'knowledge of curriculum organisation' and 'knowledge of resources.' These were two of the components of PCK formulated by experienced teachers as presented by Lee and Luft (2008) (see section 2.2.2.1). Teachers find it difficult to select the appropriate teaching activities when their level of SMK, their knowledge of 'curriculum organisation' and 'knowledge of resources' tends to be insufficient.

These episodes showed that the participant teachers were facing a number of difficulties in planning their chemistry lessons. Loucks-Horsley et al., (2010) argue that "teachers' content knowledge influences how teachers engage their students in subject matter and how they evaluate, choose and use instructional materials" (p. 62). Lacunae in SMK hampered the development of PCK because the teachers had problems to develop a topic, link concepts, find the appropriate activities and put them in the right sequence. When participant teachers were speaking of such difficulties I started to question whether these difficulties were also manifested in lesson delivery and how their perception as non-specialist chemistry teachers was affecting the teaching of chemistry.

8.2 Challenges during chemistry lessons

The teachers' questionnaire and narratives provided the first insights regarding how they were feeling when teaching an area in which they felt they were less knowledgeable and consequently less competent. Such experiences led them to develop insecurities and uncertainties that affected their level of confidence. In this research study lesson observations provided a further dimension to explore this situation. I was interested in observing the challenges or what Hobbs (2013b, p. 7) describes as experiences of 'discontinuity' arising during a chemistry lesson. From lesson observations I gained a better understanding of their teaching practices and how their insecurities and anxieties were affecting their lesson delivery.

Surprisingly classroom observations demonstrated that the majority of the participant teachers managed to prepare engaging lessons that were student-centred and included activities and experiments. The teachers did not use traditional approaches but encouraged students to think, discuss and build scientific knowledge. Teachers managed to use their pedagogical knowledge from their area of expertise and transfer it to organise and develop their lessons outside specialism. On the other hand I noted that for two particular teachers with a limited background and teaching experience, their lessons were characterised by more frequent pauses, closed questions and inaccurate explanations. Such findings suggest that early career teachers and those that lack a background in the subject find it more challenging to teach outside specialism.

Although classroom observations were showing that teachers were coping in their chemistry lessons, in particular circumstances I noticed that teachers were experiencing a sense of disruption and discontinuity that was affected by what Hobbs (2013b, p. 11) describes as "the practices and demands of the subject" (in this case chemistry). At times they appeared hesitant in their lessons and they were very conscious about whether they were passing on incorrect information to their students. In their interviews they confirmed that they experienced difficulties and felt constrained when teaching outside specialism. Challenges were also evident when teachers were explaining concepts, dealing with misconceptions, answering questions and when conducting and explaining experimental work.

8.2.1 Feeling constrained when teaching outside specialism

Whilst listening to the participant teachers' stories I noted that they were constantly comparing their styles of teaching within and outside specialism. They felt more comfortable teaching within their science specialism compared to teaching outside their area of expertise with the exception of Sarah and Karen. Since these teachers believed that they had good background knowledge in chemistry they mentioned less challenges in teaching chemistry. On the other hand, the other six teachers noted that they experienced more limitations when delivering chemistry lessons.

Robert believed that when teachers teach science topics within their area of specialism they automatically "*focus more on the area which is [their] forte.*" In his case he claimed that "*if the topic is within your area of specialism you are going to make more effort than biology and chemistry.*" He thought that this happens with other teachers who are specialists in other areas, thus the *"biology specialists will tackle the biology topics in more detail"* and "*those who are chemistry specialists will focus more on chemistry."* When teaching within specialism Robert thought that a teacher can better prepare the students for what is to be studied later on in secondary school. He argued:

> *A specialist teacher will prepare the students a bit further than a non-specialist. When I taught light and sound I prepared the students for what was to come in physics. As you are explaining you automatically give more detail. I think it comes naturally. It is not a technique or a strategy. I could not do that in chemistry. I won't go beyond the expected level because I don't have such knowledge.*

Within the local context a science teacher is expected to teach all areas of science during the first two years of secondary school. The major dilemma arises because teachers do not possess the same level and depth of knowledge in the three science domains. In fact when teaching their non-specialist area participant teachers felt that they were not able to deliver the same type of lesson. Both Robert and Maria felt that in chemistry they could not "*go a step further"* but they "*stick to the curriculum"* and at times they struggled to make the subject interesting. Feeling limited and incapable of using further examples and analogies can also affect, as Whannell and Hobbs (2018) argue, the teachers' well-being as well as one's personal self-image as a science teacher. Both Maria and Robert felt that they could not take any risks and go beyond what is prescribed in the curriculum because as Maria explained, "*I don't venture outside the curriculum because with my background I cannot speak about certain things I don't know. I don't give them the interesting stuff, which is a pity."*

When non-specialist teachers have a minimal knowledge in the subject they tend to follow the textbook closely (Hashweh, 1987). They are not confident to try out new ideas, so they stick to their scheme of work to feel safe and secure (Kind 2009a). In the local scenario teachers made use of the suggested activities prescribed in the integrated science syllabus. In fact Maria found that "*the new science curriculum is very guided and very helpful."* She contended that these documents provided the necessary guidelines of what needed to be taught, without deviating from the topic. In summary, most of the participant teachers felt completely different when teaching across specialisations. They had more flexible pedagogies within their area of expertise but they felt rather limited and constrained when teaching unfamiliar areas.

8.2.2 Explaining concepts

One of the major constraints that participant teachers faced in delivering their lessons was their ability to simplify and explain concepts. In the questionnaire five out of eight mentioned that they found it challenging to simplify complex ideas and five were not sure whether they could explain concepts in their non-specialist area (see Table 8.1). The one-to-one conversations confirmed this view, where teachers stated that they became anxious if they were not giving correct explanations when teaching unfamiliar areas. They felt that they provided less elaborate and detailed explanations and they were not sure whether they were able to simplify chemical concepts. For instance Maria stated that her explanations in chemistry were generally "*vague.*" On the other hand when she taught physics she could give many examples and deviated from the topic. She felt that when teaching physics she "*can explain and to try to make it more practical*" and pointed out that she tried to:

> *....simplify it, keeping out what is complicated. But in chemistry I can't! So I start wondering 'Am I making sense?' ... 'What I am saying? Does it make sense?' I ask the chemistry teachers ... luckily the other science teacher has a [chemistry] background. I start asking them to check if I said something stupid ... at times I went into class and corrected myself. I don't see anything wrong in that. However I will be really tense... like 'What am I saying?' If I cannot picture it in my head then I am not sure about it. That is where I feel weak.*

From the students' perspective an exemplary science teacher is one who is able to explain scientific ideas clearly (Wilson & Mant, 2011). Lessons can turn out to be quite stressful episodes when teachers feel that they cannot provide appropriate and effective science explanations. Providing limited explanations shows that teachers' SMK is incomplete and they consequently possess less sophisticated and flexible PCK, hence lessons are more tightly controlled (Childs & McNicholl, 2007).

The use of class discussion can also generate teacher's anxiety. Amy was a firm believer in the discussion method, however during a lesson observation I noticed that at times she was *"getting rather nervous"* when students were engaged in discussions (*Lesson observation field notes: November 2014*). She later on confirmed that "*with discussion you would not know where it was going to go off to, so I was not sure how it would turn out.*" In one of her lessons Amy introduced acids and encouraged students to elicit the difference between strong and weak acids by showing different examples of acids like lemons, oranges, vinegar and bench acids. In this lesson I noted that:

> *…students realised that weak acids are not harmful or corrosive. Strong acids were defined as corrosive substances which burn your skin. Students had already seen the corrosive safety label in previous lessons and the teacher checked with the students what the word corrosive means. Students answered that it can burn or eat away your skin. Then one particular student mentioned that if a padlock is placed in sea water they say that it gets corroded. Students were now having a discussion about the meaning of the term corrosion that is whether the padlock corrodes or rusts when placed in sea water. The teacher answered that corrosion in this case is a different reaction from the corrosion of acids. However here she felt hesitant and she looked at me to check whether she was providing a correct explanation.*
>
> (*Lesson observation field notes: November 2014*)

From her behaviour Amy showed that she was not sure about her answer and in her interview she confessed, *"At times I have said things and I was not completely sure if I told them the right thing or not."* Lack of knowledge in particular concepts can lead to situations where teachers avoid teaching particular areas. In fact Amy admitted that she only explained the difference between strong and weak acids and she avoided explaining the difference between a dilute and concentrated acids because she got confused with these definitions.

Daniela explained that in her non-specialist area "*there are certain areas, concepts where [she] feel[s] uncertain..."* She explained that she "*felt stuck"* when students did not understand the meaning of the term fuel and she did not know *"how to explain it and what other words to use."* In line with Childs and McNicholl (2007), teachers in the local context had difficulties in providing elaborate and detailed explanations or using analogies to explain scientific concepts. As a result they became very concerned about their explanations because they thought that they could be passing on wrong information to the students. In fact passing on misconceptions was one of the greatest concerns when teaching chemistry topics.

8.2.3 Teaching and misconceptions

Perpetuating misconceptions about chemistry concepts was a major concern for all the teachers participating in the study. For instance Daniela said that she worries that she might teach something wrong. Many were afraid that they might be passing on incorrect ideas or misconceptions due to their lack of content knowledge. None of the teachers wanted to perpetuate their own misunderstandings since it could compromise the quality of their teaching. Laura noted that while she was weak in the subject she still paid *"more attention to how [she says] certain things to make sure [she does not] pass on misconceptions."* Similarly Maria was afraid of passing on misconceptions due to her weak background in chemistry and expressed that, *"my biggest struggle is that since I don't have a deeper knowledge of chemistry I stick to this criterion: I never want to mislead my students. I am always afraid of creating misconceptions myself, that is my biggest fear."*

The perpetuation of teachers' misconceptions to their students is common in literature (Driver Squires, Rushworth & Wood-Robinson, 1994; Hashweh, 1987; see Kind, 2014b). During one of the PD sessions targeting common misconceptions in chemistry, it was noticed that one of the teachers had particular inaccuracies about the topic of evaporation and she wrote that *"the increase in UV radiation increases the temperature causing the water to evaporate and disappear" (Reflective Journal: July 2014)*.

In their research Kind and Kind (2011) state that biology and physics specialists had more misconceptions in chemistry than chemistry specialists. When chemistry is taught by non-specialist teachers there is a greater probability of passing on knowledge inaccuracies since non-specialists have a poor understanding of basic ideas of chemistry, leading to what Kind (2014) refer to as inaccurate learning. This was also common among the participant teachers. In view of this Karen insisted that it was important for a teacher to have good background knowledge and explained that:

> *I also need to have background knowledge otherwise I may say incorrect things or pass on misconceptions. When students are older they will still have this misconception and they will say 'This is what the science teacher told us!' I am worried about this!*

Karen asserted that one needs to become aware of one's own misconceptions otherwise *"you will teach the same mistakes."* She recommended that teachers should revise their concepts through research and self-evaluation.

Possessing the knowledge of students' misconceptions is one of the components of PCK as described by Shulman (1986). According to Table 8.1 all teachers mentioned that they were more able to identify students' misconceptions within their subject specialism rather than outside specialism. In their conversations teachers who studied chemistry at post-secondary level commented that they could detect students' misconceptions and challenge students' ideas. This is similar to the findings of Hashweh (1987) where more knowledgeable teachers could detect students' preconceptions and correct them. In their interviews Sarah, Laura, Karen and Daniela pointed out that they were very attentive to students' misconceptions in their lessons. For example Karen could *"easily identify when students are using incorrect* *terminology like dissolving and melting."* She corrected such misconceptions every time they came up. Laura recognised that it was not the oxygen in water molecules that causes rusting but the oxygen dissolved in water. She could identify this misconception because the same misconception arises in biology. She attempted to challenge this idea using different examples in her lesson about rusting as recorded in the following field notes:

> *The teacher asked: 'how do you know that water is boiling?' Students answered that you see 'bubbles'. When the teacher asked students to explain what is in the bubbles, some students said oxygen, others water; other students thought that some hydrogen is coming out as well. Here there seems to be a misconception that when water boils oxygen and hydrogen are given off besides steam. The teacher gave the following explanation: 'When you say there is oxygen in water, oxygen is mixed. It dissolves like when we add sugar to coffee'. Then she further asked: 'when we boil water what are we removing from it?' Some students answered oxygen. However most students were still confused about what happens when water boils because they were firing answers haphazardly. The teacher drew a diagram on the board showing that oxygen molecules are in between water particles. More students started grasping the idea that oxygen will leave when water is boiled, however it was very difficult to get this concept across.*
>
> *(Lesson observation field notes: February 2015)*

Only a few students seemed to grasp the idea that oxygen dissolves in water and that with heating it becomes less soluble. In fact after the lesson Laura explained that, "*this misconception also features in biology with Year 10 students. When I teach breathing in fish, students ask 'will fish take oxygen from the water molecules?' This misconception is ever present and very hard to get rid of."*

These episodes highlight how teachers were very concerned about perpetuating their own misconceptions. Furthermore they encountered challenges when attempting to answer students' questions.

8.2.4 Answering students' questions

A common challenge that arises when teaching outside science specialism is dealing with students' questions. Teachers' level of confidence varies remarkably when answering questions in different science domains as can be seen in Table 8.1 where all teachers felt more confident to answer students' questions within their specialism rather that outside specialism. These views were confirmed in the interviews. Laura contended that *"in your area of expertise it is easier because if they ask you a question, you have heard it before and you* *know what to say.*" Similar to the teachers in Sander et al. (1993) study, participant teachers could answer questions off the top of their head, elaborate on students' ideas and link with new content within specialism. Answering questions outside one's area of expertise proved to be a more daunting experience because of uncertainties and lack of SMK. As Robert explained:

> *When students ask questions you feel more confident in your subject area, you give more elaborate explanations and you keep going on. But if it is not your area you are more anxious. It is a different approach… When answering questions outside subject specialism I ask myself: 'Where will this question lead to?'… 'How will I answer?'… ' I hope that I am not giving an incorrect answer.'*

Many of the participant teachers felt insecure and unsure when answering students' questions. Maria wondered whether she was giving the correct answer because:

> *My biggest fear is always one… If you don't know the background in chemistry, you risk telling your students something wrong and that for me is the worst thing that can happen. Then I feel really shaky… because they ask good questions, some students really challenge you… if I don't know exactly what is happening in the background, I cannot tell them.*

Answering students' questions is generally identified as one of the challenges when teaching an unfamiliar area (Kind, 2009a; Millar, 1998). Teachers struggle to answer students' questions because of lack of content knowledge and their confidence in that knowledge (Millar, 1998). Outside their area of expertise participant teachers felt more anxious because they could not anticipate students' questions. Daniela reiterated this concern in saying that *"you will be afraid about what they are going to ask, what they are going to come up with."* Teachers become uneasy when students ask challenging questions. Amy stated that at times students come up with questions that she "*does not know how to answer"* because she forgot most of the chemistry she learnt at school. She explained that:

> *I get a bit flustered… not really sure whether I am giving the right answer or not which makes me a bit awkward... sometimes, when they come up with things I do not really know how to answer. I have an A Level in chemistry and I forgot most of it since it was a long time ago. I did not like the subject so I forgot most of it.*

When observing teachers' non-verbals during the lesson observations I noticed that at times teachers felt perplexed because they got stuck in answering particular students' questions. At this point it was clear that teachers felt uncomfortable because they could not answer all the students' questions. In fact Karen explained that she did not manage to answer the students' questions and was afraid that her students would start doubting whether she was knowledgeable enough in the area. This can have an effect on the teacher's self-efficacy and identity as a science teacher. In relation to this she explained:

> *When students ask questions I want to give the correct answer because I do not want to pass on any incorrect information. Then I become apprehensive when I tell the students that I need to check the answer... they might start saying "does the teacher know anything?"*

How teachers define themselves as science teachers is shaped by significant others such as students and colleagues, as explained in Chapter 2. Students frequently evaluate whether their teachers have deep and solid background knowledge in SMK from the class interactions and the type of pedagogy adopted. As a result teachers feel more under scrutiny when teaching their non-specialist area particularly when tackling students' questions and when conducting practical work.

8.2.5 Preparing, handling and explaining experimental work

Although the teachers who participated in the study had a number of insecurities when teaching chemistry they all stated that they enjoyed teaching the subject since lessons included many activities and experiments. However preparing for and handling experiments rendered them quite nervous. Five teachers stated that they found it challenging to set up and explain an experiment in their non-specialist area (see Table 8.1) whereas two were undecided. This was another major challenge encountered when teaching chemistry topics because teaching through practical work requires both conceptual and procedural knowledge and teachers had limited knowledge in both areas. Robert admitted, "*I did not have any clue about the experiments I had to use in the lessons plans."* He could not look back on his student days and recall what he had done since he never studied chemistry. This was an additional difficulty that he encountered:

> *...since I don't have a chemistry background, I don't remember the teacher conducting an experiment, I can't recall the experiment…. In physics there is this experiment in this lesson, so I do the experiment, I derive theory and the law… But in chemistry I don't have an idea of the experiments that can be done. I don't have a background.*

Although Laura studied chemistry at secondary and post-secondary level, she still had difficulties in selecting the most relevant experiments related to the topic especially due to her poor background in the field. She explained that:

> *When it came to science, especially in the chemistry experiments, it was not that easy for me because as I have said before my experience of chemistry at school was not very good. We barely did any experiments. I had chemistry at Intermediate level but we did not do any experiments. So chemistry experiments were a bit taboo. I did not know what to expect. I did not know what things mean, so it is more lack of knowledge, lack of experience but when it comes to biology is different because it is my area.*

When teachers lack knowledge about experiments and what they are meant to illustrate they may tend to avoid including practical work in their lessons. In the previous scholastic year, Robert stated that he did not include many experiments in his lessons because he could not link the concept with an appropriate activity or vice versa. Moreover he was not comfortable to explain what goes on in an experiment due to his limited background:

> *I did not use many chemistry experiments because I did not know the thinking behind the experiments. I knew about the experiment, I watched it on YouTube, but what is really happening in reality? Like there are many experiments of acids and alkalis which involve colour changes and are nice. I did not use them in class because I did not know the thinking behind them.*

Both Amy and Laura felt more out of their comfort zone when tackling experiments because they had difficulties in explaining chemical reactions. Amy hoped that her students would not ask her for any explanations *"about what was going on in the reaction because [she could not] explain it*". Laura felt very frustrated about this situation. She acknowledged that a teacher needs to have this background knowledge. She believed that doing experiments for the sake of doing observations is too superficial. Consequently she felt annoyed that she was not able to give an adequate response to students' questions related to laboratory experience:

> *I feel really annoyed because there were many reactions and I did not know what was happening…. Like if there was a precipitate, what was the precipitate? I feel really annoyed when students ask you 'What is this Miss? Don't you know?'*

Difficulties in explaining what goes on in chemical reactions were also noted during lesson observations. In a particular lesson about the reaction of magnesium with acids of different concentrations Robert provided an incorrect explanation of the chemical reaction. In my lesson field notes I observed that:

> *Magnesium ribbon was reacting with citric acid and each beaker had a different concentration of acid. In one of the beakers magnesium turned shiny and in the other it turned white. At this point the teacher explained that magnesium had reacted 'to produce white ash'. I realised that the teacher still had difficulties in explaining what goes on in a chemical reaction because he had provided an incorrect interpretation of the reaction since the production of white ash is linked to the oxidation of magnesium not to the reaction of magnesium with an acid.*
> *(Lesson observation field notes: May 2015)*

Weaknesses in SMK were manifested in the teacher's explanations because Robert gave an incorrect interpretation of the experimental observations. He could not transfer his competence and skill from his area of expertise to teach chemistry and argued that:

> *...you don't just need to know the experiment but also need to know how to explain the experiment. These aspects do not mean the same thing. There is a big difference between conducting an experiment and carrying out an experiment to explain a concept.*

Dealing with unexpected experimental results can make the teacher feel uncomfortable as indicated in Table 8.1, where four teachers stated that they found it difficult to explain why experiments fail to work outside their area of expertise and two were undecided. Practical work is challenging when teachers lack knowledge about technical and safety aspects and when teachers do not know how to deal and explain unexpected results (Childs & McNicholl, 2007; McNicholl et al., 2013). Both Christine and Amy experienced similar situations when their students were testing the pH of the various household items. After the laboratory session Amy confided, *"when students added universal indicator to household items they were not all changing colours as I expected. Some of the colours surprised me and that worried me a bit."* As a result Amy felt annoyed because she could not find a plausible explanation to interpret unexpected results and explained that:

> *I hate it when it happens but I try and explain. Sometimes unfortunately things happen and I cannot understand what is taking place. It could be contamination... but the colour is not even on the pH chart which I find very weird and it was tested twice. I don't know!*

Christine experienced a similar situation, when students were testing the pH of bleach. In my lesson field notes I recorded that:

> *Students predicted that the bleach was alkaline. The teacher was amazed by the result as the bleach turned out to be acidic. The technician suggested using another sample of bleach. The second bleach turned out to be alkaline… then the teacher felt relieved and concluded that in general bleaches are alkaline. The two results were written in the table of results.*
>
> *(Lesson Observation field notes: May 2015)*

After this incident Christine realised that "*it does not mean that bleach is always alkaline. Different brands can vary.*" She resolved her anomaly with the help of the laboratory technician and recounted, *"at that point when I got the results of bleach I was not feeling comfortable. It would not have crossed my mind if the lab technician had not suggested trying another type of bleach."*

These incidents illustrate that teachers become very confused when unexpected results arise in laboratory sessions. They are still not confident enough to turn unexpected situations into learning experiences, by questioning and thinking what could have gone wrong in the experiment. They needed the support of others and Christine managed to come out of this situation with the help of the laboratory technician. On the other hand Daniela, who was the most experienced teacher, explained that she did not become anxious when unexpected results took place. She felt comfortable to repeat the experiment and discuss the sources of error than could have influenced such results due to similar experiences within her subject specialism.

8.3 Challenges when teaching outside specialism

The research findings have shown that the participant teachers were facing a number of challenges when teaching outside specialism, where such challenges are very similar to other research studies tackled in this area (Childs & McNicholl, 2007, Hashweh, 1987; Kind 2009a, Millar, 1988; McNicholl et al., 2013, Sanders et al., 1993). Their major difficulties involved finding and developing a sequence of activities in preparing their lesson, having a limited repertoire of activities, giving less elaborate explanations, perpetuating misconceptions, answering students' questions and tackling practical work. Due to the discrepancies experienced when teaching within and outside specialism teachers were having difficulties in negotiating, what Hobbs (2013b, p. 25) describes as a "fully elaborated professional identity" as teachers of science.

The participant teachers were experiencing, as Hobbs (2013b) describes, a 'discontinuity' in their identity when crossing the boundary, that is switching from teaching within specialism to outside specialism as expressed by different levels of confidence, competence and self-efficacy. Using Akkerman and Bakker's (2011) theory of boundaries, "for a teacher to experience a boundary they need to see the difference between 'fields' and recognise the 'discontinuity' that arises; that is the disruption being caused by the boundary" (Whannell & Hobbs, 2018, p. 38). For the participant teachers, the boundary existed because they had to learn different content knowledge and practices in the different science areas. Although some research (Childs & McNicholl, 2007; Sanders et al., 1993) suggests that teaching outside specialism can lead to a number of negative experiences such as feeling less confident and experiencing a low level of self-efficacy, other research, notably by Hobbs, (2013a; 2013b) suggests that the challenges faced by teachers when teaching out-of-field (in this case outside specialism) can be powerful learning experiences. The next chapter looks at the strategies or mechanisms that teachers use to be able to cross boundaries and to lead them to expand their professional identity as a science teacher.

Chapter 9

Strategies used by teachers when teaching chemistry

One of the key themes I wanted to explore in this thesis was how teachers were managing to teach outside their science specialism. This chapter explores the strategies or mechanisms that teachers use to teach an unfamiliar area, thereby answering the second research question. In the literature these can be described simply as strategies (Childs & McNicholl, 2007; McNicholl et al., 2013), or SMK sources (Kind, 2009a) or else as 'boundary objects' (Akkerman & Bakker, 2011; Hobbs, 2013a, 2013b). In this chapter I refer to the strategies used as mechanisms and as 'boundary objects' where the use of boundary objects can enable teachers to bridge the social and contextual worlds between different fields or subjects (Akkerman & Bakker, 2011).

I was interested in exploring the mechanisms or boundary objects used by the participant teachers because, as previously described, I realised that the teachers felt unqualified, ill-equipped and anxious when they entered an unfamiliar territory (that is teaching chemistry topics). The teachers' narratives in this study suggest that teachers used two types of mechanisms when they negotiated the subject boundary. They used 'coping mechanisms' in order to survive in their classrooms such as following prescribed material, drawing on their current knowledge of their specialist subject and/ or using traditional methods of teaching. On the other hand when participant teachers wanted to learn and make the leap they used 'enabling mechanisms' or 'boundary objects' such as conducting research and seeking for support from colleagues. Repeated teaching experience helped them to develop their SMK and PCK and increase confidence in teaching their non-specialist area. Their sense of agency, which is part of their professional identity, provided the necessary impetus for teachers to make this leap or what Hobbs (2013a; 2013b) describes as "boundary crossings." Figure 9.1 shows the different types of mechanisms that teachers used in preparing and teaching chemistry lessons.

Coping mechanisms	Enabling mechanisms/ boundary objects
• following prescribed material • using their knowledge from their subject specialism • using traditional teaching methods	• conducting research • seeking support from colleagues • repeated teaching experiences

Figure 9.1: Different types of mechanisms used in teaching chemistry topics

9.1 Coping mechanisms

When teachers in the current study felt overwhelmed with challenges presented in teaching chemistry they resorted to coping mechanisms to handle the situation. Initially, for example, Robert and his colleagues opted for a modular approach in teaching science; hence he avoided teaching outside specialism. However, when this research was carried out the eight teachers were teaching all the topics in the integrated science syllabus. From their narratives particular teachers were using different coping mechanisms that enabled them to survive in their classroom and hide their insecurities about their lack of confidence and content knowledge. This included (1) following prescribed material, (2) using knowledge from their subject specialism and (3) using traditional pedagogies.

9.1.1 Following prescribed material

When teachers lack confidence in a subject they generally stick to what is prescribed in the curriculum or in the textbook, as has been found by Kind (2009a) and Hawseh (1987). In the previous chapter it was noted that teachers felt constrained when teaching chemistry and as a result they did not attempt to conduct risky activities. Maria said that she did not dare *"venture outside the curriculum."* In fact for the topic of chemical changes she resorted to using a particular set of experiments suggested by her colleague who is a specialist chemistry teacher. She stated that:

> *I spoke to a friend of mine who has a chemistry background. She indicated three experiments that are a bit 'wow' for students… and I stick to those. I put the chemicals on the bench. Students come in and as soon as they mix them the reaction happens. I use a double lesson for just three reactions. I get each group next to me on the bench and as it is happening I discuss with each group. 'What is happening? What do think?'… I do the test for oxygen and hydrogen. Usually out of a double lesson I am then left with twenty minutes in which I tell them to do a write-up. But I stick to those!*

Following a prescribed curriculum or a set of practical tasks shows that teachers are very insecure to try out new activities. On similar lines, Laura and her colleagues developed a pack of notes for Year 8 students. By following the same material Laura felt better and secure because all the teachers were following the same structure and sequence of lessons. The notes provided a sense of continuity and ensured consistency within a boundary that was familiar to Laura. As a result of this continuity Laura felt more reassured because as she explained "*I am covering everything that I have to do, the amount of detail is neither too little nor not much… I am moving on the same lines as other teachers.*"

This coping strategy helped teachers to deal with their uncertainties arising when teaching an unfamiliar area. Teachers felt more secure to follow suggested ideas or prescribed material such as lesson notes because they were following common practices and hence they could not go wrong. By using this coping strategy they remained on the side of the boundary with which they were familiar.

9.1.2 Using knowledge from subject specialism

Another coping mechanism used by the participant teachers involved using their knowledge of their subject specialism in order to understand and formulate explanations of chemistry concepts. Rather than crossing the boundary they opted to stick to that which was familiar to them. For instance the topic of 'matter and kinetic theory' is a common topic in physics and chemistry. The physics specialist teachers like Robert and Maria could retrieve their knowledge from their subject specialism and use it to teach the topic of 'understanding matter', without the need to conduct further research in their lesson preparation. Robert related that the topic of 'understanding matter' felt closer to physics and he felt comfortable teaching it. He used his background knowledge to prepare for this topic and thus he explained that, *"you try to make sense of things basing on what you know, like I will be trying to understand some chemistry topics by using ideas from physics."*

This strategy is also outlined in a research study carried out by Nixon and Luft (2015) where biology teachers use real world examples and their knowledge of biology to explain chemistry concepts. Very often they construct and expand their understanding by associating their knowledge within their subject specialism with that outside their area of expertise. However in the current study since the topic of kinetic theory is a common topic in both disciplines, two of the physics specialists were using their own knowledge to teach this unit.

Robert also tried to use his knowledge of physics to understand and convey simple explanations of other chemistry topics. When Robert had to teach simple distillation he tried to relate the shape of the glassware to everyday materials. He compared the shape of the condenser to that of a pen in which there are two concentric tubes. He used his knowledge of the concepts of changes of state studied in physics to explain the changes of states during the distillation process. He recalled that whilst preparing for his lessons:

> *I went into class and I had no idea of distillation. I sat down and I started looking at the equipment and tried to understand how it works. I looked at the condenser and thought that it looked like a biro, so I started making some sense of the equipment from what I knew. From physics I said: there is evaporation... then cooling, so it is condensation. Then I formulated the story. It just came about by observing the condenser and trying to associate each piece of equipment and how it works with things that I already knew. At first it did not make sense but after a number of reflections and by using my previous knowledge I managed to understand it.*

Maria, as a physics specialist, used knowledge from her physics background to explain specific chemistry topics because she felt that they were more related to physics as in the topic of 'understanding matter' and 'separation techniques.' Daniela made use of similar strategies in laboratory sessions. She was seen by the other participants to be quite confident in conducting experiments. She later on explained that when doing chemistry experiments she used her biology background and applied them to practical work. By using this coping mechanism the participant teachers could work out what could be translated from their current set of knowledge and skills and use it to teach the new subject area. This was more common with the physics specialists due to common topics between chemistry and physics.

9.1.3 Using traditional pedagogies

When teachers are not confident enough to teach outside their area of specialism they tend to resort to traditional methods of teaching and pedagogies because they believe that this approach will give them greater control in their lesson (Harlen & Holroyd, 1997). Although I did not manage to observe traditional pedagogies in my lesson observations, during the interviews one of the teachers stated that he used this methodology whenever he felt overwhelmed to cope with the various challenges presented in teaching chemistry.

Robert stated that when teaching physics, his area of specialism, he always tried to follow an inquiry-based learning approach. Since he felt less knowledgeable in chemistry he delivered a different type of lesson that restricted students' input. He confessed that the lesson plan would be designed in such a way that it will *"be full of activities."* He described what he did after conducting an experiment: *"I immediately switch on to something else and I don't give time to students to ask questions."* Although in principle this went against Robert's philosophy of teaching and learning and his content-specific beliefs, he planned different lessons to avoid revealing his insecurities about his lack of content knowledge to his students. He further explained that in other lessons he changed the sequence of activities in the lesson to restrict students' questions where:

> *First I teach the topic and then I do the experiment at the end of the lesson. Like for example in acids and alkalis: acids neutralise alkalis and then we talk about the jellyfish, bee sting, toothpaste. Then we see the experiment and I would have answered all the questions from beforehand…. What will happen? The students will ask fewer questions. If you were to use the experiments as an introduction to the lesson, students would ask many questions and once one student starts with a question they start building up… so I change the lesson plan and when I am not sure about something I leave it till the end of the lesson such that most of the questions would have been tackled in the topic and there won't be any questions during the experiment. When I am confident with the topic then I start with an experiment but if I am less knowledgeable I leave the experiment to the end of the lesson. If I start with an experiment I will trigger the students' curiosity and they will start asking questions…. This will have a ripple effect on the whole class. Students start pooling questions and the teacher is under test at that time.*

Traditional teaching methods were used in a study reported by Lee (1995) where the teacher maintained strict classroom order by keeping students busy working exercises from their textbook. Although Robert did not use individual work, as in Lee's study, he purposely narrowed down classroom discourse to gain more control in his lessons. This is similar to the findings of another study by Harlen and Holroyd (1997) where teachers emphasise expository teaching and minimise questions and discussions. Robert identified an area of 'discontinuity' between teaching his subject specialism and teaching outside specialism. While a firm believer of inquiry-based practices, he was not capable of using these ideals when teaching his non-specialist subject. He found it very difficult to overcome such 'discontinuity' presented in the different subject areas and resorted to restricting an inquiry-based approach to learning. As he explained, by constraining students' conversations and curiosity *"the students will already have an idea of what's about to happen. This decreases some of the students' motivation. Experiments are done to prove what was said rather than to stimulate the students' thinking."*

His diverse experience when teaching within and outside specialism impacted his degree of confidence and his belief in his ability to deliver a lesson according to his philosophy of teaching and learning. These feelings of inadequacy kept Robert teaching at the boundary without being able to make the crossing.

9.2 Enabling mechanisms or boundary objects

Teachers with enough support and successful experiences can manage to encompass their new role as teachers of their non-specialist area (Hobbs, 2013a; 2013b). As Beijaard et al. (2004) argue the teachers' sense of agency helps them to work towards their target goals. When teachers manage to move out of their comfort zone, they find many opportunities for learning to teach their non-specialist area and they make use of enabling mechanisms or what Hobbs (2013a; 2013b) describes as 'boundary objects' that act as a bridge between the known social world of their subject specialism and the unknown world of their non-specialist area. This implies that with support non-specialist teachers are able to 'cross the boundary' through a process of active transformation and a reconceptualisation of their teacher identity (Akkerman and Bakker, 2011). The participant teachers made use of a number of enabling mechanisms or 'boundary objects' that enabled them to transform themselves as science teachers. These included both non-human objects, such as carrying out research using books and the Internet, as well as human objects through the support of colleagues. Repeated teaching experience was another boundary object that increased the teachers' self-confidence when teaching unfamiliar areas. Therefore these 'boundary objects' enabled the participant teachers to develop new knowledge and skills and allowed boundary permeability between their subject specialism and their non-specialist subject, in this case, chemistry.

9.2.1 Conducting research

One of the most common strategies used by the participant teachers that allowed them to 'cross boundaries' involved conducting research from books or the Internet and reading other resources like the integrated science syllabus since it included a list of suggested activities for every lesson. Such findings were evident from the results of the questionnaire where all teachers used different resources particularly the Internet to retrieve activities to make their science lessons interesting (see Appendix 8). This was also confirmed during the teachers' interviews. Conducting research was one of the main supporting strategies described in the research carried out by Childs and McNicholl (2007) and Kind (2009a), where teachers generally read books and teaching schemes to develop their expertise and learn new SMK and PCK in preparing their lessons. In the current research teachers recognised the need to conduct research because they felt less knowledgeable in chemistry and needed to address their weaknesses or gaps in knowledge. Maria insisted that she went *"a lot online and read books"* to upgrade her background knowledge, whilst Amy did *"some reading beforehand*" to remember chemistry content. Robert acknowledged that he needed to *"prepare further in a chemistry lesson"* because he also needed to prepare *"for what the students may ask."* In other words, teachers spent more time looking up and reading information as well as searching for suitable activities. Laura described this laborious process and how she tried to make sure that she had all the correct information before teaching a lesson outside her subject specialism as:

> *Having to research a bit more than I would if I were teaching biology because I had forgotten certain things and I wanted to be sure that I was giving them the right information and that I was explaining things in the right way so they wouldn't have misconceptions.*

Daniela spent considerable time reading various books and using the Internet to ensure that she was knowledgeable enough when teaching outside specialism. She stated, *"I read a lot because I do not know enough. I always want to know lots about the topic and I spend quite some time looking up information."* Similarly, Sarah consulted resources and used visual resources to facilitate her understanding of conducting particular experiments. She stated, "*I look up videos in chemistry so that I will be certain about what I need to do in experiments…. and how to answer students' questions."*

Karen used both books and the Internet to find interesting inquiry-based activities for her students:

I do research most of the time. There is [a] website…that I like to access. I look up YouTube. I don't just use the websites that I have on my scheme of work. Every now and then I look up things because they create new resources and new websites. When I go to the bookshop I go to the children's section and look for new science books…. I am always researching and trying to do new things.

During the preparation stage Amy and Daniela also thought of *"worst case scenarios"* or anything *"that could go wrong in the lesson."* They also tried to *"think of all eventualities"* that might crop up in a lesson. Daniela included extra notes in her lesson plans to ensure that she was well-prepared. The responses of these teachers and their efforts to conduct research show that teachers resorted to using this enabling mechanism to overcome their insecurities. They wanted to feel more knowledgeable and in control of their lessons. The participant teachers consulted various resources not only to upgrade their content knowledge, but especially to improve and overcome their limitations in their PCK. They wanted to find suitable and engaging activities, provide correct explanations, learn how to conduct experiments and feel prepared to answer students' questions. This implied that conducting research enabled teachers to 'cross the boundary' to feel more prepared and competent to teach a different science area.

9.2.2 Support from colleagues

Asking for help from colleagues who are specialist in the area is another common support mechanism used by the participant teachers, where seven teachers generally or often asked for support from their colleagues (see Appendix 8). Support from colleagues enables teachers to gain enough confidence to be able to 'cross the boundary' from their specialist to their non-specialist area. During the interviews Laura, Amy, Robert, Maria and Christine mentioned that they often discuss their difficulties with their colleagues and ask them to suggest activities for their lessons. This strategy was commonly used by teachers who felt that they had major weaknesses in chemistry content. They often asked for support related to the preparation and execution of unfamiliar chemistry experiments. Consulting colleagues who are subject specialists is a very common strategy among non-specialist teachers as has been found in different research studies (Childs & McNicholl, 2007; Hobbs, 2013a; Kind 2009a, McNicholl et al., 2013). Non-specialist teachers very often draw on and learn from their colleagues who are specialist in the area, when they are informally sharing knowledge and ideas of classroom practice.

Laura's colleague helped her prepare class activities and provided the necessary explanations related to chemical reactions. Maria asked her colleagues to suggest suitable chemistry experiments for her lessons. Amy often asked the senior teacher, who had been teaching science for a number of years, to suggest examples of experiments. At her school Amy had another colleague, who was a newly qualified teacher and together with the senior teacher they often conducted experiments prior to the lesson. In this way Amy could revise the chemistry content and feel more prepared and confident for the lesson. She said that:

> *Every time I do experiments, I practice… then I do feel better after…. We try the experiment beforehand. First of all it's fun just the three of us trying out experiments together. Every time I try it I feel better. I feel like I know exactly what is going to happen because I have done it so I can see myself doing it and I feel better doing it.*

Robert found different forms of support from his colleagues. In his first year the science teacher provided the students' notes so he could easily devise his lesson plans. He explained, "*it was helpful to have my colleague's notes. I wasted less time and I could plan lessons on these notes.*" When he was uncertain about his explanations he asked for clarification from other subject specialists as shown in the following anecdote:

> *Once I was teaching a biology topic and I taught something wrong. I happened to have a double lesson. In between lessons I went next to the biology teacher and asked him about it and he told me 'no it is different.' In the second lesson I went in and corrected myself. It is important that you correct yourself rather than leaving the students with misconceptions.*

Very often Robert asked his colleagues to suggest possible activities and experiments. However he recognised that he could not rely completely on their support and he needed to take more ownership in the process. He explained that:

> *I did not have any clue as to which chemistry experiments I had to use in the lesson plans. I discuss some of them with my colleague but I cannot do it all the time: asking questions like 'What are you going to do? How are you going to do this?' You need to cope on your own.*

A competent teacher needs to have a deep subject content background to use it and transform it into subject matter for teaching. Although Robert recognised that support is truly beneficial for a non-specialist teacher, he felt that he needed to become more autonomous in his work. Here Robert was concerned about his identity, especially how 'others' saw him and judged him as a science teacher. This suggests that non-specialist teachers struggle to keep up 'an image of a competent teacher' because when they get stuck they are constantly asking for support about their gaps in content knowledge and for examples of suitable activities for their lessons.

When Christine started teaching science, her colleague who was a chemistry specialist gave her immense support. She worked very closely with her colleague and they "*have the same notes, lesson plans and schemes of work.*" She learnt a lot from the colleague on whom she relied whenever she had difficulties. Christine felt that she had improved in her teaching because of the support available at her school. She explained that:

> *….chemistry is not my area but I like the subject. I work together with my colleague, for example if we have to do a workbook. She is more specialised in chemistry and there is always help. Whenever there is help from colleagues you will manage to do it.*

Before her lessons, Christine wanted to feel more prepared in tackling students' questions and asked her colleague about "*possible questions that the students can ask.*" After the lesson she often checked with her colleague that she had given correct responses to students' questions. Christine in fact explained that:

> *Before the lesson if I find any difficulties I will talk to my colleague. I try to clear the difficulties from before, in case students ask questions. There will be high ability students who ask questions and I get annoyed if I can't answer. But I got stuck at times so I tell the students that I will let them know in the next lesson… and then I go and talk to the chemistry teacher.*

As indicated in Chapter 8, an underlying issue that comes out from the teachers' narratives is the overwhelming concern of giving students the wrong information or consolidating misconceptions. To resolve this issue many of the non-specialists teachers asked for support from the subject specialist to check their understanding and construct accurate explanations. Both Laura and Christine had a very good working relationship with their colleague who was a chemistry specialist. They found that consulting their colleagues was, what is described by Eraut (2007), a quicker and more effective way of getting information from more knowledgeable others because, like in another research study (Childs & McNicholl, 2007), they did not need to spend time going through textbooks or other resources.

Some teachers noted that laboratory technicians also provided the necessary support in case of difficulties. Robert discussed his queries with the laboratory technician before doing an experiment to gain reassurance and control of his actions. Furthermore he conducted trial runs with the laboratory technician and discussed what could go wrong in the experiment:

I ask the technician before I do a demonstration experiment so that I am sure of what I am doing. I ask about how I can vary the experiment by adding a bit more or less from particular chemicals…. You need to know what can go wrong in an experiment.

Like Robert, Christine conducted trial runs because she liked to "*try out the experiments [she was] not sure about, so [she would be] more confident ... in front of the students.*" She discussed experimental results with the laboratory technician when conducting trial experiments before the lessons. During an interview she stated that:

…if there is a result that I am not so happy with, I will ask the lab technician whether I am conducting the experiment correctly. If she does the experiment and obtains similar results we try to find out what happened. If she does the experiment and it works, then I am doing something wrong. At times you say better try out this experiment beforehand to make sure that it works well.

Laboratory technicians are an important source of expertise in supporting non-specialist teachers in preparing for practical work (Helliar & Harrison, 2011; McNicholl et al., 2013). Both Robert and Christine consulted with and learnt from laboratory technicians whenever they had gaps in chemistry knowledge. As suggested by the teachers in this study, they frequently asked for support from the other science teachers, chemistry specialist teachers and the laboratory technicians. This is very similar to what has been found by Childs & McNicholl (2007) where teachers were learning and developing both SMK and PCK in the context of their workplace through the support of their colleagues.

Colleagues provide the necessary support in planning and teaching by suggesting various activities, experiments and analogies. During these interactions PCK is enacted in context and "created in practice" (McNicholl et al., 2013, p. 157). In line with other research (Kind, 2009a; Hobbs, 2013a), teachers in this study felt that they gained more confidence and competence in teaching the subject after collaborating with colleagues. For them, collegial support led to the development of what Hobbs (2012) describes as "a more positive identity in relation to the subject" (p. 28). The participant teachers had a good relationship with their school colleagues and they spoke highly of them. They felt that they could easily and openly discuss their difficulties without feeling embarrassed about their lack knowledge or as being perceived as less 'knowledgeable teachers.' Teachers were very grateful for the assistance provided by the colleagues because it helped them to feel reassured and more knowledgeable in what they were doing, thus increasing their motivation and confidence in teaching chemistry topics.

9.2.3 Repeated teaching experience

Repeated teaching experience makes the teachers become more familiar with teaching particular topics. When teachers teach the subject a number of times they gain confidence (Hobbs, 2012; 2013a) and learn how to deal with classroom challenges. The boundaries between the less familiar area (in this case the teaching of chemistry) and the more familiar area (their subject specialism) can start to fade away when the teacher becomes more familiar with the content knowledge, teaching strategies and student learning needs through repeated teaching experience. As Whannell and Hobbs (2018) argue, the boundaries between the different areas become permeable. When the participant teachers were interviewed a year after the research study they commented that repeated teaching experience helped them to gain confidence in teaching chemistry topics. After her first year of teaching science Daniela became more confident in her work because she explained that during the second year:

> *I don't have to test activities over again. I don't need to research so much more about certain concepts, because it is the second time so I had learnt certain things. When you reflect on what worked and what did not work you would know more from before what terms and questions you need to use.*

PCK develops over time through the process of planning, teaching and reviewing. Through repeated teaching experiences teachers learn to construct, what Hashweh (2005) calls 'teacher pedagogical constructs'. They learn how lessons can be developed and how to anticipate students' misconceptions and questions. Repeated teaching leads to more successful lessons because teachers feel more prepared at tackling various issues and incidents. After teaching science for the second time Laura felt that:

> *This year it was good. There were fewer incidents, fewer issues. As time is passing it is becoming easier, I think. You already know what students' misconceptions are; you already know how to handle them. I think the more time passes, the more experienced you become…. when it comes to problems you know how to go about them, or how to present things which are more interesting.*

From one year to another Karen felt more prepared to answer students' questions. She used the questions that students had asked in the previous year to develop her lessons. With time she observed that she learnt how to answer students' questions because:

> *… it will get better through experience. Year after year I will be hearing new questions. If I keep a note of them or remember them I would have already thought about these questions when it comes to lesson planning. I will be more prepared for such questions in the future.*

Teachers within this study mentioned that reflection on previous lessons was necessary to improve on their work. Karen explained what she did whilst reflecting on her lessons: "*I keep on researching, I go over the notes, write comments on what I can improve for next year. Every year you learn from your mistakes and you try to improve.*"

Through repeated teaching experiences teachers gained more reassurance in their work and increased their self-efficacy. They became more familiar with what to expect in their classes with regard to common students' difficulties and types of questions asked. They learnt how to adjust the levels of explanations to young students. In the process they were building and refining their PCK. When I met the teachers, a year after commencing the research study, they exhibited less anxiety because repeated teaching experience helped them to feel more confident in their work and enabled them to 'cross the boundary' between different subject areas.

9.3 Crossing the boundary

The enabling mechanisms or 'boundary objects' previously mentioned prompted teachers to exercise their sense of agency, apply their knowledge and adapt to new practices and situations. In the process teachers were learning how to use their adaptive expertise, that is, they were learning to apply knowledge effectively to new situations. As Hobbs (2012) argues, when teaching outside specialism "teachers find themselves in situations where they must 'do research', learn from colleagues and be adaptable. How a teacher copes in these situations is not just critical to their practice but also for their professional identity" (p. 26). When teachers were using these enabling mechanisms they were adapting to different situations and teaching the different subject areas. They were able to 'cross boundaries' and feel more competent in preparing and teaching a new area. On the other hand when they used coping mechanisms they did not expand their knowledge base and remained on the side of the boundary that was familiar to them. The next chapter discusses the experiences gained by the teachers during the PD programme. It explores how the PD programme provided a supportive structure that could enable teachers to expand their knowledge base, change their practices and become more confident to teach their non-specialist area.

Chapter 10

Teachers' experiences of their professional learning journey

The participant teachers attempted to overcome the challenges related to teaching their non-specialist area by using enabling strategies in order to embrace a professional identity as teachers of science. As argued by Hammerness, Darling-Hammond and Bransford (2005), their personal and professional identity as specialist teachers was shaping their dispositions where they placed their effort, the kind of professional development opportunities they sought out and what obligations they saw as being intrinsic to their role as science teachers. The participant teachers assumed agency and took a personal decision about their own professional learning by participating in the PD programme.

Drawing on data from individual interviews carried out along the year, focus group interviews and from the reflections of the researcher's journal this chapter gives snapshots of the teachers' journey during the professional learning experience. It also explores the teachers' reflections of this PD programme and how teachers made sense of the experiences as learners and teachers within a professional learning context.

10.1 Starting the professional learning journey

Whilst listening and reflecting on the teachers' stories narrated along the research study, I came to realise that participant teachers began their professional learning journey with common starting points. They all wanted to improve their confidence to teach chemistry and overcome the challenges they were facing (see Chapters 8 and 9). They had common concerns since most of them felt weaker at teaching chemistry compared to when teaching their science specialism. These common aspects encouraged and motivated the teachers to participate and travel together along their professional learning journey.

10.1.1 Deciding to participate in the professional development programme: A personal choice

The participant teachers continuously spoke of their contrasting experiences when teaching different topics in science. They felt capable and competent in teaching their area of specialism but less capable and proficient in other areas. The discontinuity in identity (Hobbs, 2013b) prompted them to seek further support because through joint effort they believed that they could improve and gain confidence in teaching chemistry. Furthermore, as Christine stated "*knowing that there was something ongoing made it more likely for you to have a chance to learn.*" Participants decided to voluntarily opt to participate in the PD programme for a variety of reasons. The most common reason cited by all the teachers was to "*feel more confident when teaching chemistry.*" In addition the teachers mentioned specific reasons why they wanted to participate in the PD programme. Guskey (2002) contends that teachers generally attend professional development because they believe that they will expand their knowledge and skills, grow in the teaching profession and enhance their effectiveness with their own students. In fact in the current study, the teachers started on their professional learning journey in order to (1) gain a deeper knowledge in the subject, (2) acquire pedagogical skills such as new teaching ideas and various examples of learning activities, analogies and experiments and (3) improve their attitude towards chemistry.

10.1.1.1 Gaining a deeper knowledge in the subject

Having a deep understanding of the subject content knowledge in a subject area is fundamentally important in becoming a teacher (Shulman, 1986). The participant teachers wanted to develop their knowledge base and gain a deeper understanding of chemistry. For those teachers with a background in chemistry, like Daniela, Amy, Karen, Sarah and Laura, this was simply a matter of revising their knowledge and skills. For instance Daniela explained, *"initially I did not know the difference between a strong and a weak acid. I knew it a long time ago but I forgot it."* Then through research she revised this concept and managed to explain it when discussing the pH scale.

The teachers who did not study chemistry at school, like Maria, Robert and Christine, saw the PD programme as an opportunity to "*obtain a deeper knowledge of the subject"* as well as to learn how to translate the content knowledge to *"be able to teach the subject"* and *"adapt it for the younger students."* For instance Maria explained how:

> *This journey started because I always felt I had a handicap when it came to teaching chemistry since I have never studied it. When I started I said: 'let me improve my chemistry, so then when I give my lessons I will feel better.' My intention was to learn more about the subject, especially on how to teach certain topics.*

Kind (2000b) argues that a good foundation of content knowledge provides a stronger sense of security in teaching. The teachers' arguments confirm that teachers need to have a good grounding in their SMK which is a fundamental aspect of the teachers' knowledge base as outlined in the theoretical framework in Figure 2.2.

10.1.1.2 Acquiring pedagogical skills

In addition to increasing their SMK, the participant teachers also wanted to improve their practice and teaching pedagogy. As described in the literature, lessons outside specialism tend to be tightly controlled, rigid and constrained (Childs & McNicholl, 2007). This was also observed with the participant teachers, who in their interviews described their difficulties in relation to lesson planning (see Chapter 8). Robert explained that:

> *I had spent a year struggling with science. Then I saw this course. I felt that after a year of trying to teach science, where at Year 8 there is more chemistry and biology than physics, I had to improve. So I came to the professional development programme. I wanted to acquire more knowledge on the subject and more importantly how to be able to teach the subject.*

The teachers wanted to embark on the PD programme to able to gain new ideas in teaching chemistry. For example, Karen wanted to *"gain more ideas, more resources and more confidence in practical work that [she had] not done in a long time."* She also wanted *"to gain confidence in planning inquiry-based learning activities."* They perceived this PD programme as an opportunity to improve their PCK.

10.1.1.3 Improving attitudes towards chemistry

Besides wanting to increase their chemistry knowledge base, the participant teachers also wanted to improve their attitudes towards the subject. Developing a positive attitude towards a subject can enhance the teacher's self-efficacy and their belief that they are able to teach outside their area of expertise. The participant teachers believed that if they had a positive attitude towards chemistry then they would be more confident in front of their students. Laura stated that she wanted to "*improve the way [she taught] or view[ed] the chemistry-related topics and to feel more confident when teaching chemistry in science units.*" Similarly Christine wished to gain confidence by improving her perception of chemistry and gain more ideas for her lessons. She revealed:

> *I always wanted to improve in chemistry. I used to feel uncertain and uncomfortable when it comes to teaching chemistry-based topics. I felt the need to gain more confidence and to expose myself more to ideas on how to prepare lesson plans and interactive resources that can help my students learn and understand chemistry in an easy and fun way.*

The teachers' stories suggest that they embarked on this professional learning journey in order to expand their professional knowledge base by revising their content knowledge, expanding their PCK and re-evaluating their beliefs about chemistry teaching in order to gain a more positive outlook of the subject and improve their current practices. Regardless of the reasons why the participant teachers decided to embark on the professional journey, what was clear from the outset was that this was something that the teachers wanted to do. It was a personal choice that would help them, as stated by Amy *"to improve and move forward… to evolve as a teacher and not remain stuck in a rut."* As described by Beijaard et al. (2004) the teachers' agency to make such personal choice made them open to engage in new learning experiences. They were ready to develop what Luehmann (2007) describes as a new professional identity.

10.2 Nurturing a community of learners

The eight teachers started to get to know each other during the INSET sessions. Nurturing a community of learners within this context offered a number of challenges. These were mainly related to the teachers' self-efficacy beliefs in teaching outside specialism. According to Bransford et al. (2000), teachers feel more vulnerable to share experiences and practices in which they feel to be less competent. Hence it was not easy for non-specialist teachers to share their experiences because, as Du Plessis, Gilles and Carroll (2014) argue they could be seen by others as ineffective or incompetent teachers. With time teachers worked as a community of learners because they realised that they were living common experiences in their classrooms. Furthermore, when they felt safe and supported by the other members they developed closer connections and engaged in collaborative work that enhanced their professional learning.

10.2.1 Bonding over shared experiences

During one of the INSET sessions teachers were given the opportunity to start sharing how they were feeling when teaching outside specialism, particularly when teaching chemistry topics (see Appendix 2). At first it was not easy to break the ice but after reading the case study written by Laura, the participant teachers opened up and they started sharing their difficulties and talking about the challenges they were facing. They also started discussing how teaching outside specialism was affecting their self-perception as a science teacher. In my reflections, I noted that:

> *Admitting one's challenges and preoccupations is not any easy task. I appreciated the teachers' honesty and humility in stating that they encountered challenges and felt insecure in teaching their non-specialist area. It is not easy to admit your weaknesses in front of other teachers you don't know! It may cause some teachers to be anxious in sharing their difficulties. When Laura openly admitted that she had written her experience in the case study it facilitated the process for the other teachers to share their own experiences. Slowly, slowly everyone started sharing how they felt when teaching chemistry and they discussed which topics were considered easy or challenging to teach.*
>
> (Journal entry: July 2014)

As the participant teachers shared more of their experiences, it became clear that they were bonding over the fact that they were all going through similar challenges and issues when teaching outside specialism. They felt relieved that they were not alone in their struggles. From these initial discussions everyone realised that, as Sarah described: *"others have similar problems to me. I am not alone."* Feeling less isolated in their struggles and experiencing similar issues helped them to feel at ease with each other. Daniela felt *"comfortable to be working with other teachers facing the same pre-occupations"* while Maria said, *"I found a group of colleagues that share my same ideals and I am comfortable to speak about ideas or concerns that I might have.*" Karen also stated that she "*felt more comfortable to open up with teachers who are in my same situation… like they tell me 'even that happened to me!'… Oh so I am not alone!"*

By sharing their stories and experiences the teachers could understand each other's background, insecurities and needs. This helped them to bond with each other because as Robert commented, *"knowing that there are more teachers who do not have a background of chemistry like me, made me feel more comfortable when discussing and sharing my problems with the whole group."* Teachers felt comfortable to share their own difficulties because as Christine mentioned, all participant teachers felt that they "*were all in the same boat."* As Wenger et al. (2002) argue, discovering common interests and needs are essential elements in building a community of learners.

Another factor that helped teachers to develop such a bond was that they all wanted to overcome their difficulties. They were all eager to work together to achieve their final aim: that of becoming better science teachers. This marked the start of the community of learners because as Maria explained:

> *Then we started discussing and realised that we were all literarily sharing the same experience, we all felt weak in one subject. We all feel that sometimes we don't do enough or we feel sometimes it is not good enough for the students…. It became clear from the beginning that we all shared the same concerns…. I realised that this experience would help me improve in my profession in general…. Then it felt really comfortable. It made us work a lot together.*

In my view, this initial bonding experience was vital to nurture a community of learners. Wenger et al. (2002) explain that the "key issues at the beginning of a community is to find enough common ground among members for them to feel connected and see the value of sharing insights, stories and techniques" (p. 71). The teachers in the current study discovered that like their colleagues they shared common challenges and developed similar strategies to overcome their difficulties. These common factors provided the initial motivation and drive for teachers to work together in a community of learners as described by my reflections in the research journal:

> *As the discussion developed, teachers realised that they had common difficulties and felt relieved that they were not the only ones struggling with planning of particular chemistry topics. This feeling gave them the impetus to share their concerns and listen to each other. They also admitted that they felt relieved that there were 'all in the same boat.' I felt that this feeling motivated them to look forward to share their ideas and practices.*
>
> (Journal entry: July 2014)

During the INSET this fostering of a community of learners was evident; however it was not without its tensions. Some teachers like Laura, Daniela, Amy and Maria felt that it was rather difficult to develop long-term and lasting working relationships with the teachers from other schools. Laura explained that she *"was apprehensive to work with teachers [she] did not know because it normally [took] time for [her] to get to know people."* Although these teachers recognised that working together would be of great benefit to their professional learning they needed time to develop a sense of trust and relationships with the other teachers.

This sense of apprehension was carried over during the second phase of the PD programme. During the first workshop I felt that the "*participants were still testing grounds and getting used to each other"* (Journal entry: December 2014). Through the year the participant teachers began to trust each other more. Laura explained that they *"were with the same people throughout the year so you gained more confidence and trust with these people."* In the workshop sessions the participants felt more comfortable since they were a smaller group compared to the INSET sessions (these sessions included other teachers who did not participate in the study). As Maria explained, *"it was an advantage that we were less in number as we immediately started working comfortably together and it was very natural."*

In other words at the beginning of their learning journey some teachers felt that they required more time to work comfortably with other teachers and feel part of a community of learners. Wenger et al. (2002) speak of this time factor issue and remark that time is needed for a community to develop to a point where members can genuinely trust each other and share their own personal knowledge. Laura confirmed that *"a sense of trust was built since with time you get to know more people."* Once the participant teachers built trust and started to feel safe and supported within the community of learners, they developed stronger relationships that helped them to overcome their insecurities when teaching their non-specialist area.

10.2.2 Feeling safe and supported

In my view, one of the factors that enabled the teachers to engage in the community of learners was that it provided a safe and supportive space for teachers to discuss their experiences. Daniela described that the learning community was a *"place of sharing both positive and negative experience because it was a place where one felt safe to discuss difficulties too."* This type of environment is critical in cultivating a community of learners because as different research studies show, it enables teachers to take risks, discuss their concerns and reveal their own personal self (De Winter, 2011; Wenger et al., 2002;

Woolhouse & Cochrane, 2010). When the participant teachers started to form stronger ties and develop a sense of collegiality, they felt that within the group they were not threatened or judged. As Laura explained there was an "*overall feeling of being in a place where people want to help you improve and not make you feel that you are being scrutinised and judged.*"

Respect and trust are also important elements in fostering a community of learners (see Stoll et al., 2006; Wenger et al., 2002). However, respect and trust do not happen by chance, they need to be nurtured through the various interactions. Trust develops through sharing and disclosing personal experiences that leads members to understand one another, their ways of thinking and approaching dilemmas to develop solutions (Wenger et al., 2002). As Amy confirmed, she felt that within the community of learners, they *"happened to be a group of teachers who are dedicated and try hard. You take what they say more to heart. You build trust."*

The one-to-one meetings with the participant teachers taking place during the year also facilitated the development of trust between the teachers and me in the role of a researcher. I noted that as our relationship developed teachers felt safe to confide their strengths and weaknesses as science teachers. These conversations were essential and beneficial as I could empathise with the participants, understand their background and their struggles and discuss what they wanted to achieve through professional learning. Trust was nurtured with time and the dynamics within the learning community strongly influenced this process.

The participant teachers all felt respected by the other members when they consulted each other and asked for help. They believed that their contributions and sharing of experiences were appreciated. Sarah stated that as a member of the community of learners she felt, *"more valued, as a person and as a teacher."* This feeling was common among all the participant teachers in this study.

Luehmann (2007) argues that when teachers became part of a community of learners they will be developing a new identity and this involves taking risks, such as that of not being successful or appreciated by others. Having a safe and supportive context was essential for the participant teachers since they had a number of insecurities and they lacked faith in their ability to teach outside their area of specialism. They needed to expose their vulnerabilities in front of others before they could grow and develop a new identity as science teachers. Initially Sarah was shy to share her experiences and admitted that she found it "*difficult to express [her] ideas in a group*" but then Sarah felt that the positive environment encouraged her to disclose both her strengths and personal dilemmas. Sarah argued, *"other members made me feel comfortable to express my ideas within the group.*" Furthermore Maria felt that the community *"gives you the strength to face your fears,"* hence the community environment supported teachers to reveal their own struggles and then face their difficulties.

10.2.3 Forming connections

The community environment encouraged teachers to strengthen their relationships. Robert claimed that the environment created in the community *"helped [them] to connect together."* Besides this he noted that since teachers managed to build a constructive atmosphere they *"could criticise each other and everyone would accept that without mocking each other."* On similar lines Karen explained that participants were open to each other's ideas and *"no one said mine is better so I will stick with mine. No one was rigid. Everyone listened to one another and applied what they had heard."* Within this supportive environment teachers started to form connections, they were open to each other's feedback and no one looked down on the other. Karen also pointed out that different ideas were easily accepted and teachers were not afraid to ask for a second explanation or what they perceived to be trivial questions. She explained that she felt "*comfortable asking even the silly questions"* because *"no one is a chemistry specialist. No one is an expert. If it is silly for those with a background, it is not silly for us; we are all in the same boat."* Feeling at par reduced power differences within the community because, as Sarah explained, *"no one said mine is better than the rest, so you don't feel excluded.*" The teachers felt that none of the members had a superior attitude, otherwise this would have hindered the process of a cultivating a community of learners. The teachers developed connections and links that made them feel comfortable with each other after developing a sense of trust and reciprocity.

As the community of learners started to bond I was reflecting on where I should position myself within the community of learners. I wanted to find a compromise between the tensions that could arise from my different roles; that is that of a researcher, the designer of the PD programme and being seen as the expert in chemistry. As Cohen et al. (2018) suggest I could have been perceived as having more power than the research participants, be it in terms of knowledge of chemistry and in designing the PD programme. I also had my concerns regarding how I could affect the dynamics of the community of learners. Besides this, I was also very cautious about my influence on others since the teachers were seeing me as a facilitator who was organising and developing the sessions. To overcome the power differentials, as suggested by Cohen et al. (2018) I tried to create an atmosphere where the teachers could feel at ease and participate freely in the community of learners. I respected and valued all the teachers' ideas as they constructed knowledge within the learning community. Furthermore to reduce power differentials I asked the teachers to suggest an agenda for each workshop session hence giving them the necessary power to make their own decision in their learning process. In fact for the second and third workshop teachers suggested sharing their own work and hence they became engaged in peer teaching and learning.

Since I was meeting the teachers on several occasions throughout the year, that is during the one-to-one interviews, in lesson observations and in the workshops, I started to form stronger bonds with these teachers. Initially I tried to stay as much as possible at the periphery of learning community by intervening only when necessary in order to facilitate the development of the sessions. With time I felt that my role started to shift from that of facilitating the learning sessions to that of becoming part of the learning community. The teachers also noted this change and pointed out that along the year they saw me as becoming one of the members of the learning community. Robert explained that:

> *I saw your role as a leader… and at the same time you participated with us. It is like you were not really doing the study and I really liked that a lot and it was also very effective. Although you were an expert in chemistry you were still like us. That is something that I observed… that you were on our level… OK you were there, but in reality Doreen was not really there… You were not a step above us, but you blended in and that made a difference.*

Another finding that emerged from the current study is that some teachers felt that they were only able to make these connections with the newly formed community, rather than with their school colleagues. In Chapter 9, the teachers acknowledged that seeking advice from an expert colleague was an important strategy to overcome the challenges in teaching outside specialism. Yet, some of the participant teachers felt more comfortable sharing their experiences and difficulties with the teachers who formed part of this community because, as Amy described, the community members had a *"more similar mindset."* She further explained that:

> *At times I do not feel comfortable discussing this with some of my colleagues at school. I don't know why, maybe they expect a certain standard. But I would not have gone to my colleagues to ask about particular problems especially particular people. Whereas here, when I had difficulties I felt more comfortable asking about them rather than with the teachers at my school.*

Robert also explained that within the community of learners he felt less threatened. He felt free to express his concerns knowing that he would not be looked down upon or considered to be less knowledgeable than others.

In creating a collaborative and supportive environment, teachers need to be willing to work with others rather than in isolation. Maria was very vocal about her beliefs about the importance of team work. She previously worked as an engineer and from her experience she related that:

> *I came from an industrial environment. I worked as an engineer in a factory. You cannot do things on your own. It is impossible. There is no time, there is too much to do. I am accustomed to working in a team. There was never a time that I did something on my own without anyone seeing it. Unfortunately in teaching it is ironic how teaching is connecting with people, but in reality in terms of work we tend to stay on our own.*

Fortunately, Maria found the connections she was looking for in the community of learners and felt:

> *…very comfortable to be honest, maybe because I am used to working in a professional environment in teams…. Even characterwise, I was always the type of person who if I have a problem and I know that you experienced it I will come and tell you, 'Listen, I am stuck in this, 'what is your idea?' I was always like that. So I never had problems speaking out.*

Developing connections in the community of learners encouraged Maria and the other participants to open up, share their successes, weaknesses and disappointments and support each other through the professional learning journey. These connections developed within a safe and supportive environment enabled the teachers to move out of their comfort zone and become motivated to improve and change their practice.

10.3 Professional development leading to learning

One of the main aims of the PD programme was to help teachers develop and improve their chemistry content knowledge, their teaching practices and their attitudes towards chemistry by encouraging collaborative learning as indicated by the framework for professional learning in Figure 4.1. Initially the teachers started out on an individualised personal journey, with the motivation of improving themselves as science teachers. When they came together, the meetings generated enough energy and enthusiasm for the teachers to discuss and share their experiences and eventually for the community of learners to coalesce (see Wenger et al., 2002). The participant teachers, as Skerrett (2010) describes, started to inquire into their practice, ask questions about their difficulties and gaps in knowledge that led to the negotiation of new meanings and knowledge. As pointed out by Stoll et al. (2012) "evidence of teacher talk and exchange about professional issues is a key indicator of a learning community" (p. 240). Participating in a learning community was becoming "a complex process that combines doing, talking, thinking, feeling and belonging" (Wenger, 1998, p. 56). Teachers described that the most powerful learning experiences in this PD programme were related to (1) having an active role in their learning by conducting various hands-on activities, (2) learning with and from others by planning lessons, sharing and discussing their practice, (3) becoming reflective practitioners and (4) implementing activities in practice.

10.3.1 Taking an active role in their learning

During this professional learning experience teachers observed that they had taken up an active role in their learning when they felt involved and engaged as learners as they participated in various activities such as developing resources and conducting experiments. Maria was grateful that she had the opportunity to produce and develop resources with the other teachers that were relevant and more applicable to her teaching context. She affirmed that:

> *We created things. Usually you hear a lot of talk and then you say 'fine, go do them in class.' In reality we created material which can be done in class. Many tried them out. We saw that they worked. We gained knowledge, we gained a lot and we could not ask for more. It really made an impact on the way I teach and on the way I approach things.*

Teachers felt actively involved when conducting hands-on experiments because as Daniela explained, she felt that she could learn more by "*actually performing the activities rather than just watching demonstrations.*" She explained during the laboratory sessions teachers could learn more about the purpose of each experiment and how it can be used to demonstrate chemical concepts. She affirmed that "*it takes on another dimension when you literally conduct the activities. You are not only reading it on the Internet or on a book. As you are doing it, you own it. It becomes more real.*"

Teachers conducted the experiments in groups and they could discuss their difficulties with each other and with a chemistry specialist teacher. Maria observed that through peer learning she learnt new content knowledge and how she could make use of chemistry experiments in her lessons. As a result she felt that she "*had gained a lot of confidence in [her] work especially when it came to experiments.*" She reflected, *"I learned more about experiments I can do in class and also enhanced my chemistry knowledge in relation to these experiments."* Robert also stated that he gained new ideas and skills when conducting practical work and said that:

> *…the fact that I was able to do some experiments for the first time meant I was able to learn a lot, mainly on the preparation needed to do such experiments in class. Now I am aware of in which part of the experiments problems may arise.*

Conducting experiments was one of the challenges experienced by the teachers in this study (see Chapter 8). When teachers worked with equipment they felt more prepared to undertake any potential issues they could come across when doing practical work and this impacted their confidence and skill. Daniela mentioned that hands-on work "*helped [them] to work with more confidence… because [she] had already done it and practiced it.*" Amy also grew more confident *"in handling different apparatus and discovered other experiments which would be fun to use with students*."

By taking the role of active learners the participant teachers felt that they had engaged in a valuable learning experience. Similar to other research studies (Darling-Hammond et al., 2009), they had the opportunity to engage as learners by carrying out hands-on activities that later on they could use in their classes, thus adding relevance to professional learning.

10.3.2 Learning with and from others

Teachers felt that one of the major strengths of the community of learners was that as described by Laura, it was *"a group of professionals who share and learn from each other."* A collaborative approach to learning encouraged teachers to discuss, inquire and learn from each other's work and expertise, thus breaking down barriers of isolation. Their collective participation became what Desimone (2009) and Stoll et al. (2012) describe as a powerful form of teacher learning. All the teachers recognised the importance and benefits of working with others, where as Sarah described: "…*you learn more through sharing of experiences. Teaching can happen more effectively in a learning community. You are not alone."* As found with other research studies (De Winter 2011; Kane & Varelas, 2016; Smith 2014, 2015;

Woolhouse & Cochrane, 2009, 2010), working in a collaborative supportive community was found to enhance teacher professional learning.

I was interested in exploring why working with colleagues was such a powerful learning experience. I therefore looked into the teachers' narratives and found that the sessions helped them to tackle challenging aspects in teaching their non-specialist area; for example in formulating lesson plans. Teachers believed that they did not have enough SMK and PCK to plan good chemistry lessons. Working collaboratively on lesson planning was found to be a valuable aspect of this professional learning experience because teachers recognised that they learnt from one another and gained more teaching strategies and ideas, thus enriching their PCK. For Daniela, *"discussion on lesson planning provided new ideas of how lessons could be tackled."* Laura also felt that:

> *…by planning a lesson in a group we could combine our ideas and think of related activities which I would not have thought on my own. In reality it is not related to subject knowledge. It is more creativity in pedagogy, for a teacher to portray concepts in a particular way. I think that through sharing you can get more ideas.*

From these interactions participant teachers developed their professional knowledge, since as Ellis (2007) contends, learning is not solely an individual act and that knowledge is developed in relation to other people and also in a particular context. Thus learning with and from colleagues can be considered to be an important and strategic 'boundary object' (Hobbs, 2012) that enabled the teachers to gain more confidence to teach chemistry topics.

In this research study teachers also pointed out how the sharing of examples of their lessons and their reflection about their lessons was another important learning experience. Christine argued that one of the strengths of the learning community was that teachers had the *"opportunity to join a group where [they] were able to have ongoing interaction and sharing of ideas and resources."* De Winter (2011) argues that when teachers bring their own work, demonstrate it and explain it to the other teachers, a collaborative dimension that enhances learning is encouraged within a community of learners. In this experience Laura felt that within the learning community they *"could work collaboratively with other schools and others teachers… and it was interesting because different teachers have different ideas so it was very beneficial."* Such knowledge-sharing events in which the teachers were exchanging their practices, discussing difficulties and thinking of possible solutions nurtured a sense of collegiality among teachers, because as Darling-Hammond et al. (2011) explain it encourages teachers to act as co-learners and critical friends. In fact participant teachers acknowledged that sharing of practices was one of the most powerful learning experiences, because as Christine believed, "*the other members of the group [could] learn from sharing [her] views and opinions just like [she] learnt a lot from them.*"

By sharing their lessons the teachers were revealing their own understanding and ways of approaching chemistry lessons. Like the participant teachers I was impressed by the variety of examples mentioned such as the use of poems, experiments, investigations and storytelling to capture students' interest in chemistry. Christine found that as she gathered different teaching ideas and resources she could widen her repertoire of teaching activities and expand her PCK. She affirmed that:

> *…when you talk to other teachers who have the same experience but come from different schools you will find out that they still do things differently. They have different activities. When you share you will always gain something from someone else, whether they have little or more experience, you will always gain ideas from other persons.*

From one workshop to another, the teachers looked forward to participating in meaningful discussions related to their practice and experiences. Such discussions were necessary for teachers to question issues, discuss critical incidents and ask for support from others thereby addressing their learning needs. In the process they constructed meanings, generated new knowledge and widened their instructional strategies by gaining new insights about their teaching. Melville and Wallace (2007) contend that when teachers participate in a community of learners and negotiate meanings they "have the capacity to access professional learning that is context specific, collaborative and visionary" (p.164). Within this experience the teachers expressed that they valued opportunities where they worked together, learned with others, reflected on their practices, exchanged ideas, shared strategies and engaged in problem-solving situations. By combining the different ideas teachers felt that they could go a step further in their learning. Robert explained that he was encouraged to risk and try out further activities in his lessons:

> *In the workshops, when everyone was sharing their ideas I started merging different ideas and I realised that there are different techniques that I was not aware of. I started applying these to my teaching and found that I had moved to point that was beyond my level. Usually I won't tend to push myself forward and remain in my comfort zone. Then once I listened to the others' ideas and I knew that they worked, I became curious and wanted to try them out.*

Through this experience teachers did not only become aware of various resources and of different ways of doing things. By drawing on each other's expertise teachers could start to locate themselves in practice and begin to make sense of themselves as science teachers (see Beijaard et al., 2004). Teachers became learners because when sharing lessons they were shaping "each other's experiences of meaning" and in doing so they could "recognise something of themselves in each other" (Wenger, 1998, p.56). Thus participation in this experience became a source of identity (Wenger, 1998). Battey and Franke (2008) argue "developing a new identity is not just about gathering new ideas: it is also about developing new frameworks for understanding their ideas and reinterpreting past experiences" (p. 145). For Maria the sharing of different practices was an eye-opener because she could understand why at times her students did not understand particular aspects in her lessons. She explained that:

> *I believe that the way you develop a topic shows how you understand it. Now sometimes with the students it works, sometimes it doesn't work because students don't see things your way. By seeing different ideas I could see the other side and realised… that is why my students are not understanding this for example… because I leave out that step, maybe if I add it, it will be better.*

Learning with and from others was found to be one of the important strategies that enabled the teachers to learn at the boundary because teachers could update their SMK and develop their PCK related to chemistry teaching. As argued by Hobbs (2013a), learning with and from others influenced how teachers reconceptualised their practice and this provided an opportunity for identity expansion as teachers could interact and reflect on their own professional experiences within the context of a learning community. During these sessions teachers also discussed their own reflections and self-evaluations and thought of ways on how they could improve their work. Thus sharing experiences and critical reflection became intertwined. Within this study teachers not only engaged in collaborative learning but also learnt how to become reflective practitioners.

10.3.3 Learning to reflect on practice

Participant teachers had various opportunities where they could reflect on and evaluate their classroom practices. The professional learning journey started becoming, as Maria explained, *"an evaluation process"* and *"a reflective process."* Sarah felt that this professional learning experience helped her to become a reflective practitioner because as she explained, after every lesson she immersed herself in reflective thinking about her own practice. This affected her own way of being since reflection was becoming an integral part of her teaching. Sarah explained that:

> *I had the chance to reflect because of the way the programme was split up. We did our first lesson plan and I felt that reflection was important. You came to observe my lesson and then I continued reflecting. After each lesson I said 'here I could have done this'... 'why did that student ask me this?' It is not the first time that I went home after the lesson and changed things immediately after…. I always used to do my reflections but after this experience I realised how important it is to reflect.*

Robert stated that one of the crucial aspects of this experience was *"the reflection part where [he] had to do the lesson, think about it, then ... discuss it and share it within the group."* Teachers recognised the importance of reflecting on their work when they critically reviewed their lessons in a professional context, both during the workshop sessions and after lesson observation. When teachers were sharing their lesson reflections they were thinking deeply on their classroom actions, discussing what they had learnt from their experience and considering alternative approaches to their lesson to enhance student understanding. They were engaged in the process of reflection-on-action (Schön, 1983) as well as on reflection-on-practice (Ghaye, 2011). They were looking back at their past experiences, thinking of positive and negative aspects of the lesson and finding how they could approach the lesson in different ways. Reflection-on-practice (Ghaye, 2011) helped the participant teachers to develop new insights and understandings to improve their actions.

For these teachers, learning was becoming a process of personal reflection (Loucks-Horsley et al., 2010; Woolhouse & Cochrane, 2010) and it encouraged a metacognitive attitude (Postholm, 2012) since they were becoming more aware of their own practice. Reflective practice enabled the participant teachers to review their motives, reasoning and decisions taken within the classroom. Marshman and Woolcott (2018) argue that "reflection is not only thinking about what went well and what didn't, but more importantly, thinking about the *processes* of teaching and exploring *why* we did things rather than *how*" (p. 101). Laura in fact argued that through lesson sharing, the teachers not only reveal how they approached the teaching of science but they also presented *"the reason why they do certain things."* She argued it is the teachers' decisions and thoughts that determine the type of teacher one chooses to be. She explained that in teaching: *"it's not just how you do things; it is why you do them because what makes us a teacher is how we present a subject."*

Subsequently, the reflective experiences shared in the learning community encouraged the teachers to engage in deeper reflection, to identify their challenges and discuss ways to overcome them. Ghaye (2011) suggests that the power to change and improve is better achieved within a group. Both Laura and Daniela recognised the importance of collaborative reflection because discussion and feedback within the community encouraged deeper reflection. Daniela explained that:

> *…the group gives you a further opportunity to reflect. You reflect when you are in your own but you will not go into such depth. But when you are discussing with another person or a group I think you reflect in more depth.*

Thus, similar to a study carried out by Camburn (2010), the teachers in the current study used reflection to determine the dilemmas in their teaching and develop potential solutions. More importantly since the reflection was being carried out within the safe environment of the learning community, reflection did not simply remain an introspective exercise but "engagement in discourse with others move(d) your reflection away from introspection to that of a deliberative effort to improve future actions" (Tibke and Poyner, 2013, p. 48).

Reflection on one's own practice as well as on examining others' views and ideas about chemistry teaching is one of the possible mechanisms of 'boundary crossing' as suggested by Akkerman and Bakker (2011). When teachers reflect and evaluate different teaching approaches they are able to 'cross boundaries' because they come to "realise and explicate differences between practices and thus to learn something new about their own and others' practices" (Akkerman & Bakker, 2011, pp. 144-145). This implies that learning also involves reflection. By reflecting on their current practice and evaluating newly encountered ideas and different ways of developing and teaching chemistry topics, teachers were encouraged to move out of their comfort zone and use different teaching strategies. In the process, as argued by Hobbs (2014), participant teachers had the opportunity "to negotiate the differences in practice and reconcile the unfamiliar with the familiar" (p. 31). Teachers valued and recognised that reflective practice helped them grow in their professional journey because, as stated by Daniela, having the chance *"to write or speak out your lesson reflections and philosophy enables the person to grow and improve"*. Thus they could become more confident to teach outside specialism.

10.3.4 Implementing activities in practice

Participating in an ongoing programme spread over a whole scholastic year was found to be of great benefit for participant teachers because they became motivated to implement and apply what they had been learning in their classrooms. In view of this Laura explained that: "*throughout the year we were able to try out different activities which we could do in our* *class and also reflect on our practice."* Karen felt the interactions and dialogue within the community of learners helped her to *"feel more confident and to try out the activities that [could] enrich [her] lessons and make them more engaging and exciting."* Indeed Maria felt that after this experience she felt more capable *"to try out new things with less hesitation."* When teachers learnt about new activities they became more willing to take new risks in their teaching approaches. This is similar to the findings of Faulkner, Kenny, Campbell, and Crisan (2019) where they report that when out-of-field teachers participated in a PD programme they took more risks, learnt from their mistakes and this generated a growth in teachers' confidence.

The reflective discourse within the community of learners provided an added incentive for participant teachers to implement changes in their practice. When teachers shared their lessons plans, the other teachers generally took note of the activities together with any feedback given. Later on they adapted these ideas and implemented them in their lessons. Teachers felt more confident to use activities that had already been tried and tested out by other teachers. Sarah explained that she felt more confident in planning and conducting experiments since *"the other teachers had already conducted the experiment."* Christine believed that she gained further insights when hearing about activities discussed that were carried out by other teachers. She described that along the year:

> *…we were dealing with particular topics in the sessions and at the same time I was teaching those topics in class or was about to do them. The activities that we were doing were still fresh in my mind and I could apply them in class. There were some teachers who had covered particular topics whereas I still had to do them. They were discussing the difficulties and things that they would change. I took note of the things that they would change. Since there is someone who is testing the lesson prior to me then I would go for the better option and this helped a lot.*

Similarly Karen felt more prepared to teach the chemistry units because she developed some of her lessons based on the ideas that were previously tested out by other teachers. She stated that:

> *…once you get an idea and you are about to teach that topic you can immediately use it and try it in class. You are getting immediate feedback. Even if you are still going to teach the topics and one of the teachers in the group has already done the topic s/he can share the difficulties encountered, so you will know about such difficulties from beforehand and you will be more aware and prepared for the lessons.*

Appleton (2002) describes how teachers gain more confidence when they attempt to tackle 'science activities that work'. These types of activities are generally hands-on, interesting and motivating for the students, have clear outcomes or results, are manageable in the classroom and equipment is readily available. Appleton (2002) suggests that teachers use such activities as an "effective substitute for PCK in science, and that, with the experience of teaching such activities, these teachers then develop their own science PCK based on activities that work and their general pedagogical knowledge" (p. 404). In this study the teachers felt more secure to implement activities that were tried out and tested by other teachers, knowing that these were 'chemistry activities that work.' By using these activities teachers could develop their PCK until eventually they could adapt them according to their own classroom needs. In fact Amy described that:

> *…throughout this experience I had the opportunity to meet different teachers to get ideas from them. In many things in my life I do tend to prefer trying things out that are recommended by others already. I felt safer doing things which had been tried and tested more so than trying to invent something from scratch. So this experience matched very well with my character. I may not have necessarily done something exactly as was recommended but getting ideas helped.*

In this experience teachers were inspired to conduct changes in their classrooms and experiment with more risky activities in their lessons. This is an indication of professional learning. Guskey (2002) affirms that "change is primarily an experientially based learning process for the teachers" (p. 384). Guskey (2002) further argues that it is not the professional learning experience per se that makes teachers change their beliefs and attitudes but discovering that suggested ideas work in practice within a similar context. Therefore teachers in this current study gained the confidence to adapt and make use of new strategies and activities when they heard about their impact on student learning. In fact Luehmann (2007) argues that when teachers are enticed to try new practices, become motivated, put effort in their work and experience a degree of success from implementing new activities, they are more able to take on new identities. In this case it would mean expanding their identity as science teachers and feeling better and confident at teaching outside specialism.

10.4 Teachers' reflections on the professional learning experience

When the participant teachers reflected on the PD experience they all remarked that they had experienced a different form of PD from the usual courses they were accustomed to. The programme had a different format, it was ongoing and the teachers had taken a different role in their professional learning due to their participation in the community of learners.

10.4.1 Moving away from traditional approaches of professional development

Teachers noted that the delivery of the sessions was not based on the transmission type of teaching and lecturing methods. Amy appreciated that the sessions included *"hands-on activities and discussions and not just listening."* Sarah argued, *"if the professional development would have been designed on a traditional format I would not have participated much... even in traditional meetings, I don't participate."* Sarah emphasised that traditional forms of PD restrain the teachers' input by rendering them as passive recipients. She highlighted that teachers should be given a more important role in their professional learning and recommended that *"teachers should be given the opportunity to share their ideas. Teachers are in class and know the needs of the students. They have a principal role in the education system. They should not only be given information and instructions."*

Daniela suggested that professional learning sessions needed to include hands-on experiences rather expository teaching because *"the actual conduction of investigations provided confidence to tackle problems that could be met."* Daniela felt that the active involvement of teachers was *"lacking in traditional professional development sessions.*" She believed that teachers need to learn through *"hands-on experiences"* especially if teachers need *"to do hands-on activities with the students."* She highlighted the importance for teachers to engage as learners with the subject content that they teach. She suggested that activities presented in a PD programme should mirror the same approach to teaching and learning that teachers are expected to adopt in their classroom. Indeed Loucks-Horsley et al. (2010) recommend that "when teachers experience and reflect on how students learn, they are better able to understand why certain instructional strategies are more effective than others thus enabling them to provide powerful learning experiences to their students" (p. 53).

When PD programmes aim to inspire teachers to change their teaching methods they would need to be modelled on the learner-centred approach to learning. Loucks-Horsley et al. (2010) recommend that teachers need to have a clear image of what constitutes effective classroom and teaching. They suggest the use of inquiry-based learning, investigations, problem solving and applications of knowledge where these approaches mainly emphasise the in-depth understanding of core concepts and challenge students to review their ideas and construct new meaning and understanding. Robert commented that the PD programme was inquiry-based and took a constructivist approach to learning. When reflecting on the structure of the programme he explained that:

I liked it because you gave us the opportunity to talk. You used the same type of methodology that I use in class. You say a word or have an activity and then the others develop the lesson for you…. I was observing a similar methodology in the community. You start with a question and we discuss. We are all sharing our problems and tackling them together. I really liked that.

10.4.2 An ongoing learning programme

Participating in a long-term PD programme was a new experience for the teachers. For Sarah this long-term programme was perceived to be a learning journey when she described:

…there was a time gap between the observations and workshop so this provided time for thought…. It was a journey… it was spread over the year in the different terms and each workshop targeted particular aspects. I think it was a very good journey which was flowing and not boring. I always learnt something new so there was no repetition.

The INSET was the most popular form of PD course in Malta. Being a short course, it does not produce long-term effects or impacts classroom teaching (Brincat, 2014). Darling-Hammond et al. (2009) further argue that sporadic workshops tend to be disconnected from practice and they do not provide time for teachers to seriously study the given subject matter or to try out the ideas in their classes and reflect on their outcomes. In fact Karen spoke about the disadvantage arising from the time gap between the delivery of the INSET course and actual teaching. She argued that in the INSET you *"get a lot of ideas. You are eager to try them out but you have to wait for three months before implementation, so that eagerness fizzles off."* Besides losing motivation, Christine also stated that it was very likely that teachers would have forgotten what they learnt in summer. Maria argued how the ongoing programme was more beneficial than a short-term course. She maintained that "*it was important that the professional development was ongoing. The in-service was very minimal compared to what we achieved during the year. More things came up from one workshop to another."*

Karen emphasised that an ongoing programme was more beneficial because teachers could simultaneously learn and implement changes in their classroom. She argued that participating in an ongoing professional learning *"always keeps you on your toes"* since it drives teachers to become more productive and reflective in their teaching. It also enables them to take risks in their teaching approaches because it provides *"the impetus for teachers to try out new* *things."* Thus as Karen maintained, one becomes *"more motivated and there is renewed enthusiasm"* for teaching when participating in an ongoing PD programme.

10.4.3 'Professional development with a difference': The role of teachers within the community of learners

The teachers' reflections about this experience indicated that their participation within the learning community enhanced their learning because as Laura explained:

> *…we were a group of people who were there to help each other or support each other through difficulties. They suggest best ideas and offer their own advice, or suggest other things which can be done without being judgemental because that is very important within a community.*

Daniela pointed out that this form of PD differed from traditional programmes and she called it *"professional development with a difference.*" Participating in a community of learners provided a different dimension to professional learning because unlike other PD courses teachers were not only engaged in collaborative work but they were sharing their experiences and focusing specifically on their learning needs. Daniela explained that:

> *When we were sharing and discussing our lessons we delved into a deeper level. We were delving into our personal matter… I was sharing positive and negative aspects, it was personal, it was like sharing my diary…. This was a professional development with a difference because it was not just practising an experiment where at that point we were only working together, or working on the same task…. In the community we felt safe to share our fears and mistakes and we could openly talk about our difficulties and discuss them.*

In other words, Daniela argued that working in groups and the active involvement of teachers is an essential part of PD programmes. However it was the sharing of personal experiences and practices within the community of learners that specifically addressed the teachers' learning goals because *"all wanted to improve pedagogy and content knowledge."*

Robert mentioned that the PD programme was catering well for his learning needs because through the help provided by the community of learners he improved his understanding of chemistry:

> *the learning community is a group of people who gather together, discuss things and at the end of the session I say: Today I understood that idea! For me that was a learning community... you are talking about something you are not so fluent in and through the discussion you notice that you made some progress. That for me was a learning community. This happened in each workshop and it made an impact.*

Another important aspect that came out from this experience was that the teachers' professional knowledge was valued in the learning community. Wenger et al. (2002) argue that value is key to community life. Although non-specialist teachers may perceive themselves as having insufficient knowledge, the participant teachers still managed to offer and share different teaching perspectives. Amy increased her self-efficacy when her feedback was recognised by the other members of the learning community. She explained that: "*when I discussed with others they liked my ideas. When I was giving feedback they heard my feedback, so I have something to give. You know you feel that you have something to offer.*"

In this experience teachers recognised that they took up a dual role: that of being users and producers of knowledge within a social practice. Teachers felt that they could contribute and construct knowledge within the community of learners irrespective of their years of teaching experience because as Sarah explained, she felt that "*the community considered all the members as contributors, not just listeners… like in many of the other meetings that we attended where we did not have the opportunity to voice our ideas.*" She further argued that: *"the fact that each member was considered as a contributor helped even more."* Within this experience teachers felt that they were not perceived to be knowledge-deficient professionals (Webster-Wright, 2009). They had the opportunity to not only participate as active learners but to become active contributors of knowledge. Teachers were also being recognised and appreciated for sharing their knowledge base. This role within the community of learners affected the teachers' self-efficacy beliefs and the way they perceived themselves as science teachers because as Sarah argued:

> *…the fact that we were all contributors to the community I think helped me to feel more comfortable…. There were more ideas, we were giving feedback to each other: like I tried this out and it worked better. I felt appreciated, more capable, that is I was moving on the right track.*

In this experience teachers became learners and contributors of knowledge where they could enhance each other's learning and develop their knowledge base through the help of others. As explained in the literature (see Chapter 4) nurturing a community of learners as part of a PD programme constitutes an important aspect of professional learning where teachers are seen as knowers who can teach other teachers (see Melville & Yaxley, 2009). The teachers' self-efficacy was also strengthened through collaborative and active approaches to learning, thus as Luehmann (2007) argues, that teachers could also take on new identities as science teachers.

10.5 Becoming empowered to change one's practice

Whereas in the beginning of the study, many of the participant teachers feared teaching outside their science specialism, as they became more involved in this PD programme they started changing their perceptions and dispositions towards chemistry. They felt that along this journey they started increasing their content knowledge because as Christine explained, *"during the sessions we covered some material which the students do not need to know, so I feel that I have more knowledge than the students."* Teachers also felt they were learning about different ways of explaining and demonstrating chemistry concepts. In view of this Laura stated that after this programme she knew *"what activities [she could] do to portray certain concepts and the level of detail required in science lessons."* Teachers also gained the necessary enthusiasm and motivation to try out and experiment with new ideas in their classrooms. This led teachers to change their attitudes towards chemistry. The community of learners supported innovation and experimentation and contributed to a shared professional culture that empowered teachers to tackle their challenges to improve their practice. I could start observing this change in perception at the end of the INSET where in my journal I noted that:

> *Phrases such as 'don't' feel alone', 'feeling insecure like many', 'feel that chemistry was beyond my limits' were common in the teachers' initial discussions. These were replaced by phrases such as 'feeling relieved,', 'not afraid to tackle chemistry experiments now', 'my interest and motivation have been renewed'. I think that the fact that teachers experienced different ways of doing and teaching chemistry (since the course was rather practical and provided teachers with various ideas of classroom activities) helped them to change their perceptions and beliefs about the subject. I feel that this experience created a turning point in teachers' views because as one of the teachers admitted 'from now on this will be a serious move towards learning more about chemistry.'*
>
> (Journal Entry: July 2014)

Furthermore I noted that teachers started gaining a sense of empowerment where:

In their reflections teachers admitted that they felt empowered to tackle chemistry lessons…Teachers felt more enthusiastic to include more chemistry-related activities in their lesson plans. They gained more ideas on how to tackle particular experiments, even though they may have limited chemistry knowledge but they felt better equipped at tackling experiments. They felt that their confidence increased when they met teachers who had similar experiences and they looked forward to working together.

(Journal Entry: July 2014)

After the first phase of the PD programme teachers believed that they had the necessary ability to improve their work. They felt more equipped to plan and teach chemistry topics. This feeling of empowerment was described by Christine when she said that:

…this course showed us that I can do it when it comes to teaching chemistry. I still have to work a lot on these topics, but they are not impossible. I came to love chemistry whereas before I was a bit afraid of chemistry topics.

Within the community of learners, teachers developed a sense of collective responsibility for their learning. The teachers attributed progress in their learning due to the support offered in the learning community. Christine believed that "*that with the help of each other [they] did make progress.*" She felt that through the support provided she managed to accomplish many of her target goals. From this experience Christine found that:

This learning community helped us all in improving our teaching skills and has given us the opportunity to present chemistry topics in a way that our students will look forward to learn in a fun and easy way. We gained more ideas of how to carry out more hands-on experiments to help students understand and enjoy learning chemistry. Another thing is that I am updating myself constantly and updating my lesson plans.

The participant teachers were in fact becoming encultured into a teaching community where as described by Putnam and Borko (2000), they were learning how to think, talk and act as science teachers. As argued by Wenger (1998), the teachers were learning through the "process of being active participants in the practices of social communities and constructing identities in relation to these communities" (p. 4). At the end of the PD programme all lesson plans that were developed or shared during the sessions were gathered and compiled into a booklet. This resource pack was handed to the teachers as a means of celebrating their own efforts and achievements throughout the year. Teachers recognised that this work could not have been produced without the support of a learning community and thus collaborative practice led to professional learning. As Robert described:

> *…this pack was like the final product of what we built together. I was so happy when I saw the pack. Here is my improvement over this year. I shared the knowledge of 5Es with the others and I managed to apply it and it made an impact. This also shows that we were appreciated by you as well. We were not just a study, we were not just a number in a study. We were individuals in a study and that really affects me.*

During the last workshop session, teachers were asked to reflect about how they were feeling with regard to teaching outside specialism (see Appendix 2). They were asked to describe whether they had noticed any change in their practice and perception towards chemistry. In my journal I noted that:

> *I was impressed by the outcome of the snakes and ladders exercise. In the plenary session of this exercise teachers had to move a number of steps forwards or backwards depending on how they were self-assessing their progress. By the end of the exercise all teachers moved forwards or at times they remained stationary but none of them moved backwards. They were gaining a more positive image of themselves. They felt good about their progress and acknowledged it. Overall they were feeling that their pedagogy was improving because they were managing to engage students further in their science lessons. They still felt that they had to improve in particular areas such as dealing with misconceptions and learning more content knowledge. In fact one of the teachers commented that "the problem was reduced but not eliminated." Teachers were managing to gain more confidence and were feeling more able to tackle chemistry topics. I feel that this was an important step in their journey of becoming science teachers.*
>
> (Journal Entry: May 2015)

By the end of their journey teachers believed that their participation in the community of learners became a powerful source of inspiration from which they derived their energy and enthusiasm for teaching. In fact Maria explained that:

> *I found a group of colleagues who share the same ideals, so I know that if I want to try something out, or try an experiment I can go to them and ask. I know I can get feedback and they will understand in the way I understand it. I won't go to my colleague, maybe we don't agree so much and she will tone it down for me. I know that I can go to someone who was part of the community and s/he will give me more energy. They will push me more rather than kill it. I think that was really positive.*

The community of learners also provided the necessary ongoing support that was needed through the year. Karen felt that the community offered *"a support system"* because teachers were *"all learning together and overcoming struggles together."* At the end of the year teachers suggested to keep on meeting as a learning community. They wanted to focus not only on chemistry topics but on all science topics, that is both within and outside their subject specialism. This suggested that teachers wanted to consolidate their identity as science teachers.

The teachers' narratives showed that this professional learning experience enabled them to learn at the boundary, that is, they learned to bridge the familiar and unfamiliar practices. Darby (2009) contends that "the move from one disciplinary way of knowing, thinking and acting requires a shift in a teacher's thinking and being" (p. 172). The shift in thinking took place when teachers developed a shared commitment to work together in collaborative practice to enhance personal and group learning. Learning with and from others and reflection were two boundary objects that empowered the teachers to examine their own identity and decide about the necessary course of actions. The next chapter explores how teachers perceived themselves as science teachers prior to and through this professional learning journey and discusses how each teacher managed to negotiate his or her own personal and professional identity as a science teacher.

Chapter 11

From endings to new beginnings

11.1 The participant teachers' journey

The teachers' participation and involvement in the PD programme was a learning journey that enabled them to learn at the boundary between what they knew (their specialist subject) and what they did not know (their non-specialist subject, chemistry). The teachers' narratives suggest that they gained confidence in teaching chemistry as they expanded their knowledge base and reviewed their beliefs about teaching chemistry. As a result they started to experience shifts in their teaching identities. This chapter gives voice to the teachers as they narrate episodes of their stories along the professional learning journey. It also includes my personal reflections on their growth and development as science teachers.

11.1.1 Amy's journey

At the beginning of her journey Amy spoke about her uncertainties, particularly about her lack of confidence in preparing and conducting experiments.

Starting the journey

> *I have an A Level in chemistry believe it or not, but I forgot. It wasn't my favourite subject to be fair…. When I was young I was brought up with the main emphasis being on content. I never had the chance to carry out investigations. I was terrified of practical work in general which were all recipe type, let alone anything which required more thought because I was not given the proper skills to feel confident in myself when handling equipment. Even nowadays I find it hard to prepare and carry out investigations in class because I do not feel I have acquired the necessary skills yet…. I am very wary of the lab…. It is not a place I am very comfortable with. I am very hesitant to come up with things on my own and try new things out for myself to see how I could rearrange an experiment or vary it in any way (I.1).*

My impressions of Amy

When I first observed Amy and later on talked about her lesson I noticed that she spoke about a number of insecurities in teaching chemistry, however she looked quite confident in her lesson. She was using an inquiry-based approach to teaching. She moved around the groups and asked questions to make students think about what they were doing. She was using a problem-solving approach to teaching because she first asked her students to prepare three different mixtures and then think of ways to separate them depending on the properties of the substances present in the mixture (Lesson observation field notes: October, 2014). Amy's lessons always involved a dialogic approach to teaching, however when discussions focused on chemistry content Amy grew rather nervous because she could not anticipate the students' questions and discussions (Lesson observation field notes: November, 2014). In other words although Amy managed to get along quite well in her lesson she was experiencing insecurities particularly during lesson delivery.

Improvements along learning journey

> *A change I have seen is that I realise now that I love to carry out experiments and demonstrations with students. I feel more confident doing problem-solving investigations…. My lab work is better. It is not so restricting…. I am even calmer, like I was in the last experiment I did of neutralisation. I was calmer and even when things did not turn up as expected, I did not panic…. I feel more confident in the lab and doing experiments since I gained practical examples of what can be done with students to make chemistry more interesting…. I have a booklet of many different ideas I can use as a guide to help me think of new experiments when needed (I.4).*
>
> *I also feel more comfortable with handling unplanned situations and questions. Last time students asked me a question: 'How much sugar do you need to have a saturated solution?' I said 'come, OK let's just figure it out'. I did not mind doing something which I had not planned, but I wanted to... because they asked specifically that question…. it seems to be a lot because I had to try it out, it took quite an amount of sugar. It was warm so it took a while but they were really enjoying it and they were seeing it turn yellowish. The colour was changing and then we went into diabetes and why it is bad to take things with too much sugar. It was not something that was planned but I was comfortable enough to do it (I.5).*

Personal reflections on Amy's journey

During the year I noticed that Amy became more confident in teaching chemistry. She became less hesitant in preparing and conducting experiments and started to take new risks in her lessons. Initially she was concerned when explaining terms like solvent, solution, solute, soluble and insoluble because these words sounded very similar to students with learning difficulties. Amy took the challenge to resolve this difficulty by planning a lesson where students conducted a simple experiment and then used flash cards to match the scientific terms with material used in the experiment. She also included the 'predict, observe, explain' strategy that was discussed in the second workshop for students to predict and observe which substances were soluble in water and which were not (Lesson observations field notes: May 2015). This meant that Amy was becoming more confident to use new strategies and to think of better analogies to improve her explanations.

As Amy started to overcome the challenges with the support of the community of learners she changed her attitude towards the subject and her beliefs about her abilities to teach chemistry. Although at the end of the year Amy still identified herself as a biology specialist, this professional learning journey helped her to feel flexible enough to take on an identity as a science teacher and teach chemistry topics with less apprehension and more enthusiasm.

Amy's experience of the professional learning journey

> *I feel really happy that I formed part of this learning community because I had the opportunity to meet different teachers to get new ideas. The community encourages you to keep trying, to keep going on…. We were giving each other feedback and support (I.5).*
>
> *From this experience I learnt that I am on the right track. I don't feel as confused in the lab or as worried. There is a lot that can be done. I had the courage this time round to go and find some chemicals in our store to do a demonstration using different indicators (I.4).*
>
> *Chemistry is not the scary subject I thought it was! I know that I will have misconceptions on certain ideas but that's OK because teaching is a process…. I do feel that I grew a lot. The way I view things has changed a lot. The best part of teaching is that it continually changes me and even the way I view life. Students are a blessing because they teach me as much as I teach them. This experience gave me more courage to do more things and to change (I.4).*

11.1.2 Daniela's journey

Daniela was the most experienced teacher and considered herself to be a biology specialist. This year marked her entry into the field of teaching integrated science.

Starting the journey

> *I have been teaching biology to older students for more than ten years now. I prefer teaching biology topics. This is the first time I am teaching integrated science. I feel like a new teacher because I never taught this subject….I don't mind teaching the other subjects but it requires a lot of preparation, it entails more work. I need to revise the content, so I read a lot before the lesson because I would not like to feel unprepared for what the students may ask…. I worry that I might teach something wrong. I want to be prepared and knowledgeable about what I am going to teach (I.1).*

My impressions of Daniela

Daniela joined the PD programme because she wanted to gain support in shifting from being a specialist teacher to one who is capable of teaching all areas of science. Although Daniela considered herself as a novice teacher at teaching science, during lesson observations I noticed that she was using her pedagogical knowledge and adaptive expertise to teach chemistry. Her insecurities were mainly due to being new at teaching science and at times she felt apprehensive when students asked questions she would not know how to answer. In her lessons she used a constructivist approach to teaching by eliciting knowledge from what the students already knew and valued the students' input and discussions (Lesson observation field notes: January 2015). She used group work, hands-on activities and managed to adapt her explanations to younger students. She was very keen to try out new activities in class and used an inquiry-based approach to teaching such as the 'predict, observe and explain' strategy to encourage students' thinking and explaining observations (Lesson observation field notes: May 2015).

Improvements along the journey

> *I am enjoying teaching science this year. I feel that I am doing OK…. In the topic of acids and alkalis I took a different approach. My approach was more of a risk. I started by introducing acids and alkalis simultaneously rather than first tackling acids and then alkalis. The actual approach of the whole topic was risky because there is no book or any other reference that has such an approach…. I started from what the students know, that is, with things we have at home. I did not start with things we have in the lab. I used the indicator to group the chemicals. All the lessons were hands-on. I did not have a lesson in which I was talking all the time. I was comparing the properties of acids and alkalis e.g. both are irritant, both are corrosive (I.3).*

Personal reflection on Daniela's journey

Professional learning and discussions within the community of learners enabled Daniela to reflect on her practice and widen her PCK. The energy and the positive vibes created in her classroom motivated her to prepare lessons with more enthusiasm. Daniela was also a keen learner and besides participating in this PD programme, she also participated in another long-term PD programme focusing on students' learning styles taking place along the same year. Although initially Daniela felt more comfortable to teach biology topics, she managed to adopt a more flexible identity as a science teacher. I felt that she managed to make the leap when she took a different approach in teaching the topic of acids and alkalis showing that she became more confident in teaching chemistry.

Daniela's experience of the professional learning journey

> *I wanted to learn more chemistry as I felt that it was something I was not confident in…. It was a positive experience. I learnt about the content and methodology. There were many new ideas that were eye-openers…. It was a reflective learning journey (I.4).*
>
> *This year I changed in many aspects and I changed a lot as a teacher… because I was assimilating many ideas in these last two terms. There are certain techniques that I started using, even I started using different pedagogies. Teaching is not so much teacher-centred. I reflected a lot. I had lessons which were teacher-centred but this year I had fewer lessons with a teacher-centred approach. There was a change this year particularly with the delivery of the lesson (I.4).*

11.1.3 Sarah's journey

Sarah was an early career teacher and loved teaching her subject specialism (biology). She was not afraid to teach chemistry units due to her good background in the subject and positive attitudes towards chemistry.

Starting the learning journey

> *I don't regret becoming a teacher but I am a reserved person …. In class I feel confident even though as a person I am not…. I feel very enthusiastic. I believe that a teacher needs to be motivated first to motivate their students (I.1).*
>
> *I was never afraid of the chemistry topics, because I always liked chemistry, so I don't think it was an issue…. But since I am still new at teaching, I am open to learning more and to improving my self-confidence. That is why I decided to join the PD programme (I.2).*

My impressions of Sarah

When I observed Sarah's lessons I noticed that students were very enthusiastic. She looked very confident and in control of her actions and managed to develop student-centred lessons based on a dialogic approach to teaching (Lesson observation field notes: November, 2014; May 2015). However in her first interview Sarah described herself as a shy and reserved person. She spoke about her low self-esteem which affected the way she perceived herself as a teacher. She had many doubts about her teaching ability and at times felt insecure to answer students' questions or to give the best explanations even though she managed to conduct highly interactive lessons.

Improvements along the journey

> *I feel better when it comes to hands-on activities. Sessions are helping me in my teaching with the examples of activities and experiments provided…. Now that I know there's a group of teachers with whom I can share ideas and resources makes me feel more secure…. In the meetings I tried my best to share my experiences even though at times I find it difficult to express my ideas in a group (since I am shy). The other members made me feel comfortable (FG.2).*
>
> *Along this journey I am feeling more confident now that I know that there are other teachers who share my concerns about certain problems and issues (I.3).*
>
> *The community helped me to feel better. I felt more valued, as a person and as a teacher. When you work on your own you don't have the opportunity to feel this way because you are working on your own and reflecting by yourself. When you are reflecting with someone and you listen to someone's experience then you can say I am doing well (I.4).*

Personal reflections on Sarah's journey

Within the community of learners Sarah found the necessary support that encouraged her to open up and discuss her lessons. As I observed Sarah's behaviour throughout the year, she slowly started to gain trust and feel comfortable in sharing her practices and experiences. Her participation within the community of learners was very enriching because it prompted Sarah to further reflect on her practice and to learn from other teachers. Furthermore the learning community enabled her to increase her self-confidence when she realised that teachers became producers and contributors of knowledge in this professional learning experience. By the end of the year Sarah managed to overcome her limitations by increasing her self-efficacy and believed more in her own capabilities as a science teacher.

Sarah' experience of the professional learning journey

> *Even though in the beginning I felt I had a problem, it was worth it that I got into this…. This experience made me grow personally. When we started to meet I saw that a number of teachers were mentioning activities that I actually use, and even some ideas that you mentioned. When I shared the activities that I used in class these were approved and appreciated by the other teachers. I felt that I was moving on the right track. I am a person who likes to feel reassured, to feel secure about what I am doing. This helped me to grow in my own confidence, even professional confidence…. I can say I am capable... that I am doing my job well... that I am moving on the right track (I.4).*

11.1.4 Laura's journey

For the past five years Laura had taught biology to older students and felt rather anxious when she started teaching integrated science.

Starting the learning journey

> *I think I am more of a specialist than a generalist. I prefer teaching biology because it is in my comfort zone. I do not feel very confident when teaching chemistry because I don't have a good chemistry background…. My experience of chemistry at school was not very good, we barely did any experiments. I had chemistry at Intermediate level – we did not do any experiments. Chemistry experiments were a bit taboo or I did not know what to expect. I did not know what things meant, so it is more lack of knowledge, lack of experience (I.1).*

My impressions of Laura

Laura's negative school experiences truly affected her perception of chemistry. She lacked practical knowledge and experience and became frustrated when she could not explain what goes on in chemical reactions. She asked her colleague to help her with her difficulties and they planned activities together. Despite her limitation in chemistry she developed interactive lessons by using her pedagogical knowledge from biology. The lessons were mainly led by the students' questions and based on a dialogic approach to teaching. During discussion she refrained from passing any comments but redirected questions to prompt students to think and explain what they were thinking (Lesson observation field notes: January 2015).

Improvements along the journey

> *This year I was much more confident when teaching chemistry as this was the second time round I was teaching the topics and therefore I knew what to expect from my students…. From the seminars I learnt about new activities which can be integrated into my lessons. These activities brought chemistry lessons to life and made the lessons much more enjoyable to my students…. I feel more comfortable because I have more options whereas before I was more limited, I did not know what to do…. I like looking through experiments done in the INSET and seeing the chemistry behind them because then it is easier for me when we are in the lab. I now understand what is happening and if students ask questions I know how to explain it (I.4).*

Personal reflection on Laura's journey

Laura needed some time to feel comfortable to share her experiences in the learning community. When she gained trust she became more motivated to conduct changes in her lessons. Whereas prior to this experience Laura felt more reassured to follow the pack of science notes devised by the teachers (see section 9.1.1), during one of my lesson observations I noticed that she was ready to make the leap and extend the experiment of rusting so that students could investigate five set-ups under different conditions rather than the two-set ups suggested in the notes (Lesson observation field notes: February 2015). Along the year I noticed that Laura improved her attitude towards chemistry and felt more prepared and confident to teach chemistry topics. She still described herself as a biology specialist, but experienced shifts in her identity towards teaching chemistry. She was satisfied that she had developed her own pedagogical constructs (Hasweh, 2005) by building a repertoire of what could be done in the lessons even though she still felt that she had weaknesses in her SMK.

Laura's experience of the professional learning journey

> *My knowledge of chemistry is still very limited, but at the same time I know what activities I can do to portray certain concepts. I know what detail I have to go into in my science lessons. Now I know how to answer some questions which students might ask. Overall I feel much more confident even though I still don't feel I have the background, the basics which are taken for granted…. Now if we keep doing the same topics I know how to go about them (I.4).*
>
> *Chemistry lessons are no longer taboo and beyond me. I feel much more comfortable due to teaching experience, the discussions, ideas and hands-on approach in the sessions… all in all that made a difference. There were many positive aspects this year. This year I felt more comfortable and maybe the ideas that I passed on to my students were not based on my misconceptions. I don't think that last year I passed on any misconceptions but this year I am more aware of their misconceptions and I tried to tackle them. I also anticipated the questions my students would be asking, so I already had an idea of how to answer them (I.4).*
>
> *This experience was a journey of self-reflection and brainstorming of pedagogical ideas arising from the discussing with other teachers experiencing a similar situation (FG.3).*

11.1.5 Karen's journey

Karen claimed to be a generalist teacher because she liked chemistry and believed to have a good basis of the subject. However being an early career teacher she was more concerned with her teaching.

Starting the journey

> *Last year I had a lot of work to do in preparing the scheme of work, lesson plans and notes…. Lessons were traditional since I did not have as much time to look up activities to make the lessons more interactive. I went into class, did the theory, wrote on the board and we were done. The lessons were theory-based and I could see that the students were not getting excited…. I joined this professional development because I wanted to gain more ideas, resources related to inquiry-based learning and lesson planning (I.1).*

My impressions of Karen

Karen enjoyed teaching chemistry because it was perceived as very practical. As a young teacher she sought this opportunity to change her pedagogy and use an inquiry-based approach to teaching. She also wanted to expand her PCK and gain more examples of engaging activities in chemistry. In one of the workshops Karen shared one of her lessons about the physical properties of solids, liquids and gases that she had carried out during the previous year. She was not satisfied with how she planned her lesson (Journal reflection: February 2015). Based on the research she had carried out and from the feedback gathered in the learning community, she resolved to restructure the lesson by starting with students conducting a number of practical activities and then eliciting the physical properties of the materials used from the students' observations and discussions. I observed this lesson and noted that the students were completely captivated by the lesson. The practical activities led them to think about and come up with plausible explanations about the different physical properties of matter (Lesson observation field notes: February 2015). Thus Karen was very happy with the outcomes of this lesson and with the way students were engaged in her lesson.

Improvements along the journey

> *Last year I started the lesson you observed today with theory rather than the practical. I started discussing compression but they were completely lost. Students understand the properties of matter much quicker when we do the practical and then we discuss the properties, especially the concept of compression. The activity of the syringes is very useful to explain compression; otherwise it would be very difficult for students to understand it. These activities provide scaffolding; there is not that gap…. They are observing and experiencing these properties like pressing the air inside the syringe and they are feeling that the air is pressing against their finger (I.2).*
>
> *When I look back I feel that this year was more successful. I admit, last year I felt that there was something missing; it was too theoretical. This year, based on the students' feedback and from their attitude, when I walk into class I realise that it is different. They ask: do we have an experiment today? Students were happy that they had an experiment in every lesson (I.4).*

Personal reflection on Karen's journey

Karen looked forward to the sharing of lesson plans and to the collaborative planning experiences. She felt more prepared and equipped with the given resources in the PD programme. She learnt how to plan chemistry lessons using the 5E approach and was very satisfied that she gained various pedagogical strategies that inspired her to implement changes within her classroom. When I observed her lessons I noticed that she was moving away from traditional teaching and included practical activities, discussions and various questions that encouraged her students to think and discuss their ideas. As a result of this experience Karen recognised that she had become a different teacher because the community of learners provided a support system that was very beneficial in her initial years of teaching.

Karen's experience of the professional learning journey

> *At the beginning of this journey I had many insecurities and uncertainties in relation to my teaching skills. I wondered a lot about whether my lessons were too traditional and boring, whether my lessons were repetitive, whether they were confusing. I really needed some fresh ideas, a boost. Through this journey I gained many new ideas, resources and a lot of helpful tips…. Materials gained were used both in my primary and secondary science classes. These were used for starter activities, investigations, homework, discussion, etc…. Following each meeting I felt refreshed and eager to try out new ideas. The fact that the sessions were throughout the scholastic year was ideal as ideas could be tried out immediately. At this point I personally feel more confident, more equipped and better prepared to plan lessons, investigations, experiments, activities, etc. Looking back on this year as well on last year I can see a big improvement, especially comparing my lessons, worksheets, etc. with those of last year. The students' feedback is also more positive as students look forward to lessons more and enjoy the fact that there are more activities and experiments this year than last year (I.4).*

11.1.6 Christine's journey

Christine never studied chemistry at secondary school and she was very anxious to teach the subject. Although she initially graduated as a PSCD teacher, her love for biology made her feel like she was teaching in-field rather than out-of-field. She felt confident teaching biology and identified herself as a biology specialist teacher.

Starting the learning journey

> *I am more confident teaching biology topics. I prefer teaching within specialism however in science you need to teach physics and chemistry topics as well. I am afraid when students ask me questions related to an experiment. It is more challenging to teach chemistry than physics. There are certain things in physics that you can do as experiments and students can see them. In chemistry there is more abstract work (I.1).*

My impressions of Christine

Although Christine lacked qualifications in chemistry, along her teaching years she learnt to cope with the teaching of chemistry due to the immense support provided by her colleague who is a chemistry specialist. She managed to learn both the chemistry content and ways of teaching this subject to young students. Her colleague's support was indispensable and she could always rely on her colleague and ask when she had difficulties. In fact Christine was greatly indebted to her colleague's help, however she also wanted to learn how to deal with her own difficulties. Thus she opted to take part in the PD programme to improve her knowledge of chemistry and to obtain fresh ideas and activities to update her lessons.

Improvements along the journey

> *I always wanted to improve in chemistry…. I am much more confident when planning chemistry topics even though there are still of lot of things which I need to learn…. I can say that I have more knowledge than the students…. I feel more enriched with ideas, new ideas for practical work (I.4).*
>
> *Beforehand I used to ask my colleague to check the lesson to know whether I was doing the right things. Today I feel more confident; there is no need to ask her to check the work of every lesson. There are a few lessons here and there where I will ask her to go through it and check it out but not every lesson. I feel more reassured (I.5).*
>
> *I have more knowledge, even how to deal with a situation or how to present a situation. Before I used to feel that I would learn it in one way and present it in that way because I didn't know how to go around it differently. Now I am more capable. I have more ideas (I.4).*
>
> *…to get to this level I would have needed at least another fifteen years. I feel that I improved in a short period of time. Still there is room for improvement but I feel that I made a big step forward and I gained a bit more confidence in a short period of time because I have more ideas to use in class and if something did not work I know that I have an alternative (I.4).*

Personal reflections on Christine

When interviewed Christine pointed out that she did not feel like a novice teacher when teaching outside specialism. I recognised that along the years Christine had developed what Hashweh (2005) calls 'pedagogical constructs' based on her teaching experience. She learned to use her adaptive expertise and transfer her knowledge of teaching biology to teach chemistry. This was evident when she shared examples of lesson plans in the workshops and during a lesson observation that involved students testing the pH of a range of household items (Lesson observation field notes: May 2015).

The learning community and the sharing of different practices empowered Christine to believe more in her capabilities as a teacher and improve in teaching chemistry. Although she still expressed her preference for biology she managed to change her perception of chemistry and recognised that teaching chemistry was not an impossible task anymore. She gained more flexibility to adopt different approaches in her teaching, thus expanding her PCK. Furthermore, whereas prior to this experience Christine heavily depended on her colleague's support I noticed a significant change in her behaviour. By participating and contributing her knowledge and experience in the learning community Christine did not need to rely on her colleague to prepare chemistry lessons. She became more independent and this helped raise her self-efficacy. Christine explained that her role within the school's department had started to change because whereas in the beginning of her teaching career she used to ask for help from her colleagues, she then offered support to newly qualified teachers. She also shared the resources with her school colleagues and they eventually implemented changes in their lessons. This implied that Christine was not at the periphery of her school community but she had started moving towards the centre when she gained more expertise in the teaching of chemistry.

Christine's experience of the professional learning journey

> *I came to love chemistry whereas before I was afraid of chemistry topics. As I said I am not an expert but I am more enthusiastic now to work and improve my chemistry. I look forward to chemistry lessons as I have many more ideas of how to plan the lessons. I can teach the topics in a much easier way so the students may start to like the subject more (FG.2).*
>
> *Chemistry is not so unreachable. This experience gave me a boost and provided me with more ideas because there are more activities in chemistry which can be done in a simpler way which are fun and at the same time and students can understand them. I feel better as a teacher teaching chemistry (I.4).*

11.1.7 Maria's journey

Maria started her career as an engineer and later on decided to go into teaching. She regretted that she had never studied chemistry at school because she needed to have a background in both professions.

Starting the journey

> *I always felt that as a teacher that you are on your own and in the unknown…. When planning you sit on your own, it is your own way of interpreting the curriculum. Although to be fair the new science curriculum is very guided, very helpful. It is very difficult for you to go off track. But there is no one telling me if I am interpreting it right... if I am going in the right direction; if I am going into too much detail more than I should…. That was the worst thing I found in teaching, that you have to sit down and come up with ideas on your own. Because who am I to say that they are good? (I.1)*
>
> *My lack of knowledge puts me at risk of using the wrong terminology or explaining things in an incorrect manner…. I do not know so I cannot risk…. I don't venture outside the curriculum because with my background I cannot speak about certain things I don't know. The most challenging part is the practicals and it is ironic because those are the things that children want (FG.1).*

My impressions of Maria

Maria identified herself to be a physics specialist due to her engineering background. From our conversations it was evident that she struggled with chemistry. Although Maria conducted research she admitted that she lacked knowledge of the basic concepts in the subject. Her lacunae in her knowledge base impacted the way she approached the teaching of chemistry. She was apprehensive and felt more at a loss when preparing and teaching chemistry lessons. She admitted that she skimmed through things particularly during her explanations and she had difficulties with planning and explaining chemistry experiments.

Improvements along the journey

> *I gained more knowledge about chemical experiments, preparation of chemicals and chemical processes. I clarified a lot of queries related to chemistry that helped me understand better certain concepts and therefore I could explain them better to my students. The resources given were very helpful… I learnt more about experiments I could do in class and also enhanced my chemistry knowledge in relation to these experiments (F.G.2).*
>
> *Lesson planning is becoming an easier task, because now first of all I can distinguish between what I need to teach and what I can leave out because I understand it better. So when I am planning I am not doubting myself if I am giving the right information or not…. Now I can even be more adventurous, I now feel more positive about my planning and actually look forward to it unlike previously when I felt I was just digging deep in my own concerns (I.4).*

Coping strategies have decreased a lot now. I don't use them that much now. From year to year you improve… before when I used to tell (the students) something... I used to maybe say something silly. Now no. When we talk about chemical reactions… even simple things like combustion, before I used to ask 'what is happening?' now I can understand so I can explain it better to the students. At the same time I had that regret that I was not giving enough to my students. You will be doing a disservice to the students in reality. I always felt that way (I.4).

Personal reflections on Maria

Maria's main aim was to obtain a deeper knowledge of the subject and learn how to teach chemistry to young students. Being a firm believer in team work, she easily fitted in and shared her experiences with the community of learners despite her limitations in the subject. Team work confirmed Maria's beliefs that teachers could overcome their difficulties when they share, discuss and work in collaboration rather than in isolation. She was very pleased that by the end of the year the learning community managed to produce various lesson plans that could be used to teach most of the chemistry topics in Year 7 and 8. As Maria expanded her knowledge base she was inspired to make changes in her lessons and to feel less hesitant and uncertain in her work. At the end of the journey Maria still identified herself as a physics specialist, however this learning experience helped her to resolve some of her difficulties related to chemistry content and ways of teaching the subject. I feel that Maria needed more time to learn chemistry content and to develop a more coherent knowledge base. However this experience was beneficial because she did not only improve her chemistry lessons but her teaching in general.

Maria's experiences of the professional learning journey

This experience helped me to tackle my insecurities and be more positive in teaching chemistry topics. I approached my lessons with more enthusiasm and will to experiment. I felt more confident in my work and this helped me to provide better learning for my students (I.4).

I said 'OK' so I was feeling better about the chemistry part but then when we started discussing, it changed from just chemistry to teaching…. When we started discussing our problems, how we feel uncomfortable, it became more of a general discussion as in teaching, science and teaching in general…. It is not just a question of chemistry. For me I had already gained a lot but this was helping in my teaching in general (I.4).

11.1.8 Robert's journey

Robert introduced himself as a physics specialist and felt very apprehensive to teach outside his science specialism. He had not studied chemistry at secondary school and lacked confidence in the subject.

Starting the learning journey

> *I am learning chemistry and biology with the students. When they ask questions (especially the tricky questions) I go home and google it to find out how to answer them…. More preparation is required for chemistry lessons (I.1).*
>
> *I prefer to teach physics since I am able to produce a lesson with minimal effort. In physics I am more relaxed about being more certain of how to answer students' questions. In chemistry I have to be careful not give them any misinformation. At times I start wondering: from where am I going to start, how shall I continue, how will I put all [the lesson] together? (I.2)*

My impression of Robert

Robert faced considerable difficulties in preparing and teaching chemistry due to his limited content knowledge and subject-specific PCK. He felt very restricted in chemistry and could not go beyond the expected level due to his weak knowledge base. In the lessons that I observed Robert used different activities such as visuals, experiments and demonstrations for students to learn through first-hand experience. He developed discussion-based lessons and used questions to elicit students' ideas and opinions. Yet at times he was hesitant in answering particular students' questions, used closed questions and gave inaccurate explanations, showing that he still had some gaps in his content knowledge (Lesson observation field notes: November 2014; May 2015). This suggests that it was not easy for Robert to teach a subject in which he lacked content knowledge proving that content knowledge is truly a fundamental aspect of the teachers' knowledge base. Moreover Robert could not fall back on his students' experiences, to set up experiments in his lessons. This means that teachers like Robert would face the most difficulties in teaching a subject they had never learnt at school.

Improvements along the journey

> *I used to think that chemistry was way beyond my limits, like it is a subject that I will not manage to teach. But through this experience and I think even from yesterday's experiments… there is the practical side that I liked. Now in a way I feel more confident that I can include more experiments in chemistry (FG.2).*

My lessons plans improved. I rarely used the 5Es for lesson planning but after the workshops I started using them in my lessons plans, even in chemistry. I am a creative person so it was easy to plan with the 5Es (I.4).

Personal reflections on Robert

Robert was very conscious about his difficulties in teaching chemistry and at the beginning of the PD programme he did not participate as much. When he became aware that the other teachers were facing similar difficulties he felt comfortable to be part of the community of learners. From one workshop to another Robert gained more confidence and was not afraid to show his weaknesses in the area. He posed more questions to construct both his content knowledge and PCK.

Despite his weaknesses in the area Robert shared some of his teaching approaches such as storytelling and planning chemistry lessons based on the 5E inquiry based approach. Robert felt proud that the other teachers acknowledged his efforts and methods and this greatly influenced Robert's personal view of himself as a science teacher by increasing his self-efficacy. The discussions, reflections, sharing of lessons and teaching ideas within the community of learners were highly beneficial for Robert and these inspired him to try out new activities and move out of his comfort zone. By being part of the community of learners Robert felt that he managed to move a step further in his journey as a teacher. He gained a better insight of chemistry and of how this subject could be taught to young students. However he still mentioned that he had some difficulties in choosing the best and most suitable activity to explain a particular concept due to his insufficient knowledge of chemistry. This suggests that teachers like Robert need long-term support to develop their curricular knowledge and SMK. By the end of the journey he still identified himself as a physics specialist but this experience helped him to start changing his perception and disposition towards teaching chemistry even though he knew that he needed to invest more time in consolidating his knowledge base.

Robert's experience of the professional learning journey

I was becoming aware that this problem is not only mine…. Knowing that there are more teachers who do not have a background of chemistry like me made me feel more 'at home' even when discussing and sharing my problems with the whole group. Many of us have this problem so I won't feel shy that I might say something silly in front of a group of people. It won't seem like I am not good in this subject area….The experience of the community helped me to discover that a teacher does not know everything. It is not bad to say within a group that I am encountering problems in this area during the lesson. There is nothing wrong in admitting this. But prior to being in the community I did not think of it in that way (I.4).

In the beginning when anyone mentioned the word chemistry it was like 'Ma! Chemistry, don't mention it.' Today I started understanding some chemistry.... Once you start understanding different aspects you start getting the hang of it. But before it was like having a ball of wool and you had to create something from it, but what are you going to create if you don't know from where it starts? ... I ended up doing that activity in the engagement phase which is the most crucial part of the lesson from one idea that came up in the workshop. I started associating things with one another and making links. I started making more sense out of it (I.4).

11.2 Personal view of self as a science teacher after the learning journey

Throughout the professional learning experience the participant teachers embarked on the process of examining their practices by reflecting on their work and on their beliefs and attitudes when teaching lessons outside their area of specialism. In line with what Beauchamp and Thomas argue (2009) through reflection teachers became more in tune with their sense of self and developed an understanding on how they see themselves in practice. Reflection was an important factor that was shaping the teacher identity. The interaction within the community of learners also led the teachers to reflect on how they viewed themselves and how they were viewed by others in this particular context (Gee, 2000). Since identity is "an ongoing process of interpretation and re-interpretation of experiences" (Beijaard et al., 2004, p.122), at the end of the journey I was interested to find out how the teachers perceived themselves as teachers of science and how they negotiated their identities in this professional learning experience. I was also keen to observe whether the teachers had experienced any shifts in their identity particularly with regard to teaching outside their science specialism.

When the teachers were interviewed at the beginning and at the end of PD programme I found that they did not change their core identity and claimed to be subject specialists or generalist teachers. Daniela, Amy, Laura and Christine identified themselves as biology specialist teachers and Robert and Maria identified themselves as physics specialist teachers. These six teachers felt more fulfilled and complete when teaching their subject specialism; hence they still identified themselves as subject specialists. As Hobbs (2012) argues, their positioning in relation to the subject was based on their level of competence and confidence with content knowledge and with the teaching of the subject. For the six teachers, their previous experiences as learners, their training as specialist teachers, their level of knowledge and the affinity developed towards their specialist area strongly shaped their core identity.

On the other hand, Karen and Sarah reiterated that they thought of themselves as generalist teachers because they both liked chemistry and did not find much difficulty in planning and teaching chemistry lessons. As I engaged with the participant teachers in deeper conversations I realised that they still kept on identifying themselves by their core identities which remained fairly stable through this professional learning experience.

When teachers were teaching across specialisations they took on different identities depending on the subjects taught. Most of the teachers experienced a number of challenges when teaching outside specialism and this affected their self-perception as science teachers. They resorted to use a number of boundary objects to consolidate their knowledge base and reduce the tensions between their multiple identities. Yet this was not enough. They looked forward to participating in long-term professional learning that could help them feel more capable of teaching outside specialism.

Teachers attended the PD programme because they wanted to improve their chemistry teaching and resolve the tensions that existed between their core and sub-identities. The teachers' experiences along the professional learning journey indicated that their participation within the community of learners and their engagement in various sessions highly influenced the way they viewed themselves as science teachers. The discourse and feedback within the sessions enabled teachers to learn or consolidate the chemistry content knowledge and to gain ideas of teaching activities that could be used in their chemistry lessons. Moreover the safe and supportive environment created within the learning community encouraged the teachers to experiment and try out new ideas in their classroom. This helped them take the plunge and move beyond their comfort zone. From the feedback given and their active engagement as contributors of knowledge within the learning community, teachers reviewed the way they were looking at themselves and how others were seeing them. As a result the participant teachers started feeling more capable as science teachers because the professional learning experience empowered them to gain the necessary knowledge and skills required to plan and develop lessons outside their science specialism and review their beliefs about teaching chemistry. The teachers' stories narrated in this chapter have shown that although teachers did not change their core identities they experienced a positive shift in identity towards teaching chemistry. As discussed in Chapter 2 changes employed in subject content, PCK and in one's beliefs taking place within a social context expand the teacher's knowledge base. The teachers' narratives also showed that once teachers experienced changes within their knowledge base this influenced their professional identity. These shifts in identity could take place because, as argued by Beijaard et al. (2004), teachers engaged in a process of practical knowledge building by actively participating in a community of learners, where the interaction was "characterised by the ongoing integration of what is individually and collectively seen as relevant to teaching" (p. 123).

Part V

Discussion and Conclusion

Overview

Part V of my thesis consists of the last two chapters. Chapter 12 discusses the main research findings and implications of this study related to teaching outside specialism, the impact on teacher identity and the support mechanisms required to enable teachers to teach across specialisations. The concluding chapter (Chapter 13) outlines the main contribution of knowledge to the field and ends with my reflections on the research process.

Chapter 12

Discussion

12.1 Initial reflections

In this study I wanted to explore how science teachers approach the teaching of chemistry topics especially when chemistry is not part of their area of specialism. Within the local Maltese context very little research has been carried out in this area. As I embarked on this study I began to reflect on the role and remit of a science teacher. Like Hobbs and Törner (2019), I would argue that in science the situation is more complicated because in some countries "*science* can be taught as an integrated subject… where a biology-specialised teacher is responsible for teaching all science disciplines in a subject called *Science*" whereas in other countries science is taught "as discipline-specific subjects by teachers with a corresponding science background" (p. 8). As discussed in Chapter 1 a science teacher can have a dual role: a generalist and/or a subject specialist depending on the curriculum followed at particular year levels. Within the local context it is usually assumed that subject area specialists are able to teach all science areas irrespective of their background and experiences. This situation prompted me to question how the generalist science teachers were dealing with teaching all the science disciplines, when they had only specialised in one or two science subjects during their ITE.

12.2 Deconstructing the terminology

When I started to read the literature on the topic I came across different terminology in relation to teaching science through a generalist approach. Research studies from the UK made use of the two main terms: 'teaching within specialism' and 'teaching outside specialism' (Child & McNicholl, 2007; Kind, 2009a). On the other hand the term 'teaching out-of-field' was more frequently used in literature from the US and Australia (Hobbs, 2013a; Ingersoll, 1998). The diverse discourse being used in different countries suggested that the terminology was specific to the country in which it was being used. Thus it was important to understand the meaning of each term and to try to find out whether this phenomenon was also present in the Maltese context. Teaching out-of-field (as described in Chapter 1) is when a teacher is "assigned to teach subjects that do not match their training or education" (Ingersoll, 1998, p. 774), for example when mathematics teachers teach science. Teaching outside specialism is when teachers are teaching a subject that was not studied at degree or Advanced Level (Childs & McNicholl, 2007), for example a biology teacher teaching physics. I concluded that local science teachers were teaching a much broader area than their actual subject specialism. I therefore, decided to use the term 'teaching outside specialism' or more specifically 'teaching outside one's area of science specialism' highlighting that teachers were teaching a science subject that had not been studied at degree level. The latter term fitted perfectly within the Maltese context because teachers trained to teach a particular science subject during the B.Ed. (Hons.) programme also had to teach integrated science. In this study seven of the teachers were teaching outside their science specialism because they were either biology or physics specialist teachers. One of the teachers was actually teaching out-of field. Christine had originally graduated as a teacher of PSCD but ended up teaching biology and science. What was interesting in Christine's case was that she felt in-field when teaching biology due to her love and interest for the subject but she felt less confident to teach chemistry, a subject that she had never studied, not even at secondary school.

Within the UK system teachers 'teaching outside specialism' are also called 'non-specialist teachers'. I often use the latter term in describing the teachers' narratives within this thesis. Yet I always felt that this term has a negative connotation, thus agreeing with Hobbs and Törner (2019) that being called a non-specialist could mean placing the teachers in a deficit position. Throughout this journey as I started to build a relationship with and got to know the teachers on a deeper level, I felt that I could never address them as 'non-chemistry specialist teachers' even though they often attributed their anxieties and difficulties to their limited content knowledge and teaching strategies in chemistry. These teachers were qualified science teachers certified to teach their area of specialism, yet at the same time they were teaching integrated science and were striving to adopt a science teacher identity. I believed that it would be best to address them as science teachers because as their narratives revealed (see Chapters 7 to 11) they all demonstrated a strong pedagogical imperative (Hobbs, 2013a). They all wanted to transmit their passion for science by designing engaging and fun lessons. I wanted the teachers to be identified as science teachers because, as argued by Woolhouse and

Cochrane (2015), this would help them strengthen their professional identity and empower them to overcome their difficulties.

In a recent publication (Hobbs & Törner, 2019) a group of researchers and practitioners with an interest in sharing and exploring issues relating to the out-of-field phenomenon coined the term 'teaching across specialisations.' This term encompasses both teaching out-of-field and teaching outside specialism. In my opinion this term is more suitable because it provides a strong sense of ethos and aims to improve the teachers' sense of identity in teaching the different subjects. Indeed this is what I hoped to achieve in trying to find ways of supporting the teachers to teach chemistry topics as part of this research study.

12.3 Developing a theoretical framework

In this study I wanted to explore and gain a better understanding of the meanings and implications of 'teaching outside one's area of science specialism.' As a researcher I wanted to give voice to the science teachers and provide them with the opportunity to describe their classroom experiences and express how they were feeling when planning and teaching different science topics. The teachers' narratives (Chapters 7 and 8) confirmed my initial impressions that they were experiencing a series of challenges that affected their self-efficacy beliefs. As a researcher, I was not content with simply listening to the teachers' narratives and reporting them but I wanted to understand why they were experiencing these difficulties and how this was affecting their perception as science teachers.

I turned to the literature to identify the roots of the challenging experiences that were creating a feeling of inadequacy. I found research studies that discussed the teachers' professional knowledge base. Shulman's (1986) categories of the teachers' knowledge base emphasise the cognitive aspect and indicate that SMK and PCK, besides the other knowledge categories, deeply shape the way teachers plan and deliver their lessons. I continued to delve deeper into the literature and the model of teacher professional knowledge and skills (Gess-Newsome, 2015) was also underscoring the affective aspect. The teachers' beliefs, values, orientation towards teaching, motivation and their perception of self-efficacy among other factors contribute to their knowledge and skill. The teacher's knowledge base is shaped by context during the act of teaching (Gess-Newsome, 2015). It is also influenced by social interactions particularly when teachers discuss their classroom practice and ask for teaching ideas to explain particular concepts (McNicholl et al., 2013). Reading further, I began to understand that the four factors: the cognitive, the affective, contextual and social dimensions play a fundamental role in the shaping of the teachers' knowledge base. The model described in Chapter 2 (Figure 2.2) became the backbone of my theoretical framework. It helped me analyse the teachers' narratives and develop an understanding in terms of how their professional knowledge base impacts their decisions and practice when teaching across specialisations. This model was also used to derive the professional learning framework for teachers teaching outside their area of expertise as shown in Figure 4.1.

12.4 Teaching integrated science: Adopting multiple identities

In this study I was also interested to find out how teaching across specialisations could impact the development of the teachers' identity. Developing an identity as a science teacher is a complex process and is affected by a variety of factors which include the teachers' personal experiences and beliefs, the context and social interactions as well as the subjects they teach (see Figure 2.3). One of the key findings of the current study is that as reported by Gee (2001), the participant teachers adopted multiple identities as they operated in different practices and contexts. At the beginning of the study I found that teachers did not only describe themselves as teachers but as Siskin (1994) argues, they were deriving their professional identity from the subject that they taught. Although teachers perceived themselves as science teachers they did not view themselves in the same way. The teachers could be grouped into two: two teachers identified themselves as generalist teachers, having no preference to teach a particular subject area, whereas six teachers identified themselves as specialist teachers, being more confident to teach their area of specialism (see Chapter 7). The teachers recognised that they had the responsibility to teach all areas of science, but the subject specialists in particular questioned their capability to teach each discipline in an effective way.

All the teachers who participated in the study, whether they considered themselves to be generalists or specialists, needed to negotiate their multiple identities (Gee, 2001) when teaching across specialisations. Beauchamp and Thomas (2009) suggest that generally the multiple identities or sub-identities are "more or less central to the overall identity and must be balanced to avoid conflict across them" (p. 177). What is specific to the current study is the fact that the teachers who viewed themselves as generalist science teachers did not seem to experience any conflicts between their multiple identities. They believed that they had a good foundation in all areas of science and had positive experiences in chemistry and in their area of specialism as young learners. However, the subject specialists had a different point of view. It was clearly evident that these teachers experienced a different sense of self when faced with the demands of teaching an unfamiliar area. In my view, this experience caused a sense of disruption within the teachers' professional identity and like Hobbs and Törner (2019) I would argue that:

> …. in many situations and for many teachers, the prospect and practice of teaching a new subject acts as a disruptor, disrupting what they might be familiar with and feel proficient within the case of more experienced teachers or in the case of new teachers, disrupting expectations that they were teaching as a specialist in their chosen field (p. 12).

This sense of disruption was manifested in the teachers' narratives (see Chapter 7 and 8) when they stated that they felt more flexible in using different explanations and activities within their specialist area, whereas in chemistry they felt restricted and constrained and could not deviate from their lesson plan due to their poor background knowledge. This disruption also created diverse and opposing emotions. Teachers oscillated between feeling competent with a high sense of self-efficacy in their area of expertise to feeling anxious and uncertain and with a low sense of self-efficacy outside their science specialism. This in my view is one of the key findings in this research study, where the inconsistencies related to their self-image and personal sense of self led teachers to experience, as Hobbs (2013b) argues, a discontinuity or tensions between their multiple identities. Due to contradictory experiences, teachers doubted their competency as science teachers and admitted that they experienced more challenges and issues when teaching their non-specialist area rather than their area of specialism.

12.5 Challenges faced by teachers when planning and teaching chemistry topics

An important theme that runs across the literature review and the analysis of results in this current study is the emphasis on the challenges that teachers face when teaching their non-specialist area. The teachers' profiles in Chapter 7 provided an initial understanding of the conflicting experiences in their role as generalist science teachers. The findings presented in Chapter 8 highlight the main challenges the teachers experienced in teaching their non-specialist area, thereby answering the first research question which is: *What challenges do science teachers, who are non-chemistry specialists, face when teaching chemistry topics in* *the Maltese integrated science curriculum?* The participant teachers identified that they encountered difficulties both during the planning stage and whilst teaching chemistry lessons.

12.5.1 Challenges faced by teachers when planning chemistry topics

International research studies (see Section 3.2.1) suggest that one of the major challenges when teaching outside specialism is related to lesson planning. In the current study, the teachers felt more constrained in planning chemistry lessons because they admitted that they had limited content knowledge and a restricted repertoire of teaching strategies. As outlined in their narratives, in Chapters 7 and 8, their previous poor experiences of learning the subject did not help them to generate the required interest and appreciation of the subject. What is particular to the current study is that the three science teachers who did not study chemistry at a young age were more at a loss than the other teachers in the study. They spent a long time conducting research to learn new content and to understand how the concepts interlink. They learned to construct simple explanations after gaining a basic understanding of the major ideas in a topic. On the other hand, the other teachers also spent considerable time doing research but they focused more on finding interactive activities after revising what they had learnt during their school days.

During the planning stage the participant teachers struggled to translate their fragmented knowledge into lessons. Similar to other studies (Childs & McNicholl, 2007; Sanders et al., 1993) they encountered major difficulties in finding and selecting the appropriate activities from a multitude of resources, and in formulating a sequence of activities in their lessons. Another difficulty that emerged only in this study and that was not mentioned in the literature in section 3.2.1, was that two of the teachers revealed that they lacked knowledge of the chemical terms and felt lost when conducting research on the Internet. This shows that there is a strong relationship between content-specific knowledge, curriculum organisation and knowledge of resources. When content-specific knowledge and knowledge of curriculum were limited, teachers believed that they did not have the adequate skills to conduct an effective Internet research to find the best resources.

In a study by Lee and Luft (2008) experienced science teachers recognised that a sound knowledge of science content is a crucial part of the teachers' knowledge base. SMK has been highlighted as a fundamental component of the teachers' knowledge base both by Shulman (1986) and in the model of TPK&S (Gess-Newsome, 2015), as well as in the theoretical framework for this study (see Figure 2.2). As a result I would argue that the lack of content-specific knowledge in chemistry was the main stumbling block in planning chemistry lessons. The major implication of this situation is that when teachers have gaps in their knowledge they find it more difficult to emphasise the key ideas in a topic and show how they interlink. They also struggle to find the best ways of representing these ideas to their students. Thus teachers with limited SMK have less developed and flexible 'personal PCK' (Gess-Newsome, 2015) in terms of applying knowledge and reasoning, in making the necessary instructional decisions and in using effective pedagogical approaches. I believe that this situation puts more strain on the teachers because during the preparation time they would need to make up for the missing content knowledge that was not learnt during ITE. As Childs and McNicholl (2007) suggest, teachers also need to learn how to translate content knowledge into successful teaching episodes. Hence teachers teaching outside their area of specialism have to work harder and invest more time to make up for the missing components in their professional knowledge base (Kind, 2009a). This was also true for the teachers in the current study. Although the participant teachers had spent considerable time to learn both the content knowledge and ways of teaching it, they still felt distressed and unsure of the lesson outcomes, thus affecting their self-efficacy beliefs. As outlined in Chapter 8 they always blamed their lack of content knowledge for their limited ability to plan interesting and engaging lessons and this affected their perception of themselves as science teachers.

12.5.2 Challenges faced by teachers when teaching chemistry topics

In the literature five main challenges are identified when teaching outside specialism. These include using traditional methods of teaching with restricted classroom interaction, having a limited repertoire of analogies and representations to explain concepts and having difficulties in answering students' questions. They also faced challenges when preparing and delivering practical work and had knowledge inaccuracies and difficulties to deal with misconceptions. The participants also encountered similar challenges in their chemistry lessons as summarised in Figure 12.1. The participant teachers feared that they could perpetuate their knowledge inaccuracies in their explanations, when answering students' questions and in practical work. They were also highly concerned that their students would eventually discover their limitations in chemistry and judge them to be less competent teachers.

Problematic areas identified in the literature	**Problematic areas identified in the current study**
Traditional lessons and limited classroom interaction →	Feeling limited and constrained to go a step further in their lessons, stick to the curriculum (as identified in interviews).
Limited explanations and use of analogies →	Limited skills in simplifying and explaining concepts leading to less elaborate and detailed explanations.
Difficulties in answering students' questions →	Difficulties in answering students' questions: giving less elaborate answers, unsure of their answers and afraid of giving incorrect answers.
Difficulties in preparing and delivering practical work →	Avoiding practical work; difficulties in selecting suitable experiments; difficulties in conducting experiments, difficulties in explaining correct and incorrect results and sources of error; could not explain chemical reactions taking place.
Knowledge inaccuracies and difficulties in dealing with misconceptions →	Knowledge inaccuracies; teachers afraid of passing on misconceptions or failing to identity them.

Figure 12.1: Major constraints in teaching chemistry lessons compared to the constraints identified in literature

Based on the results of the current study I would argue that teachers encountered challenges because they had lacunae in their chemistry content knowledge, which affected the development of their subject-specific PCK. The model of TPK&S (Gess-Newsome, 2015) emphasises that besides having generic knowledge that guides one's planning and teaching, teachers should also have topic-specific professional knowledge. Such knowledge helps teachers to determine effective teaching strategies, use multiple representations, understand students' knowledge and misconceptions and use particular examples to highlight the main ideas of the topic (Gess-Newsome, 2015). I believe that it was this topic-specific professional knowledge related to the teaching of chemistry that was insufficient in their professional knowledge base. Teachers also struggled to develop a passion for the subject and became anxious in their chemistry lessons due to their insufficient knowledge base. This implies that, as Hobbs argues (2013b), it was the combination of the lack of content knowledge and teaching strategies and personal experiences that affected the teachers' confidence in teaching outside specialism.

Having an insufficient knowledge base and demonstrating lower levels of confidence in teaching outside specialism could lead to the development of a fragmented sense of identity. In this study, as teachers reflected on their practice they became aware of the pedagogical differences when teaching within and outside specialism and came to believe that they could not teach chemistry in the same way and with the same passion and enthusiasm as their subject specialism. Similar to studies in other contexts (Hobbs, 2013a), this led them to feel less confident and they experienced low self-efficacy by believing that they were not so capable of teaching their non-specialist area. The results confirm that subject-specific SMK, PCK and teachers' self-efficacy beliefs are interlinked and they have an impact on the teachers' professional knowledge base as well on the teacher identity. In my view, the negative experiences related to teaching outside specialism could lead the teachers to situate themselves in what is described by Hobbs and Törner (2019) as a deficit position and that this perception could have repercussions on their decisions, on their classroom practice and on their identity as science teachers.

Yet surprisingly, although the participant teachers confided how they experienced similar difficulties to those found in the literature (see section 3.2.2), I noticed a contradictory result related to delivery of chemistry lessons. In their interviews the participant teachers stated (see Section 8.2) that they lacked flexibility and used a limited number of activities compared to when teaching their subject specialism. One particular teacher, who lacked a background in chemistry, also mentioned that he used traditional lessons when he could not cope with the situation. However during lesson observations I did not observe traditional lessons with restricted student interaction. On the contrary students eagerly participated in discussions and hands-on activities (see Chapter 11). Although teachers had pointed out that they experienced a number of restrictions in their lessons, they nevertheless did not use didactical approaches but aimed to plan engaging lessons. In my view this is an important finding in this study because although teachers were experiencing various challenges they did not resort to traditional pedagogies to hide their insecurities. They aimed to overcome their challenges by using boundary objects, as explained in Chapter 9 and plan similar lessons to those used when teaching within specialism. This shows an important disposition in the teachers' identity because they were willing to learn to overcome their difficulties.

12.6 Overcoming the challenges: Negotiating subject boundaries

The challenges arising in teaching outside specialism did not hinder the teachers from planning student-centred lessons based on discussions and hands-on activities. From my observations (see Chapter 11) lessons flowed quite smoothly and there were only minor setbacks. Students enjoyed the lessons and looked forward to conducting chemistry experiments. When I reflected on why and how the participant teachers were able to conduct successful chemistry lessons in spite of their limitations, I was drawn back to the theory of boundary crossings suggested by Akkermann and Baker (2011) (see Chapter 3). I used the results of the study as well as the theory of boundary crossing in order to answer the second research question which is: *How do non-specialist chemistry teachers deal with the challenges that they face when teaching chemistry topics in integrated science?*

Hobbs, Du Plessis, Quinn and Rochette (2019) argue that teachers experience discontinuities when they recognise that the new practice does not complement their current practice, thus a boundary exists when the teacher identifies differences in practices. Although generally the sociocultural differences existing between the boundaries can be problematic, the boundary literature values these differences. Discontinuities between boundaries can be overcome through a process of "re-establishing practices despite differences in practices" (Hobbs et al., 2019, p. 103). Therefore boundaries can be "potential learning resources rather than barriers" (Akkermann & Bakker, 2011, p.137). I resorted to use the theory of boundary crossing because as Hobbs (2013b) argues, it provides a "platform for re-conceptualising these experiences as opportunities for professional learning" (p. 9). I realised that this was actually happening in the case of the teachers in the current study. They were learning and adapting to new fields to include new understandings, to change practices and expand their professional identity.

In my view, what is crucial in this process of boundary crossing is that teachers need not only learn new knowledge to become accustomed to a different subject culture but they must be open and flexible to transform their beliefs and attitudes towards teaching a new subject. This might be more difficult to achieve especially when teachers had negative experiences and limited success in learning the subject during their school days. Like Luehmann (2007) I would argue that the participant teachers had to adapt and take on a new identity in learning to teach all the three science disciplines.

Although the majority of the participants identified themselves as subject specialists with a preference for teaching their subject specialism, they were still open to take risks and tried their best to be successful even in areas in which they did not feel so competent (see section 7.3). This implies that teachers did not have fixed and rigid identities, otherwise they would have exhibited reluctance and resistance to teach outside their subject specialism. In learning to expand their teaching identities, teachers were required to develop their adaptive expertise. Bransford, Derry, Berliner, Hammerness & Beckett (2005) argue that when teachers develop their adaptive expertise they are more likely to change their core competencies and expand the width and depth of their expertise. Within this study teachers used their adaptive expertise by successfully making use of their pedagogical knowledge to develop chemistry lessons. They were using their generic teaching skills to find ways to transform what they already knew to teach another subject. In developing their adaptive expertise the participant teachers did not only widen their cognitive knowledge base, but as Hobbs (2013a) argues, they had to review their motivation, personal beliefs, habits of the mind and dispositions towards teaching a new area.

This resulted in a change in my own perceptions and ideas about teaching outside one's area of specialism. From my previous encounters with science teachers, teaching outside specialism posed a number of challenges and resulted in a negative experience for teachers. When I worked with the participant teachers, and accompanied them on their professional journey I came to the understanding that teaching outside specialism, "is not in itself negative for a professional teacher, but it can lead to different outcomes, either positive or negative and anywhere in between" (Hobbs and Törner, 2019, p. 12). In the current study although initially teaching outside specialism was stressful for some teachers (see Chapter 7 and 8), they sought to overcome these disruptions by engaging in professional learning. The teachers made the conscious decision to move away from being in a deficit position. They wanted to be more in control to teach an unfamiliar area and gain confidence as generalist science teachers. Thus they became open to expanding their identity as science teachers.

According to Akkermann and Bakker (2011), learning at the boundary can take place through four different processes: (1) identification of discontinuities, (2) coordination of boundary objects, (3) reflections on practice and identity and (4) transformation of practice and identity. At this point I would like to reflect on the second process, that of coordination of boundary objects and discuss how the participant teachers used boundary objects to negotiate subject boundaries and their teaching identity.

As described in the literature (section 3.3) the most common support mechanisms used to overcome challenges when teaching outside specialism included conducting research from books, Internet and other resources, consulting colleagues who are specialist in the area and repeated teaching experiences. Teachers also use their knowledge from their science specialism to understand chemistry concepts or else stick to familiar practices to feel more safe and secure. From the findings presented in Chapter 9 the participant teachers used similar strategies to those identified in the literature (section 3.3). I grouped these strategies into two sets, that is: (1) the coping mechanisms and (2) the enabling mechanisms. I will discuss how these mechanisms helped the teachers to resolve their difficulties in their day-to-day practice and whether they enabled the teachers to increase their professional learning and expand their professional identity in negotiating the boundary between teaching familiar to less familiar areas.

In order to overcome the disruptions caused by teaching an unfamiliar area it is very common that teachers follow text books and/or schemes of work and use traditional methods (Childs & Nicholl, 2007; Hashweh, 1987; Kind 2009a; Lee, 1995). The results in section 9.1 show that at times teachers used coping mechanisms as fix-it strategies to cope with the short-term problems. These coping strategies included (1) following prescribed material, (2) using knowledge from subject specialism, and (3) using traditional pedagogies. When participant teachers used these coping strategies they managed to resolve the situation only temporarily because they still claimed that they were less confident to teach chemistry as described in the beginning of their journey (see Chapter 7). Therefore I would argue that by using these coping strategies teachers remained on the side of the boundary that was familiar to them because they did not gain new knowledge to expand their knowledge base. These strategies were generally used by the teachers with limited background knowledge in chemistry especially when they felt overwhelmed to teach an unfamiliar area. By using coping mechanisms teachers could hide their insecurities and appear to be in control of the situation even though they had a number of weaknesses in their SMK and PCK.

On the other hand, participant teachers used enabling mechanisms or boundary objects to learn new content and feel competent in teaching a new area (see section 9.2). These three strategies: (1) conducting research, (2) support from colleagues and (3) repeated teaching experiences enabled teachers to become accustomed to the different knowledge, culture, practice and beliefs of another subject. Asking for support from colleagues and conducting research were also the two most popular strategies described in the literature (see section 3.3). As argued by Hobbs (2013b) "boundary objects are central to professional identity development because they improve the likelihood of learning through the boundary crossing event" (p. 11). The findings in section 9.2 illustrate that when using boundary objects (such as conducting research and using support from colleagues) the participant teachers were able to resolve some of the tensions and challenges arising in teaching chemistry. The enabling strategies increased boundary permeability because by conducting research and seeking support from colleagues the participant teachers could establish continuity as they were transforming their knowledge, beliefs and attitudes towards teaching their non-specialist area. Hobbs (2013b) argues that "being immersed in the new field, understanding the landscape, working out what can be translated from one's current set of knowledge, skills and attitudes, constructing new knowledge sets and being supported in these processes, are determinants of boundary permeability" (p. 23). Therefore by using these three enabling strategies teachers managed to increase their knowledge base and they felt more prepared and confident to teach their non-specialist area.

The findings of this study show that when teachers employed simple fix-it mechanisms or more enabling mechanisms they were exhibiting different levels of adaptability. I would suggest that when teachers employed simple fix-it strategies they did not feel ready and equipped with the necessary knowledge and skill to move out of their comfort zone. On the other hand when they employed enabling strategies they were ready to take the leap, overcome the challenges and embrace the teaching of a new subject. Since the teachers' level of adaptability depended on particular circumstances and on the choice of boundary objects, the teachers in the current study can be placed along the adaptability scale suggested by Hobbs (2013a) described in section 3.4. Their position on this scale illustrates the teachers' level of commitment and willingness to adapt to teach a new subject area. It also indicates their disposition to expand their professional identity from subject specialists to generalist science teachers.

Hobbs (2013a) argues that the teacher's position on this scale mainly depends on two kinds of level of commitment: (1) *the personal imperative*: stemming from the teacher's personal interest in the subject and (2) *the pedagogical imperative*: arising from the teacher's commitment of wanting their students to succeed. From the teachers' profiles given in section 7.2, I would suggest that as generalist teachers both Sarah and Karen demonstrated these two levels of commitment. They both liked chemistry and were interested in the subject thus having a personal imperative. They also wanted to plan engaging lessons for their students to succeed and enjoy chemistry, hence showing a pedagogical imperative. Therefore, I would suggest that the generalist teachers could be placed on the right hand side of the scale, as in Figure 12.2. Both teachers can be seen to be 'pursuing an interest' due to their strong level of commitment derived from both imperatives. Consequently these teachers were open to expanding their identity to embrace the teaching of chemistry. Indeed both teachers expressed how they liked teaching chemistry topics and did not find so many challenges in teaching their non-specialist area.

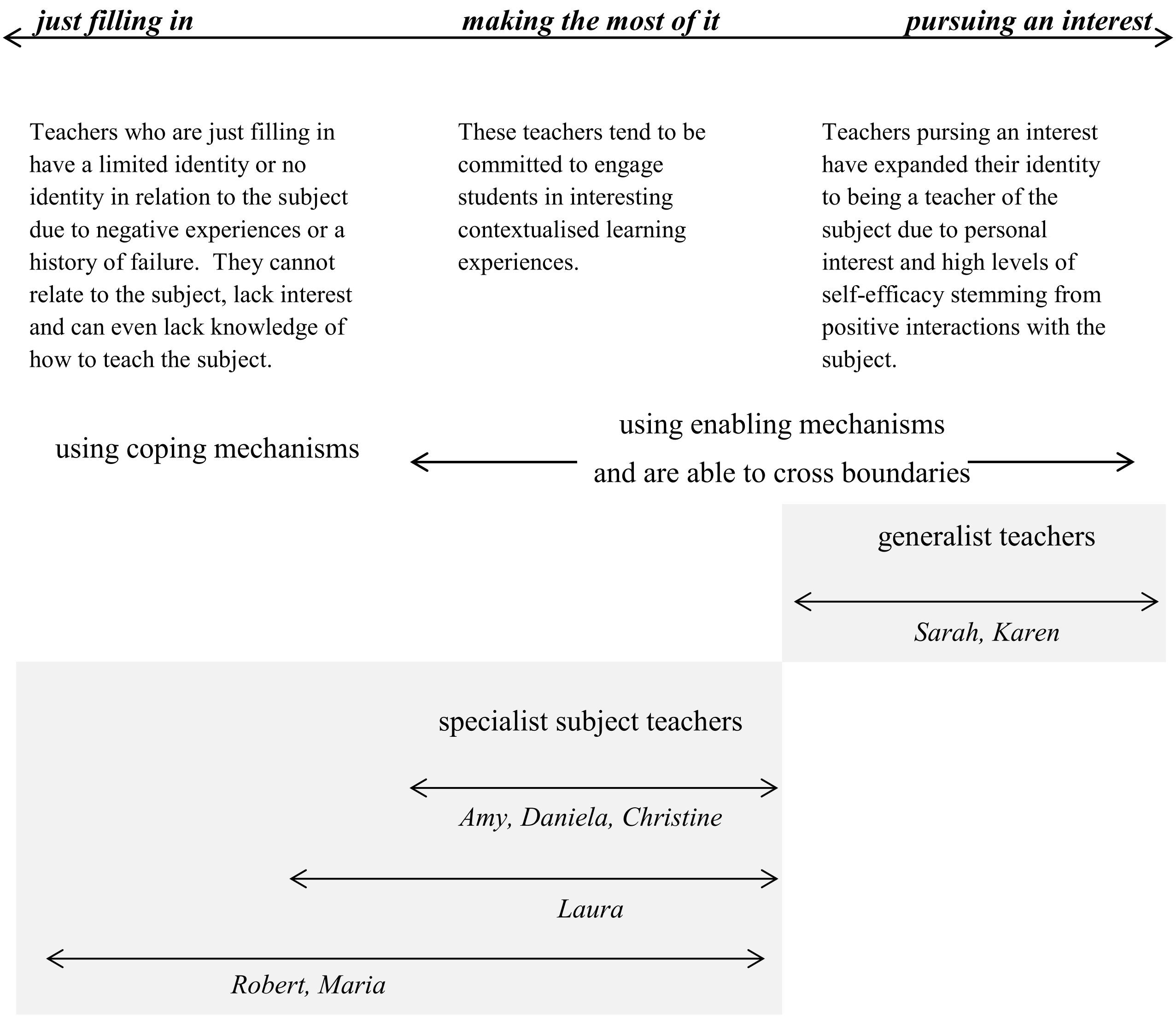

Figure 12.2 Teachers' position on the adaptability scale

On the other hand, the subject specialists had difficulties in connecting with the teaching of chemistry due to various reasons. They either had limited background knowledge (Maria, Christine, Robert) or poor experiences as young learners when learning chemistry (Amy and Laura) or they were new at teaching science (Daniela). Due to such circumstances their personal imperative was somewhat lacking. Yet all the subject specialists wanted to plan engaging chemistry lessons, hence they demonstrated a strong pedagogical imperative. Indeed these teachers spent considerable time preparing the lessons and asked support from their colleagues. The combination of the personal and pedagogical imperative, although they may not have been at par, provided enough drive for the teachers to commit themselves to improve their practice. Therefore, I would suggest that the subject specialists (Amy, Daniela, Laura, Christine, Maria, Robert) could be placed at the middle of the scale where they could be seen to be 'making the most of it' (see Figure 12.2). The lesson observations showed that these teachers had a high pedagogical commitment. They made use of boundary objects or enabling mechanisms in preparing their lessons, showing their readiness to adapt and teach a new subject.

However at times teachers like Robert, Maria and Laura used coping mechanisms when they felt overwhelmed to teach outside specialism (see section 9.1). Laura felt reassured when she followed the prescribed notes prepared by the teachers at her school. Maria made use of less risky activities and Robert at times used didactic teaching methods to purposely limit the students' participation and discourse. The use of coping mechanisms limited their adaptability. Thus I would suggest that Laura, Robert and Maria were also shifting towards the left-hand side of the scale towards the 'just filling in' role in order to cope with pressures involved in teaching an unfamiliar subject. Along the year Laura took the initiative to modify the experiment presented on the teachers' notes (see chapter 11). She was learning to adapt to the teaching of a new subject thus she was shifting from taking up the 'just filling in' position to 'making the most of it.' On the other hand, the narratives of Robert and Maria have shown that their insufficient knowledge in the area limited their level of adaptability. They made use of coping mechanisms since they found it difficult to develop a new identity besides their core identity. Robert and Maria also shifted between the 'just filling in' and 'making the most of it' positions and this depended on the type of mechanisms used in preparing and teaching chemistry topics.

In other words, the generalist or subject specialist had different levels of adaptability as indicated by their position on the adaptability scale in Figure 12.2. The findings also suggest that there is a relationship between the use of strategies (whether coping or enabling mechanisms) and the teachers' willingness to adopt a new identity. Teachers used boundary objects to expand their professional identity or coping mechanisms to survive in their classrooms.

12.7 Supporting teachers teaching outside their science specialism

By using boundary objects teachers managed to resolve some of their difficulties, yet they were not all satisfied with their teaching and with their fragmented sense of identity. They decided to seek support when they could not make enough progress on their own. Although they were specialist teachers in one science discipline this was not sufficient to teach all areas of science effectively. Like Du Plessis, Gillies and Carroll (2014) I would assert that it is a "misunderstanding to assume that teacher expertise in one field would automatically translate into expertise in other fields" (p. 91). I believe that it was the teachers' sense of agency that led them to pursue their learning and take the risk to overcome the challenges. As Beijaard et al. (2004) contend, agency is an "important element of professional identity, meaning that teachers have to be active in the process of professional development" (p. 122). Teachers can exercise agency in different ways depending on the goals they want to pursue and on the resources available. For the participant teachers seeking further support involved making a conscious decision to improve their practice and their self-perception to become better science teachers. As discussed in section 10.1.1, they made a personal choice to participate in a PD programme because they wanted to develop subject-specific content knowledge and PCK, improve their attitude towards chemistry and feel more capable of teaching an unfamiliar area.

Developing a PD programme that provided the necessary support for the non-specialist chemistry teachers was a crucial aspect of this research study. It was a learning journey not only for the participant teachers but even for me in the role of designer of the PD programme. When reflecting on this process I would say that the experience gained with the participant teachers, the role of the teachers in the PD sessions and the engagement with the literature helped me to reflect on the meaning of professional development that leads to professional learning. These reflections which were based on my interpretation of the results of the study and insights from the literature helped me to answer the third research question which is: *What kind of support structures that promote professional learning would science teachers who teach outside their area of science specialism benefit from?*

12.7.1 Reviewing the professional development programme

The long-term PD programme was designed on three core features represented in the framework (see Figure 4.1), namely professional knowledge, professional beliefs, situative and sociocultural learning. The first phase of the PD programme focused on consolidating the participant teachers' SMK and PCK through the conduction of different experiments and investigations, as well as when they developed tasks to target common misconceptions in chemistry. One of the sessions examined the teachers' beliefs, particularly their self-efficacy beliefs about teaching outside specialism. During the INSET teachers started to form connections when they found out that were experiencing common difficulties. This marked the pre-community of learners phase. In the sessions teachers developed their expertise from external experts (chemistry specialist teachers facilitating the session) and also by tapping into internal expertise as they engaged in collaborative work.

The second phase of the programme was based on the same core features of the professional learning framework. When teachers conducted experiments, devised lesson plans and shared their own work they were addressing both their SMK and PCK. Teachers also reflected on their work thereby exposing their content-specific beliefs about teaching chemistry topics. Their self-efficacy beliefs were addressed in the last session when teachers had to self-assess their own learning journey. Within the community of learners teachers participated, reflected and negotiated their own learning. They produced lesson plans and resources which they could later on use in their classroom.

The two phases of the PD programme were based on a different design and included: (1) features of the 'specified approaches' to PD where initially content and resources were provided to the participants and (2) features of an 'adaptive approach' where the structure and content was based on more flexible parameters by being designed in response to the teachers' needs (Koellner and Jacobs, 2014). The programme could also be viewed as a transformative model of PD (Kennedy, 2005), since it increased professional autonomy that could bring about teacher change.

12.7.1.1 Reviewing the first phase of the professional development programme

In the literature a number of important features have been outlined to design effective PD (see section 4.5), such as ongoing learner-centred sessions, a collaborative approach to learning, being relevant to classroom practice, developing SMK and PCK and encouraging reflection on practice. Besides reading the literature I attended a PD course for the chemistry non-specialist teachers in the UK. As Loucks-Horsley et al. (2010) contend, my previous PD experiences were highly influential at the beginning of the study because they shaped my professional judgements about what to include or not in the PD programme. As discussed in Chapter 6, I decided to devise the INSET sessions based on the important characteristics of PD in which teachers were actively involved in their learning to develop their content knowledge and pedagogical practice in a collaborative environment.

I decided to move away from designing traditional sessions because such courses have often been criticised as being ineffective in promoting professional learning (see section 4.3.1.1). I also believe that traditional approaches to PD would reinforce the view that external expertise is more important than internal expertise (Smith, 2017), thus non-specialist teachers would be rendered as passive recipients who needed to obtain knowledge from more knowledgeable others. I rejected the idea of designing a traditional PD programme because I believed it would not bring about changes in the teachers' personal view of themselves as science teachers and would hinder the process of negotiating their professional identity in attempting to teach across different science disciplines.

In designing the first phase of the PD programme I was mainly influenced by the prevailing approaches of PD described in the literature and those experienced as a teacher. Although the PD programme did not take a traditional approach and did not involve the delivery of information, at that point in time I believed that my role as a designer of PD was that of developing an effective programme that focussed on creating activities to enhance the teachers' knowledge, skill and enjoyment of the subject to increase their professional competence and help them to gain confidence in teaching outside specialism. The course content was predetermined and aimed to address the common needs of teachers teaching outside specialism (see section 6.3.1). In my view, this step was necessary for teachers to become enculturated and immersed into a different scientific field other than their subject specialism to gain an understanding of both the content and ways of doing chemistry.

The teachers' feedback after the INSET was mixed. On the one hand the participant teachers were positive as they stated that they had acquired more content knowledge and ideas for teaching chemistry and this increased their sense of self-efficacy. They also made use of the resources when planning their lessons over the summer holidays. On the other hand they also pointed out that since the INSET was only a short-term summer programme they could not implement changes in their practice (see Chapter 10). This is similar to what has been reported in other studies (see Birman et al., 2000) that suggest that short-term PD programmes do not provide enough time, activities and the required content to instil permanent changes in classroom practice.

From this experience I believe that the INSET was a necessary initial step to bring a number of teachers together to become familiar with the teaching of chemistry and address their common challenges, yet it posed a number of limitations to the process of ongoing learning. First of all being a summer course the teachers could not experiment and implement what they had learnt in practice. Secondly although after the INSET the teachers mentioned that they became motivated to move forward along their learning trajectories I feared that this enthusiasm would dwindle over the summer holidays, unless it was sustained in the next scholastic year. Thirdly although teachers gained a background in chemistry, I questioned whether this would be sufficient to help them change their beliefs and attitudes towards the subject and feel comfortable to take on a new identity, because as Loucks-Horsley et al. (2010) argue "it takes time for new knowledge to be translated into beliefs and changes in practice" (p. 52). This implies that short term courses are not enough for teacher to experience "change in their thinking, knowledge and skills, and approaches to instruction" (Knapp, 2003, pp. 122-123). When I reflected on the outcomes of the INSET I knew that this was only the beginning of the teachers' learning journey. A long-term ongoing programme, as was originally planned could provide the required support for teachers to apply changes to their practice. Since the second phase of the programme was held during the scholastic terms teachers could apply their learning to their classes.

12.7.1.2 Reviewing the second phase of the professional development programme

The second phase of the programme was also devised on the effective characteristics of PD (see section 4.5) and on the core features outlined in the framework in Figure 4.1. However the second phase of the PD programme was based on an adaptive model (Koellner & Jacobs, 2014) and had an emergent and flexible design. As suggested by Hawley and Valli (1999), PD should involve teachers in identifying what they need to learn and in the development of the learning experiences. I wanted the teachers to have a voice and to take more ownership of the learning, therefore it was the teachers' suggestions and their learning needs that determined the agenda for each workshop as described in section 6.3.2 and in Appendix 2. In this second phase, the participant teachers became co-designers in the professional learning journey, because as Smith (2017) suggests I believed that "teachers would need to be positioned as key decision-makers about what mattered for their own professional learning" (pp. 5-6). Furthermore when teachers designed lesson plans or shared their work they were also developing their own learning experience. Simultaneously an ongoing evaluation was taking place along the year to find out how the sessions were impacting the teachers' learning and classroom practice.

Akkermann and Bakker (2011) suggest learning at the boundary can take place through the transformation of practice and identity. The collegial experience, the ongoing learning and reflection encouraged teachers to take more risks and try out different activities suggested by the other teachers. Teachers felt more secure to make use of activities that had already been tried and tested out by others because as Appelton (2002) contends, these activities were perceived to be the ones that work and produce effective results. When teachers became open to new ideas, implemented changes and observed positive outcomes in their practice, as Guskey (2002) suggests, they changed their beliefs and attitudes about chemistry. From this experience I would argue that two key factors were instrumental for teachers to learn at the boundary. These included (1) a bottom-up approach by involving the participant teachers to identify their learning needs and (2) their continual discussions and self-reflections within the community of learners.

Based on the results of the current research I would argue that professional learning is enhanced in a learning community. The teachers' narratives have shown that by using "reflection and dialogue as tools for learning" (Easton, 2008, p. 759), teachers were able to articulate their professional knowledge and learn from each other. The ongoing PD provided a renewed enthusiasm for teachers not to get stuck in a rut but to become inspired, reflect and implement changes in their lessons. As Smith (2014) contends PD should be viewed more as a process rather than a sequence of events. This study has confirmed that a long-term learning experience within a community of learners brought about changes in one's thinking and practice resulting in professional learning. These findings support the fact that learning through social interaction and within a context can deeply impact the teachers' professional base as portrayed in the theoretical framework in Figure 2.2. This also had an effect on the teachers' identity.

12.7.2 Community of learners

The formation of the community of learners was key to the teachers' professional learning. As described by Stoll et al. (2012), the aim of the learning community transpired to be that of providing support and allowing the participant teachers to critically interrogate their practices and take a shared responsibility for individual learning and growth. Like Hirsh and Killion (2009) I would contend that when the community members formed a deep sense of trust, it allowed them to perform at their best and gain more confidence to experiment and implement changes in their practice. The process of learning in a small but trusting and supportive community, as Darling-Hammond and Richardson (2009) maintain, made the most impact on the teachers' growth and development.

Within the community of learners teachers had the opportunity to deeply reflect on their practice and share their personal reflections with their colleagues. Akkermann and Bakker (2011) suggest that learning at the boundary can take place when teachers reflect on practice and identity. By sharing their reflections teachers delved deeper into their thinking, understood the motives behind their actions and sought better ways of enhancing students' learning (see section 10.3.3). When teachers became reflective practitioners, they started situating themselves in their practice. Most of the participant teachers initially saw themselves in a deficit position, as those who lacked content knowledge and ways of teaching chemistry, hence they failed to connect with teaching outside specialism. By reflecting on their practice teachers started identifying their strengths, weaknesses and ways of improving their lessons. Reflection became a significant learning tool because as Ghaye (2011) argues it helped the teachers to develop new insights and understanding. Through reflection-on-action, as Park and Oliver (2007) maintain, teachers reviewed their own lessons and as a result they made modifications to their existing knowledge of PCK. Reflection also enabled knowledge production (Ghaye, 2011) and this contributed to the collective expertise within the community of leaners. The teachers' reflections and input were valued by the other members of the learning community and this enabled them to make the leap from feeling insecure to increasing their self-efficacy as science teachers.

Professional learning was derived from both external and internal expertise. Teachers tapped into external expertise when they were conducting research, consulting their school colleagues and discussing difficulties with the chemistry specialist teachers in the INSET. Within the community of learners the participant teachers learnt to resolve their difficulties by turning to internal rather than external expertise. Teachers used knowledge from their professional knowledge base and contributed to educational discourse within the community. Teachers identified the challenges they were experiencing or, as Hobbs et al. (2019) calls them, the 'differences between practices' and aimed to re-establish practice by identifying what was common to bridge the gap between teaching different science subjects. They managed to re-establish practice through the help of others such as when working collaboratively to prepare inquiry-based lessons. Through constructive discourse they were challenging their thinking, developing meaning and, as Stoll et al. (2012) argue, coming up with "new insights and knowledge that led to intentional change to enhance their practice" (p. 4). In this process teachers were acquiring new knowledge, modifying and reconstructing their knowledge base and gaining collective expertise, thus becoming empowered to deal with the difficulties when teaching outside specialism.

Within the group the teachers had a range of expertise, as some had studied chemistry at Advanced Level and some had not. In one way or another, each teacher shared valuable insights related to content knowledge and/or pedagogical aspects and consequently everyone acknowledged the benefit of learning from one another (see section 10.3.2). Like Hirsh and Killion (2009) I would claim the diversity between community members enriched this collaborative experience.

One important aspect that emerged from the current study was that by discussing their experiences teachers recognised that they had become contributors of knowledge within the learning community. Although they were non-specialist teachers, they felt that they had something of value to contribute to the community. They shared content and pedagogical knowledge, philosophical insights about teaching and learning and their enthusiasm towards teaching. I believe that this was another important finding in this study because although teachers did not feel so competent in chemistry, they managed to learn how to make use of their adaptive expertise and share it with others in order to increase the collective expertise.

From this PD experience I would argue that in order to support teachers to learn at the boundary it is more important to shift "the focus from what teachers are missing to what they can bring to the interaction and what can be learned" (Hobbs et al., 2019, p. 108). Hence PD programmes particularly designed for non-specialist teachers should adopt this type of approach because when teachers share their own expertise and discuss it with others they can turn their challenges into learning opportunities.

Not only this, but when teachers were acknowledged for their work and effort, they were being recognised by others as a certain type of teacher. Luehmann (2007) emphasises this aspect of recognition of oneself by others and states that "professional identity development… not only requires opportunities to participate in relevant experiences and the discourse but to have one's participation interpreted and recognised, as well as valued and accepted, by self and others" (p. 833). I think the recognition of one's efforts and practice by others despite having a deficit background was the main turning point in the teachers' professional learning journey as it empowered them to improve their self-efficacy beliefs and expand their professional identity as science teachers.

The next chapter provides a conclusion to this thesis which outlines the major contributions of knowledge to the field of teaching outside specialism. In this final chapter I will also discuss how my thoughts evolved as a researcher, practitioner and initial teacher educator.

Chapter 13

Conclusion

The aim of this thesis was to shed light on how a group of Maltese science teachers, who are non-chemistry specialists, approach the teaching of chemistry topics. The study tried to answer three research questions that focused on (1) identifying the challenges related to the teaching outside their science specialism, (2) explaining how teachers deal with such challenges and (3) investigating professional learning opportunities that would help teachers gain confidence in teaching outside specialism. This chapter reviews the research findings and discusses the key implications for two important fields: teaching outside specialism and professional development, and the contribution to knowledge in these areas.

13.1 Research findings and their implications

A number of key findings emerged from this research study which have important implications both within the local context and on an international scale. The primary finding that emerged in relation to the first research question was that teaching an unfamiliar subject offers a number of realistic challenges for science teachers and it has serious implications on classroom practice, on students' attitudes, on the teachers' wellbeing and on their professional identities. Therefore, more attention and support need to be given to the teachers teaching outside their science specialism because specialist teachers cannot easily switch to become generalist science teachers. Another result of the study that emerged in response to the second research question was that the teachers' background knowledge, their beliefs about chemistry and their perceived identity impacted the way they approached teaching across specialisations and overcoming the challenges they faced. An important implication of this finding is that these factors bear an effect on the teachers' disposition to learn. Furthermore teachers need support mechanisms, what have been described as boundary objects, in order to teach effectively across specialisations. These boundary objects such as conducting research, asking for support from colleagues and repeated teaching experiences play an important role in the development of a science teacher identity. The findings have also shown that many times teachers cannot make the shift from being 'specialist' to 'generalist' teachers on their own. In response to the third research question, regarding what support structures are most beneficial for teachers teaching across specialisations, it emerged that the design of the PD programme and the role taken by teachers in this experience are critical aspects in constructing supportive structures for these teachers. These need to be taken into consideration when developing PD programmes for teachers to teach across specialisations.

13.1.1 Facing realistic challenges when teaching across specialisations

The first research question attempts to identify the challenges faced by science teachers when teaching outside their science specialism. Within the local context the non-chemistry specialist teachers faced realistic challenges when planning and teaching chemistry units. Teachers experienced difficulties in selecting the appropriate resources, in developing a sequence of activities as well as in conducting an effective Internet research when planning lessons. Teachers mentioned that they had a restricted repertoire of activities. During lessons they were afraid of passing on misconceptions and incorrect information to their students, when delivering explanations and answering students' questions. They also encountered challenges when selecting, conducting and explaining what goes on in chemistry experiments. This was more common amongst teachers with a weak background in chemistry and poor attitudes towards the subject.

The findings of this research confirmed that the teachers' professional knowledge base affects the planning and teaching across specialisations, similar to the research findings of Du Plessis (2013). The results in the current study suggest that teachers had a less developed professional knowledge base in their non-specialist area compared to their area of specialism. The main challenges were due to their insufficient cognitive knowledge base, that is limited subject-specific SMK and PCK, together with a lack of passion in teaching the subject. These factors affected the teachers' self-efficacy beliefs concerning their ability to teach outside their area of expertise.

Additionally, teaching outside specialism presented "additional layers of complexity that have implications for the teacher personally, practically and socially" (Hobbs et al., 2019, p. 88).

The teachers' doubts and frustrations influenced the development of their professional identity, that is how they viewed themselves and how they thought they were perceived by others in a particular context. The six teachers who identified themselves as subject specialists, experienced an inner conflict and felt more vulnerable when teaching outside specialism compared to when teaching their subject specialism. As a result they experienced tensions between their multiple identities and were afraid that they could be judged as incompetent science teachers by their school colleagues and students due to their limitations in chemistry. The disruptions in their identity were mainly caused by a fragmented knowledge base.

These findings challenge the taken-for-granted assumption that specialist teachers are adequately prepared to teach any science discipline (Nixon et al., 2017). School administrators and policy makers need to reconsider the assumption that a teacher who has specialised in one science area during their ITE is able to take up the role of a generalist science teacher. The change in identity from being a specialist to a generalist teacher does not occur overnight. The participant teachers only experienced shifts in their identity rather than a complete transformation after participating in a yearlong PD programme. According to the research carried out by Du Plessis (2017), it takes from three to five years for teachers teaching out-of-field to adapt themselves and consider themselves as specialists in the area because teachers need time to "internalise the expectations of a specific subject, content knowledge and pedagogical content knowledge" (p. 22).

Teaching outside specialism has other important implications on the teachers' wellbeing and on the students. When non-specialist teachers feel restricted due to their limited competences they become frustrated and as a consequence some may try to find ways to avoid teaching the subject or as suggested in the literature, leave the teaching profession (Ingersoll, 1998). Teaching outside specialism can also impact the students' attitudes towards science because when students sense that their teachers are struggling to teach a particular subject they become discouraged and opt out from following a career in science. This becomes a matter of concern both within the local context as well as internationally. In fact, in the UK, the RSC (2014) recommends that subject specialists should teach chemistry to maintain the integrity of the subject and instil enthusiasm in the area. The findings have also shown that teachers were highly concerned about how they could influence the students' attitudes and interest in science. Osborne and Dillon (2008) claim that students' interest in science is high at age 10 but tends to dwindle at age 14. This implies that the quality of science lessons and the teachers' professional knowledge base are critical in the early years of secondary school. This implies that difficulties related to teaching outside one's area of expertise need to be addressed. In order to support teachers to become generalist science teachers long-term professional learning is required for teachers to develop both their knowledge base and a passion to teach a new area. Repeated teaching experience and in-house school support can improve the teachers' identity provided that teachers are willing to learn and develop their adaptive expertise in teaching across specialisations.

13.1.2 Dealing with the challenges: Developing adaptive identities

The second research question of this study explored how teachers dealt with the challenges when teaching outside specialism. Teaching an unfamiliar area entails taking on a new identity and the results of this thesis have shown that this is not a simple and straightforward process. Luehmann (2007) argues that taking on a new identity involves risk. The findings of this study have shown that in the beginning of the study some of the teachers were afraid to take risk. They used coping strategies by following prescribed notes, using their knowledge from their subject specialism or employing traditional teaching methods to survive in the classroom. These strategies did not enable them to expand their knowledge base suggesting that they might not have been comfortable to take on a new identity.

On the other hand the findings have also shown that there were four major instances where teachers were not afraid to make the leap and 're-establish the differences between practices' (Hobbs, 2013b). First, although most of them indicated that they preferred to teach their subject specialism in the questionnaire, during the first interview it became clear that they did not mind teaching outside specialism, particularly to young students. Second, teachers made use of boundary objects such as conducting research and seeking support from colleagues because they wanted to feel more prepared and knowledgeable in an area that offered considerable challenges to their teaching. Third, despite the challenges encountered when teaching outside their area of expertise, teachers opted to move away from preparing traditional chemistry lessons. They used their pedagogical knowledge from their subject specialism, together with the pedagogical constructs (Hasweh, 2005) that they had developed along the years to plan engaging lessons built on discussions and on a hands-on approach. Fourth, the teachers' fluid identity was strongly evident when they voluntarily opted to attend the yearlong PD programme. Teachers envisaged that the PD sessions could offer them the support needed to overcome the challenges and improve their teaching in chemistry. On these four occasions teachers were ready to move forwards on the adaptability scale by adapting their professional identity as science teachers. In these situations teachers demonstrated that they had flexible identities because they were eager to learn, to reflect on their practice and be open to negotiating their personal and professional identity. This disposition enabled them to adapt to new situations and learn across the boundary.

This study revealed that the teachers wanted to move away from being in a deficit position and to become better teachers. This implies that when teachers are asked to teach across specialisations either because of curriculum demands, as in the case of teaching integrated science, or due to teacher shortages they need to be willing to expand their knowledge base and transform their beliefs and attitudes towards teaching an unfamiliar area. This will only take place when teachers have adaptive identities and a strong sense of commitment to improve their practice when teaching across specialisations. Having adaptive identities is also important when it comes to engaging in professional learning opportunities because teachers need to be open to learn and reflect on their practice in order to improve their perception as science teachers.

13.1.3 Developing professional learning opportunities

The third research question addressed the issue of the professional learning opportunities to support teachers in becoming more confident in teaching outside their area of expertise. The findings indicated that the design and content of a PD programme are highly significant in supporting teachers to teach across specialisations. This study draws out a comparison of the different support structures that were developed within the long-term programme. It reveals important insights in relation to the field of professional development that leads to professional learning. Furthermore it highlights the role of the teachers as they learn to negotiate new content knowledge and pedagogical practices when learning at the boundary.

PD programmes should be developed to address the needs of the particular group of teachers; in this case the aim of the programme was to support teachers teaching outside specialism. The PD model initially addressed the generic needs of these teachers and later it targeted their specific needs. In this latter phase teachers had the opportunity to identify their learning needs and determine the learning agenda. This tiered approach could only be made possible through a long-term programme. The two different designs in reality complemented each other. The first phase was necessary to bring together teachers from different schools to work together and revise their SMK. They conducted many activities that allowed them to familiarise themselves with different tasks that could be later used in their chemistry lessons. In the second phase, teachers focused specifically on their lesson plans, tested out their ideas in classrooms and discussed the outcomes. The teachers' participation in the community of learners encouraged the sharing and the construction of new knowledge. Reflections about practice along the journey were necessary for teachers to look at things from a different perspective, and hence review their cognitive and affective knowledge base. This study supports claims in the literature (Gareth et al., 2001; Hawley & Valli, 1999; Loucks-Horsley et al., 2010) that long-term PD programmes are more beneficial and lead to professional learning. Reflection on practice and discussions within the community of learners, as Knapp (2003) argues, brought about changes in teachers' thinking and beliefs.

The outcomes of this study have revealed that PD programmes designed to support teachers teaching outside their science specialism should not only focus on upskilling the teachers' SMK and PCK. Teachers need to embark on a process in which they can review their beliefs and reflect on their personal experiences in order to reconcile the disruptions created between their multiple identities. Indeed Luft, Dubois, Nixon and Campbell (2015) argue that PD programmes need to attend to the beliefs and identity formation of the teachers besides teaching and learning. This implies that short-term PD programmes that focus mainly on consolidating teachers' SMK and PCK are not sufficient to address the complex issue of teaching outside specialism. From the participants' experiences it transpired that beliefs and teaching identity play a key role when teachers teach across specialisations and both require time to change.

The approach taken in this PD model was based on the theory of boundary crossing (Akkerman & Bakker, 2011) and focussed on the learning mechanisms taking place at the boundary, that is as teachers move between familiar and unfamiliar practices. Whereas in the beginning of their learning journey teachers focussed more on their deficiencies and lack of knowledge, the model of PD adopted by this study encouraged them to enhance their professional knowledge upon which they could reflect and reconstruct their ideas. Through ongoing discussions and interactions within the community of learners, teachers managed to resolve their dilemmas and developed their capacity to construct knowledge together with others. This result has a significant implication for the development of PD programmes. PD models designed to support teachers to teach across specialisations need to focus on drawing out their strengths and valuing their knowledge base rather than focussing on their limitations and weaknesses.

The programme moved away from traditional forms of PD and was instead based on a transformative PD model in order to increase the teachers' professional autonomy and bring about teacher change (Kennedy, 2005). During the PD programme teachers assumed different roles in their professional learning journey. In the initial sessions teachers took up an active role in their learning. As Gareth at el. (2001) maintain, participant teachers gained new knowledge through active inquiry and problem-solving activities. In the second phase teachers became self-directed learners when they identified their own learning needs and took ownership of their own professional learning. They also became producers of knowledge when they were sharing their pedagogical insights and discussing their experiences. In the process they became responsible for each other's learning as they constructed and negotiated knowledge within the community of learners. As Smith (2017) argues, "when teachers are effectively supported to play a different role in their own professional growth and development, they have opportunity to experience, recognise and construct learning that is both personally and professional rewarding" (p. 7). This implies that the role taken up by teachers is highly significant in a PD programme. Teachers should not only be active learners but they should be encouraged to contribute their expertise and become self-directed learners if they are to experience professional learning leading to changes in their beliefs and their teaching identity.

Teachers are lifelong learners. The knowledge and skills developed during ITE need to be further enhanced through continuous professional development with the aim of supporting teachers develop their competences and skills as they learn to adapt to different environments (Eurydice, 2018). Teaching across specialisations is common in a number of countries and Hobbs and Törner (2019) argue that this area needs to be further researched. Although this research was carried out in the local context, I believe that the outcomes of this PD programme and the professional learning framework developed for this study can contribute to the development of PD programmes in different countries with the aim of supporting specialist teachers to take up the generalist role as science teachers. Hence the outcomes of this research can also be used in the development of effective teacher professional development programmes in the international context.

13.2 Contributions to knowledge

In this research I wanted to address the gaps in literature and contribute to the field of teaching outside one's area of science specialism and professional development from a researcher's perspective as well as from the point of view of a practitioner in schools and a teacher educator. This thesis highlights two key constructs that emerged out of the findings from this research. They focus on (1) the relationship between the teachers' professional knowledge base and teaching identity and (2) developing a framework of a professional learning programme for teachers teaching across specialisations.

13.2.1 Relationship between teachers' professional knowledge base and teaching identity

By investigating the phenomenon of teaching outside specialism this study unveiled how the teachers' knowledge base influences their identity, particularly in their role as generalist science teachers. The findings of this research support the concept that the factors that influence the teachers' professional knowledge base (that is the cognitive, affective, social and contextual), as outlined in the theoretical framework, affect how teachers negotiate their professional identities in different situations. According to Helms (1998), SMK determines the teachers' identity. This relationship was evident when the participant teachers described themselves as science teachers. Teachers identified with their subject area and claimed to be subject specialists since they had sound and coherent content knowledge, well-developed and flexible PCK and positive personal experiences of the subject that led them to develop positive self-efficacy beliefs. When teachers failed to identify with teaching an unfamiliar area, they expressed lack of confidence and experienced a lower sense of self-efficacy. This was due to their weak content-specific and subject-specific PCK, their poor experiences and negative affinity towards the subject. Since teachers did not have a well-developed professional knowledge base across all the science disciplines they seemed to experience a sense of disruption when teaching across specialisations.

The teachers' engagement in a PD programme aimed to develop the teacher's knowledge and pedagogy can also shape the teachers' self-perceptions and their professional identity (Woolhouse & Cochrane, 2010). The results of this study showed that through professional learning teachers expanded their knowledge base and consequently their teaching identity. By conducting a number of hands-on activities teachers developed their SMK and PCK and they started to review their beliefs towards chemistry. Through the social interaction and contextual learning experiences taking place within the community of learners, teachers learnt from one another and gained both content knowledge and pedagogical insights. They constructed their identities by participating in discourse with the community of learners. They experienced a shift in their identity when their work and accomplishments were recognised by others. This also helped teachers to increase their self-efficacy beliefs. Thus as Wenger (1998) argues, learning through social participation in learning communities enabled the participant teachers to renegotiate their professional identity. The findings seem to suggest that the personal and professional identity are influenced by the interaction of the cognitive and affective knowledge bases as they are developed within a particular context through social interaction. These findings add on to the body of literature related to the development of the teachers' knowledge base and teaching identity. The factors that shape the professional knowledge base of a teacher also influence how one views and thinks of himself/herself as a science teacher.

13.2.2 Developing a professional learning framework for science teachers teaching across specialisations

There is a vast amount of literature related to teachers' professional development in general but very little has been written about developing a PD programme for teachers teaching across specialisations. This study looked into the structures of PD programmes and demonstrated that the design of a PD programme is crucial to developing a supportive programme for these teachers. The PD session should not only address the generic needs of the teachers but it also needs to take into consideration the teachers' aspirations and their learning needs, as has also been suggested by Du Plessis et al. (2014). A long-term programme is required to bring about changes in teachers' thinking, beliefs and identity. Furthermore it is important to give particular attention to the teachers' role in professional learning. Learning within a social setting such as a community of learners is much more effective than individual learning. In this programme, as Hobbs at el. (2019) have suggested it is more important to value and recognise the teachers' knowledge and expertise rather than focussing on upskilling the gaps in the teachers' knowledge base. This implies that the teachers need to be given the time and space to articulate their knowledge and critically examine their professional experiences through personal self-reflections and discussions within a community of learners. This will empower them to take the necessary decisions and actions about their practice.

The original PD programme was based on three core features which include: (i) enhancing the teachers' professional knowledge, (ii) attending to their beliefs and (iii) underlining the importance of contextual learning within a community of learners. The outcomes of this study have demonstrated that teaching identity plays a significant role when teachers teach across specialisations. After reflecting on the PD programme designed for this study and by taking into consideration the framework for effective PD for out-of-field teachers, as has recently been suggested by Faulkner et al. (2019), I would outline that the professional learning framework for teaching across specialisations should be based on the following four features, as demonstrated in Figure 13.1.

- ***professional knowledge***: addressing content-specific SMK which includes the conceptual understanding of the subject, having a deep background and drawing links between concepts. It also includes having procedural knowledge. Teachers need to develop subject-specific PCK by learning how to plan student-centred and inquiry-based lessons and how to implement them in practice. They also need to understand how students learn and find ways of tackling difficulties and misconceptions among students. Having a coherent background helps teachers to develop curricular knowledge.

- ***professional beliefs:*** exploring teachers' own understanding and content-specific beliefs about the subject area. Teachers are encouraged to examine their self-efficacy beliefs in teaching across specialisations at the beginning and throughout the PD programme.

- ***situative learning and sociocultural learning:*** developing a safe and supportive environment in a community of learners for teachers to share, reflect and inquire about their practice. By engaging in critical conversations they find ways to overcome their difficulties in their teaching and they develop new knowledge within this setup. Teachers work collaboratively on activities that could be easily done with their students to develop their SMK, PCK and instil positive attitudes in learning a new area. Teachers introduce change in their classes and reflect on their outcomes within the community of learners.

- ***teacher identity:*** reflecting on the factors and experiences that shape the teacher identity and finding ways of reconciling differences between their multiple identities, thus setting targets for their own professional learning. By engaging in activities, sharing their work, reflecting on practice and finding solutions teachers have the opportunity to reconstruct their professional identity.

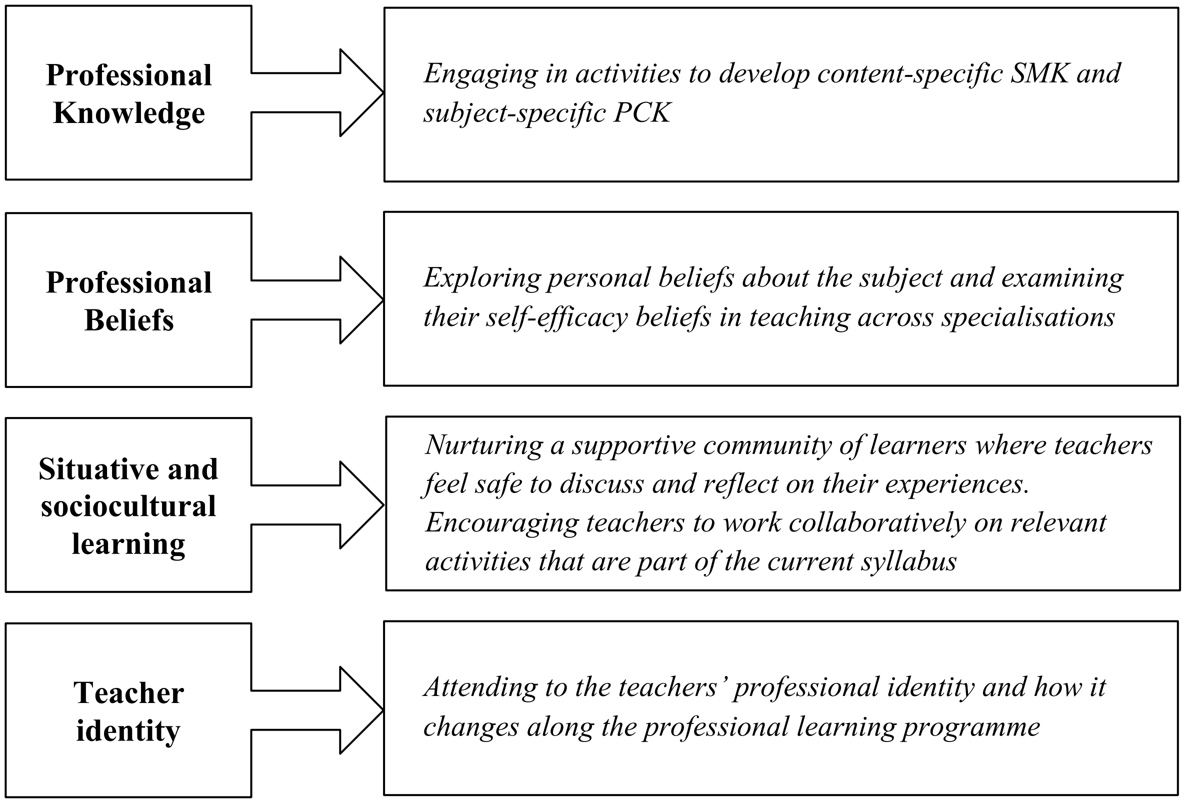

Figure 13.1: Core features of a professional learning programme for science teachers to teach across specialisations

Besides designing the programme on the above four critical aspects, two additional features need to be taken into consideration. First of all, the participants should not be coerced into attending this PD programme. Teachers need to be willing to learn to improve their practice and thus they need to have flexible identities. Teachers should also be given the opportunity to articulate their learning needs such that these are addressed in the professional learning programme. The participants should not be addressed as non-specialists thus reinforcing their weaknesses in the area. They should be addressed as science teachers to help them to reconstruct their teaching identity.

Secondly the PD provider should take a facilitator role in running the session and conduct an ongoing evaluation to monitor the development of the programme and adapt it according to the professional learning needs of participants. With time distributed leadership within a community of learners can be promoted. This reduces the position of power of expert and more experienced teachers and encourages teachers to work together towards a common learning goal.

The design of this model for professional learning is a contribution to the knowledge in the area of PD targeted to support teachers teaching across specialisations. In this journey I came to understand that learning across the boundaries can turn out to be a learning opportunity where "teachers can develop a more comprehensive understanding of more subjects and possible links between subjects, and it can give a sense of renewal and reflection on practice" (Hobbs & Törner, 2019, p. 12). This design framework will not only support teachers but empower them to overcome their challenges, take control of their own personal learning and enable them to feel more capable of teaching the different science areas, thus developing a unified sense of identity as science teachers.

13.3 Boundaries to the research study

This study followed a case study approach by capturing the lived experiences of eight science teachers in their classrooms and during the professional learning experience. Yin (2009) argues that case studies have limited generalisability in the statistical sense. Hence data collected from a small group of science teachers are not representative of a whole cohort of science teachers. Nonetheless I would argue that although this study lacks breadth in terms of the number of participant teachers, this methodological approach to research imparts strengths rather than limitations because it provides depth and a rich description of the experiences of teaching chemistry by non-specialist chemistry teachers within the Maltese context.

As a qualitative researcher I was completely immersed in the field and I was the primary instrument of collecting data using various research tools. Hence I could gain a deeper meaning and understanding of the implications of teaching outside specialism within the Maltese context. Teachers in this study were teaching chemistry topics to Year 7 and 8 students (11- to13-year-olds). The number of topics and the knowledge related to these topics is different from that required when teaching chemistry to 14- to16-year-old students. The participant teachers came from church schools because teachers in state schools were called to attend a compulsory course at the time when the PD programme was launched. Teachers opted to voluntarily take part in this project showing that they were keen to improve their practices and wanted to overcome the challenges experienced in teaching their non-specialist area. The PD programme was particularly targeted at helping teachers teach these specific units. Workshops were carried out once a term when teachers were teaching or about to teach the chemistry units. Teachers also had different qualifications and personal experiences of chemistry as young learners. This range of experiences was particular to this study and it surely affected the development of the learning community. Teachers were aware that some had an Advanced Level qualification in chemistry and some had not. This could have created power differences between the members in the community. Yet when they realised that they were facing similar difficulties they looked forward to working together and supporting each other in their learning journey. In other words the teachers' background, their qualifications and their personal experiences of chemistry were important determining factors that affected their disposition to learn. These factors also shaped the way teachers interacted in the community of learners and how they negotiated their professional identity. Since data were collected within a particular timeframe I could only witness the learning that happened during this time period. This means that outcomes of this research are related to this particular setting and provide a boundary to the case study, but at the same time they make it unique since it focuses on the particularity and the complexity of a single case (see Cohen et al., 2018).

Although case studies have limited generalisability, Yin (2009) further explains that analytic generalisations can be derived when concepts and propositions are used to explain what is happening and why in a particular setting. Therefore although the findings of a case study are highly contextualised they can be used to develop theory. Merriam and Tisdell (2016) argue that "the general lies in the particular" (p. 255) that is what can be learnt from a particular situation can be transferred or generalised to similar situations. This implies that this study has provided a detailed description of the phenomenon of teaching outside specialism by exploring the teachers' unique experiences in their real life context. The findings can be used to generate theory about the implications of teaching outside specialism on classroom practice and on the teachers' decisions, behaviour and identity. The findings can also be extrapolated when developing professional learning opportunities for teachers teaching outside their field of expertise.

13.4 Recommendations

The findings of this study have shown how teaching a subject without the necessary background presents both classroom and personal challenges. In this section I put forward a number of recommendations related to supporting teachers along their teaching career starting from ITE to developing professional learning opportunities for in-service teachers to feel more capable to teach across specialisations.

- During ITE teachers need to be prepared to teach all areas of science. These units should not only deal with the learning of subject-specific content but also with developing discipline-specific PCK by using hands-on sessions and a learner-centred approach to learning.

- The new sectoral agreement (Ministry of Education, 2017) emphasises that teachers should actively participate in continuous professional development by setting up a community of professional educators within schools. These communities can provide a culture of support for non-specialist teachers to deal with their day-to-day difficulties and help them develop adaptive expertise. Mentoring teachers by subject specialists can also be beneficial for the non-specialist teachers. Learning by working alongside others, as Eraut (2007) suggests provides a quicker and more effective way for teachers to observe, listen to each other's experiences, discuss, participate in learning activities and become aware of the different types of knowledge and expertise shared by colleagues. Peer observation and providing feedback in a safe context can support teachers in teaching unfamiliar areas. When teachers feel valued and respected within a school learning community they can contribute and add on to the wealth of knowledge possessed by the school community.

- The sectoral agreement (Ministry of Education, 2017) also encourages teachers to take part in self-sought continuous professional development programmes. This study has shown that short-term PD programmes that focus on the generic needs of the teachers are not sufficient to address the needs of teachers teaching outside specialism. This implies that teachers need to follow a long-term PD programme that supports them to teach across specialisations according to their specific learning needs.

- The design of a PD programme can also be adapted for teachers teaching across specialisation when the new subject of 'core science' will be introduced from Year 9 to Year 11 in the Maltese secondary curriculum.

13.5 Directions for further research

Teaching outside specialism has not been widely researched within the local context. The outcomes of this study can open doors to other research avenues. This research was only carried out on eight science teachers with different backgrounds in chemistry. This project can be scaled up to find out whether other science teachers experience similar difficulties, particularly investigating how physics teachers deal with the teaching of chemistry and biology when they did not study these subjects at secondary level. Similar research studies can also be carried out by focusing on the other science subjects, that is finding out how teachers who are non-biology specialists deal with the teaching of biology and those who are non-physics specialists deal with the teaching of physics topics. PD programmes can also be designed to support these teachers teaching outside their area of science specialism and focus on the teaching of biology and physics concepts. Other research studies can focus on how the teachers' background (being a specialist or non-specialist teacher) affects the students' learning and attitudes towards a particular subject and how this influences their subject choice at secondary school.

13.6 Reflections upon my journey

This research study can be depicted as a learning journey for both the participant teachers and me in the role of a researcher, a designer of the PD programme and as a teacher educator. Being a novice researcher and embarking on a qualitative study implied that I embraced the ontological and epistemological assumptions that reality is dynamic, a result of human understanding and socially constructed by individuals. In this study I presented a constructed account of the teachers' reality (Bryman, 2012) and reflected on how my personal values and bias could affect the interpretation of this version of reality.

As I deliberated on how I should carry out my work as researcher I resolved to create a non-threatening, safe and collaborative environment that was built on respect and trust in order to truthfully capture the teachers' experiences. I listened attentively to the teachers' conversations and probed carefully to make them feel comfortable to share their personal stories. This enabled me to understand their lived experiences and how they viewed themselves as science teachers. I had also experienced a fragmented sense of identity when preparing and teaching integrated science as explained in Chapter 1. Hence I could empathise with the teachers' experiences, relate to their insecure feelings and recognise how this was shaping their sense of self.

Teachers in this study were non-chemistry specialists, whereas I am a chemistry specialist. Consequently we had different levels of knowledge and affinity towards the subject. Teachers could have looked up to me as the expert chemistry teacher and I was very concerned about this. I tried to avoid direct interventions especially when teachers asked for feedback about their work after class observation. Instead I used reflective questions in the follow-up interviews so that they could formulate their own ideas, conclusions and ways of improving their lessons. With time I felt that teachers became accustomed to my presence in their classrooms. This was another step forward towards consolidating this sense of trust and respect. I felt that they were looking at me as someone who is genuinely interested in their well-being and in their professional learning journey.

The experience gained from my role as head of department did facilitate the process of designing PD experiences. Yet, it was the first time that I embarked on planning and implementing a long-term PD programme and I was unsure how the journey would unfold. I planned the INSET sessions by using research informed practices about PD. I wanted the teachers to enjoy chemistry by taking an active role in their learning and decided to expose them to the practical side of chemistry. Along the year our one-to-one conversations revealed a number of challenges that teachers were experiencing in teaching chemistry topics, hence I used these insights to develop the second phase of the PD programme.

Working alongside the teachers was one of the most enriching experiences in this research study. The year-long journey transpired into a collaborative venture as the teachers and I engaged in an ongoing conversation about their classroom experiences and about what they wanted to learn to improve their practice. We became co-travellers in our professional learning journey. The teachers' commitment to improve practice, their willingness to learn and the lessons that I observed were highly inspirational. I could see that although the teachers claimed to be non-specialist they had a wealth of knowledge and experience that they could bring into the learning community. Furthermore, the formation of the learning community was an innovative learning environment for the teachers. As the year unfolded I could observe the teachers moving from the periphery towards a central position within the community as they became producers and contributors of knowledge. This environment supported them to turn their weaknesses into strengths and believe more in their capabilities as science teachers.

As I reflected on my role as a PD designer I observed that supporting teachers teaching outside their science specialism took on a new dimension. I felt that my role had changed from designing and facilitating PD activities to that of becoming a 'boundary spanner' (Hobbs et al., 2019). This involved co-ordinating learning by becoming sensitive to the teachers' learning needs, providing a safe space for them to feel comfortable to share their pedagogical insights and developing sessions to resolve their challenges. I also introduced distributed leadership for teachers to take a more active role in setting agendas and in running the meetings.

With time I felt that I became part of the community of learners because I was completely immersed in the field together with the participant teachers. Along this journey both participants and I realised that we were all learning from each other and this helped to diminish the power differences related to the role of researcher versus participants and between the expert and the less expert teachers. My participation within the community of learners helped me to understand how the teachers were changing and developing. They were moving along a continuum from viewing themselves in a deficit position, unqualified to teach chemistry topics, to a more enabling position as they developed interest and became inspired to take more risks in their lessons. This transition enabled them to improve their self-efficacy beliefs and renew their professional identity as science teachers. My collaborative involvement with the participant teachers based on a constructivist research paradigm was truly a learning experience for me as a researcher and as a teacher educator because I gained important insights into how I could not only support but empower teachers to expand their professional knowledge and teaching identity as science teachers.

13.7 Concluding comments

The teachers' narratives and realities captured by this study have shed light on the complexity of teaching outside one's area of science specialism. The challenges encountered by the participant teachers seem to be linked to a fragmented knowledge base where this influences the teachers' attitudes towards the subject, their self-efficacy beliefs and their teaching identity. However, teaching outside specialism should not be looked solely as a distressing experience. Ongoing professional learning can support teachers to gain confidence in teaching their non-specialist area. My own experiences as a researcher in this study have continued to deepen my conviction of the importance to acknowledge and value the teachers' expertise and to create learning conditions that enable teachers to share and reflect on their professional knowledge in a safe environment such as in a community of learners. When teachers are open to rethink about their professional knowledge they become learners, reconstructing their knowledge and learning how to transform their challenges into opportunities for growth. The collaborative engagement in a learning community can be an empowering learning experience that enables teachers to expand their knowledge base and review their beliefs as they negotiate new teaching identities at the boundary.

Appendices

Appendix 1: Overview of the Maltese Integrated Science syllabus Version: 2014[7]

Year 7: Integrated Science Curriculum Units

	Unit	Objectives
SCI 7.1	Young scientist at work	1. introduce the relevance of science in everyday life. 2. introduce simple apparatus (glassware) and be able to use this apparatus in simple experiments. 3. introduce measuring instruments and be able to use them correctly. 4. guide students to perform simple experimental tasks.
SCI 7.2	Safety first	1. identify safety issues in the laboratory. 2. light and use a Bunsen Burner safely. 3. explore burning and use the fire triangle to describe fire. 4. use the fire triangle to describe a safe way of putting out a fire.
SCI 7.3	Living things	1. understand the significance of fossils and be aware of the theory of evolution. 2. explain that the seven vital functions; distinguish living and non-living things. 3. show that living things are grouped into plants, animals and small microbes. 4. sort animals into vertebrates and invertebrates. 5. sort vertebrates into fish, amphibians, reptiles, birds and mammals.
SCI 7.4	Our environment	1. identify types of feeding relationships 2. interpret food webs. 3. explore plant and animal adaptations. 4. explore different types of habitats and living organisms through a fieldwork activity.
SCI 7.5	Understanding matter	1. identify three states of matter and describe that matter is made up of tiny particles. 2. explore the properties of solids, liquids and gases. 3. explore the change of state of matter . 4. describe the arrangement of particles in solids, liquids and gases.
SCI 7.6	Energy around us	1. explore the main forms of energy and that energy is measured in joules. 2. discover that energy can be changed from one form to another and that not all energy changes are useful. 3. recognise that food is a source of energy and investigate food for its energy content.

[7] PD programme was designed on this version of the Integrated Science syllabus

SCI 7.7	Electricity	1. use electrical components to construct basic circuits. 2. use symbols to represent electrical circuits. 3. explore series and parallel circuits. 4. identify conductors and insulators and relate them to issues of safety.
SCI 7.8	On the move	1. describe what forces do and identify types of forces. 2. identify other types of forces and measure forces correctly. 3. identify forces present in objects that float and sink. 4. investigate friction between two surfaces.
SCI 7.9	Acids and alkalis	1. familiarise students with common acids, their properties and their safe use. 2. familiarise students with common alkalis, their properties and the safe use 3. using indicators to distinguish acids, alkalis and neutral solutions. 4. investigate the strength (and use) of common household acids and alkalis using universal indicator coupled with the pH scale. 5. investigate the neutralisation of an acid with an alkali.
SCI 7.10	Focus on gases	1. explore production, use and test for hydrogen. 2. identify air as a mixture of gases. 3. explore production, use and test for oxygen.
SCI 7.11	Cells and body systems	1. use a light microscope effectively and understand that cells are the basic unit of life. 2. recognise plant and animal cells and be able to observe simple cells under a light microscope. 3. identify the main organs and systems and their function.
SCI 7.12	Increasing in numbers	1. identify specialised human reproductive cells and describe the structure and function of the human reproductive organs. 2. identify and understand the body changes during puberty and adolescence. 3. understand that fertilisation is the fusion of the male and female reproductive cells. 4. understand and describe what happens during pregnancy and birth.

Year 8: Integrated Science Curriculum Units

	Unit	Objectives
SCI 8.1	Healthy Living (I) Go for Everest.	1. identify the basic food substances and their use and describe the importance of a balanced diet. 2. illustrate the digestive system and guide students to describe the process of digestion. 3. describe the breathing process. 4. illustrate the blood circulatory system.
SCI 8.2	Healthy Living (II) Life Cycle Challenge	1. identify different microbes and explore ways in which they can be useful. 2. describe how harmful microbes cause diseases and how infections can be spread. 3. identify (natural) ways of preventing and fighting infections. 4. explore the use of medicines in preventing illnesses and fighting infections.
SCI 8.3	Elements, Compounds and Mixtures (I)	1. explore that materials are made up of elements and describe what elements are. 2. illustrate some examples of elements and understand how elements are sorted out in the periodic table. 3. identify examples of mixtures.
SCI 8.4	Elements, Compounds and Mixtures (II)	1. understand what compounds are. 2. explore examples of chemical changes and present them as word equations.
SCI 8.5	Separating Mixtures	1. identify soluble and insoluble substances and factors affecting solubility. 2. distinguish between mixtures and solutions. 3. explore ways of separating different mixtures. 4. explore ways of separating solutions.
SCI 8.6	Light and Sound	1. use ray diagrams to show how objects are seen. 2. show the structure of the eye and guide students to explain how our eyes enable us to see. 3. describe sound and identify sound sources. 4. use the particle theory to explain how sound travels through materials but not through a vacuum. 5. show the structure of the ear and guide students to explain how our ears enable us to hear.
SCI 8.7	Forensic Science	1. describe the importance of forensic science to solve crimes and relate observation skills to forensic science. 2. collect and process evidence from a crime scene. 3. use separation techniques to provide evidence. 4. collect and process evidence from a fire

SCI 8.8	Climate Change (I) Energy and the Environment	1. understand energy production and its implications. 2. investigate the products of burning fuels. 3. identify the environmental implications of using fossil fuels and issues re climate change. 4. identify examples of renewable and non-renewable sources of energy and the advantages and disadvantages of each source of energy.
SCI 8.9	Climate Change (II) Environmental Chemistry	1. explore sources of air pollution and their effects. 2. explore sources of land pollution and their effects. 3. explore sources of water pollution and their effects.
SCI 8.10	Fieldwork	1. investigate a habitat and identify the human impact on this habitat through a fieldwork activity.
SCI 8.11	Earth and Space (I)	1. illustrate the movement of the Earth around the Sun and describe day/night and a year. 2. explain the causes of seasons. 3. explore the movement of the Moon around the Earth. 4. explain what happens during an eclipse. 5. explore the main features of the Solar System.
SCI 8.12	Earth and Space (II)	1. describe what gravity is and recognise that it keeps things in orbit. 2. illustrate the difference between mass and weight. 3. present the Sun and stars as light sources. 4. explore space exploration and describe why satellites are useful.

Appendix 2: The PD programme for non-specialist chemistry teachers

First part of the Professional Development Programme: INSET course

<table>
<tr><th colspan="2">Programme of Day 1: Monday 7th July 2014</th></tr>
<tr><td>Introduction of participants

Explanation of research study</td><td>The teachers participating in the INSET introduce themselves. The teachers attending the INSET are split in two groups (the participants and the non-participants in the research study) for the different activities.

Explain that the INSET course is part a Ph.D. research study. Participation in the research study is voluntary and teachers can accept to participate provided that they are non-chemistry specialist teachers. They can also withdraw from the study at any time. Confidentiality and anonymity will be assured.

A questionnaire is distributed. Data collected from questionnaire will be used to gather the teacher's profile as explained in section 6.5.1</td></tr>
<tr><td>Teaching and learning scientific concepts:

Using assessment probes to elicit and challenge students' misconceptions</td><td><u>Objectives for this session</u>
▪ reflect on their own ideas about the different concepts on particulate theory of matter.
▪ discuss students' common misconceptions about the particle theory.
▪ devise activities to challenge these misconceptions.

1. The 10 teachers participating in the study are split up into three groups.
2. Each group is given a task called an assessment probe (tasks focus on evaporation, condensation and changes of state).
3. First teachers have to write their own explanation of what happens in each situation at a molecular level, thus reviewing their SMK related to the area.
4. Then in groups they have to think and write down how students would explain each situation at a molecular level.
5. A list of students' misconceptions for each situation is provided and teachers are asked to compare their responses with the list of misconceptions drawn from literature.
6. I will give a brief overview of the constructivist learning theory. It is important to elicit students' misconceptions and think of tasks that could challenge students' ideas and help them learn.
7. Each group has to design activities or an experiment to challenge students' ideas by bringing out dissatisfaction in their ideas and leading them to conceptual change.
8. Teachers write their ideas on a flip chart and share them with the rest of the groups.</td></tr>
</table>

Case study discussion: Teaching chemistry topics	<u>Objectives for this session:</u> ▪ Teachers voice out their feelings and preoccupations, exposing their beliefs when teaching their non-specialist area. ▪ Using a case study teachers have an opportunity to reflect on teaching and learning chemistry based topics. 1. Introduction: A number of statements are shown which include: ▪ *I like teaching integrated science to Year 7 and 8 students.* ▪ *I like teaching chemistry based topics in integrated science.* ▪ *I like doing experiments in science.* ▪ *I feel comfortable preparing and carry out chemistry experiments.* ▪ *I can explain what goes wrong when chemistry experiments are unsuccessful.* ▪ *I feel comfortable answering questions related to chemistry based topics.* ▪ *My students think that chemistry is the most difficult science subject.* ▪ *I find it challenging to explain parts of a unit which deal with abstract ideas.* Teachers use smiley faces to show whether they agree ☺, disagree ☹ or have no opinion 😐 about these statements. 2. Teachers are presented with a case study in which a non-chemistry specialist teacher presents her thoughts and experiences related to teaching integrated science. Teachers are asked to answer the questions by reflecting and sharing whether they had similar experiences when teaching outside specialism. Teachers are also asked to identify a topic that is to be easy to teach and another one that is challenging to teach. For each topic teachers are asked to explain how they develop it. 3. Teachers share their own experiences when teaching particular chemistry topics in a focus group discussion, thus exposing their experiences and beliefs about teaching outside their subject specialism.
Reflections on Day 1	Teachers record their own reflections about Day 1 using the following prompt questions: ▪ *How did you feel through day 1?* ▪ *What did you learn during the day?* ▪ *What will you take with you from this day?* ▪ *Further comments and reflections.*

Example of an assessment probe

Task 1: Where has the water gone?

Sam washed his clothes and hung them on the clothesline outside. An hour later the clothes were dry.

Circle the answer that best describes what happened to the water that was in the wet clothes.

A. It soaked into the ground.

B. It disappeared and no longer exists.

C. It is in the air in an invisible form.

D. It moved upwards and formed clouds.

E. It chemically changes into a new substance.

F. It went up to the sun.

Explain your thinking. What ideas do you have to support your answer?

____

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References adapted from http://www.nsta.org/publications/news/story.aspx?id=50062

Case Study Discussion

This year was my first year teaching science and overall I can say that it went well especially in biology related topics, yet at the same time there were times when I felt insecure and out of my comfort zone especially when teaching chemistry units. The greatest difficulty arose when trying to teach 'The Periodic Table'. The main difficulty was the fact that everything was so abstract and some elements are radioactive so we couldn't even see photographs of them. Another issue when teaching the topic was how much detail should we go into and whether we should discuss trends in the periodic table or not.

Teaching separating techniques was much easier since it is something which is very hands-on, practical and can easily be applied to a given problem. As a topic it can easily be done through laboratory investigations and it is something students can use in their everyday lives.

Questions for reflection:

1. Did you experience a similar situation? Can you describe it?

2. Identify **one particular chemistry topic** in which you felt that it was **fairly easy and straight forward to teach**.
   a. Explain why.
   b. How did you go about it?

3. Identify **one particular chemistry topic** which you considered as **challenging to teach.**
   a. Explain why.
   b. How did you go about dealing with such a situation?

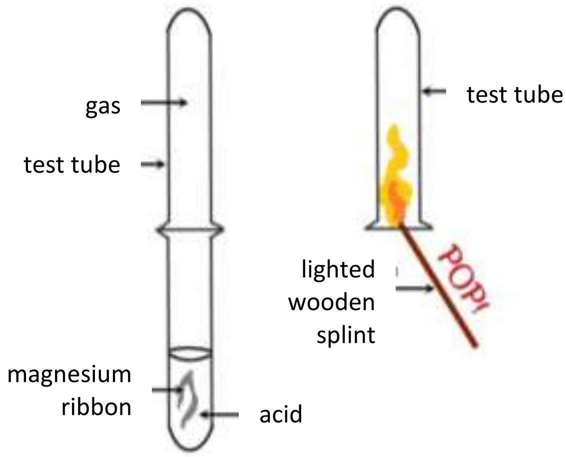
<table>
<tr><th colspan="2">Programme of Day 2: Tuesday 8th July 2014</th></tr>
<tr><td>Introduction: experiments and investigations in integrated science</td><td> A demonstration experiment is carried out (adding concentrated sulfuric acid to sugar). Teachers briefly discuss the benefits of conducting practical work with Year 7 and 8 students. Teachers are split in groups and they conduct experiments that are set up in two laboratories by moving from one station to another. The 10 participants in the study are split into three groups. I follow one of the groups and another two colleagues of mine who are chemistry specialists follow the other two groups. Besides acting as facilitators we observe the teachers' actions, discussions and ways of how they tackle the experiments. </td></tr>
<tr><td>Laboratory session: conducting various hands-on experiments and investigations</td><td> <u>Objectives of the session:</u> explore simple chemical reactions and observe changes.
identify type of chemical reactions taking place.
discuss theoretical background of each experiment and revise SMK.
complete the planning of chemical investigations and devise the methods, precautions, fair tests and taking results.
learn at one's own pace and tackle experiments of increasing difficulties.
work in collaborative teams. 25 experiments are presented in the guide book based on a number of chemistry topics from the integrated science syllabus. The experiments are related to the topics of acids and alkalis, focus on gases, elements, compounds and mixtures (I) & (II), separating mixtures and climate change I. 10 of these experiments are of the investigative type. The teachers are given a copy of this guide book. However in this session they are given a pack called 'teachers' sheets' for the 11 experiments that have been set up for today's session. 11 experiments set up in two chemistry labs include: Fizzy reaction competitions 1 – producing hydrogen
Fizzy reaction competition 2 – producing carbon dioxide
Turning water into red wine – neutralisation reactions
Colorful solution and mixtures – precipitation reactions
Exothermic and endothermic reactions
Preparation of oxygen – using different catalysts to prepare oxygen
Do elements and compounds have similar properties?
Investigation: controlling the amount of gas produced in a baking soda and vinegar reaction
Investigation: homemade indicators</td></tr>
</table>

	▪ Investigation: ingredients mix up ▪ Investigation: oranges and lemons Teachers' conduct experiments by following the instructions from the 'Teachers' sheets. During the investigations they have to devise their own method. Then they discuss and answer questions related to the experiment, for e.g. explaining why particular steps are taken in the method, precautions taken, the results, interpreting results, extending the experiment, discussing the theoretical background and the chemistry concepts associated with each experiment.
Reflections on Day 2	Teachers record their own reflections about Day 2 using the following prompt questions: ▪ *How did you feel through day 2?* ▪ *What did you learn during the day?* ▪ *What will you take with you from this day?* ▪ *Further comments and reflections.*

An Example of an experiment sheet from resource book of experiments:

Experiment A 5: Fizzy Reactions Competitions I

Some chemical reactions produce a gas as one of the products. Which gas is produced in these reactions? How can you test for the gas?



You will need:

- magnesium ribbon; [highly flammable]
- zinc foil; [low hazard]
- calcium granule, [highly flammable]
- 1.0 mol/dm^3hydrochloric acid; [low hazard]
- splints
- 6 test tubes
- measuring cylinder (10 cm^3)

What to do:

1. Pour 5cm^3 of dilute hydrochloric acid in 3 clean test tubes.
2. Place a piece of magnesium ribbon, zinc foil and one calcium granule in each test tube simultaneously.
3. Place an inverted test tube over each one to collect the gas and note observations.
4. After some time, light a splint and insert in the inverted test tube.

What do you observe?

Reaction of acid with	*Observations*	*Effect on the lighted splint*
calcium		
magnesium		
zinc		

Think about:

a. *What is the general reaction of a fairly reactive metal with a dilute acid?*

b. *Compare the reactions of these metals with an acid. What can you conclude?*

c. *Do you think that copper will react in the same way with a dilute acid?*

d. *Why was an inverted test tube used in this experiment?*

e. *How did you test for gas evolved between the metal and an acid?*

f. *Write word equations for the reactions taking place between each metal and the acid.*

g. *Which variables were not changed to ensure a fair test?*

Notes

- The aim of this experiment is to investigate how three different metals react with a dilute acid.

- Calcium is the most reactive metal out of the three metals. The most vigorous effervescence is observed and hydrogen gas is released. Magnesium reacts vigorously with acid but zinc reacts at a steady rate. Copper does not react with dilute acid.

- In general fairly reactive metals react with an acid to produce salt and hydrogen.
  E.g. magnesium + hydrochloric acid → magnesium chloride + hydrogen

- Hydrogen is less dense than air. It rises upwards and is collected in the inverted test tube.

- Hydrogen is tested by inserting a lighted splint in the inverted test tube and gas burns with a pop.

- Risk assessment of the reaction of calcium with acid: If a test tube is a quarter-filled with 0.4 $moldm^{-3}$ hydrochloric acid, the amount of calcium added must be limited to 1 to 3 granules or a turning at a time. There is very little reaction with dilute sulfuric acid because the calcium is coated with calcium sulfate which is only slightly soluble in water.

- Alter the set up to collect hydrogen gas and test it. Always produce hydrogen in a small scale. Collect hydrogen in a test tube over water and never in a gas jar since hydrogen is highly flammable.

Programme of Day 3: Wednesday 9th July 2014	
Lecture demonstration: The chemistry of the atmosphere	This lecture demonstration, presented by Mr. Timothy Harrison and Prof. Dudley Shallcross from Bristol ChemLabs, includes a number of experiments related to different gases present in the atmosphere. Properties and reactions of these gases are discussed and illustrated through different experiments.
Some updates regarding e-content and the integrated science syllabus	The education officer of integrated science highlights the changes in the syllabus for the next scholastic year. Resources (known as RLOs), based on the syllabus are disseminated to teachers.
Reflection and group discussion: Transferring experiences to classroom practice	Teachers are given a number of questions to help them reflect on this professional learning experience. Questions include: ▪ *Did you develop any new ideas whilst participating in discussions? Give examples.* ▪ *Did you develop any new ideas whilst engaging in practical work? Give examples.* ▪ *What did I learn during the past days?* ▪ *I used to think………… but now I know…………* ▪ *What will I take back to the classroom? Write your own reflections.* The above questions are used to facilitate a focus group discussion.
Evaluation of the experience	A final evaluation sheet is given and teachers reflect about a number of aspects related to the professional learning experience. These include: ▪ *How did you feel during this three day professional development course?* ▪ *How did you feel sharing your experiences?* ▪ *How did you feel working in different groups?* ▪ *In what ways were the sessions beneficial or not beneficial to you?* ▪ *Are there any changes/ improvements you would like to add to your teaching techniques?* ▪ *Did the professional development course meet your expectations?* ▪ *Would you suggest any improvements to the sessions?* ▪ *Write down any further comments or reflections you would like to add.*

Second part of the Professional Development Programme

Workshop 1: Getting together and working together **3rd December 2014**

Designing Workshop 1: Personal reflections

The workshops are being designed in response to the teacher's needs and concerns about their practice. The sessions are intended to help teachers identify where they stand in their knowledge and beliefs about their practices and find ways to improve their work through collaborative practice (Mamlok-Naaman et al., 2018). The teachers' requests will shape the learning agenda of each workshop. Planning the learning agenda based on the assessment of teachers' needs has also been suggested in the literature (Bransford et al., 2000; Darling-Hammond & McLaughlin, 2011; Stoll et al., 2012) about professional learning.

From the first set of interviews carried out in October and November 2014, the participant teachers stated that they wanted to improve their lessons by gaining further ideas, examples of activities and experiments. Most of the teachers are still early career teachers and they are still building their PCK. For instance, although Karen had come across inquiry based learning in PGCE, she still wants to learn how to apply this pedagogy in her lessons. For this workshop she proposed that we could tackle:

> *How to devise an inquiry based lesson? Because that is one problem that I encounter for instance: How can I introduce it in a lesson? How can I have a student-centred lesson? Instead of relating theory and then doing the activity afterwards… Last year for instance I usually used to relate the theory first and at times I used to start with an activity but that was quite rare. I would like to learn more about introductory activities that can be used for students to come up with ideas and then we keep building on these ideas. That's it…. How will I introduce a lesson and then how is it going to be developed?*

Robert had also proposed that for each lesson he:

> *…would like to start with an experiment or a demonstration, to obtain the wow factor and get students interested. I am very interested in engagement activities.*

Besides the above suggestions (that is using starter activities to introduce lessons) in their interviews teachers suggested that they would like to:

- *gain more resources to be used in classrooms,*
- *create activities about specific topics,*
- *use inquiry based learning,*

- *obtain basic information on chemistry content,*
- *share ideas and experiences,*
- *conduct experiments,*
- *develop lesson plans,*
- *learn how to explain abstract concepts,*
- *start from application based problems leading to scientific theory,*
- *discuss what resources were applied in class after the INSET.*

After reflecting on their suggestions, I aimed to use their ideas and develop the first session of the day. According to their suggestions teachers want to develop student-centred lessons. In the INSET they enjoyed conducting and learning by doing experiments, hence I am thinking of combining a student-centred and a practical approach to learning. The first session can start with teachers conducting a set of short experiments that can be used as starter activities in their lessons. This would link with inquiry based learning (using the 5E approach: Engage, Explore, Explain, Elaborate and Evaluate) since the 1st E focusses on engaging students in the lesson. The starter activities can also focus on application based problems leading to scientific theory. Then teachers can select one particular starter activity and plan a lesson in groups. Lesson planning will be an opportunity to discuss chemistry content and find ways to explain any abstract concepts. Therefore through this session I will manage to tackle most of their requests.

For the second session I am thinking of finding out whether teachers are ready to share their lessons. Both Maria and Amy suggested that teachers can share their own classroom experiences. Maria stated that she wanted to "*continue to share experiences of teaching chemistry and how we develop the topics.*" Since this will be the first meeting after the INSET I feel that teachers still need time to get to know each other, develop connections and build relationships. At this point I think that teachers may not feel so comfortable to share their lessons since they do not feel so confident in chemistry lessons. I am going to use a case study to gauge the teachers' readiness in sharing their work. I have developed this case study using the data that was collected in the INSET. Teachers will read it and highlight the phrases that they connect with and then discuss their ideas. This will also help me to understand further (1) how they feel when teaching outside specialism, (2) their experiences during the INSET and (3) how comfortable they feel to discuss and work with colleagues. I am hoping that by the end of the first workshop teachers would feel more comfortable to share their experiences in the next workshop session.

Programme of Workshop 1: 3rd December 2014	
Welcome: Getting to know each other	Welcome: In this workshop we are going to continue our learning journey and these workshops will be called 'Getting together, working together", promoting the idea of working in teams rather than individually. I believe that we can learn more when we work and discuss our ideas with others. In the ice breaker activity each teacher picks up a card and expresses how s/he feels by completing the following sentences: 1. *I am looking forward to…* 2. *I am happy that …* 3. *I would like to learn …* 4. *I am here because …* 5. *My main question is …* 6. *When thinking about chemistry I think …* 7. *Teaching science means to me …* 8. *I think students enjoy science because…..*
Looking at teachers' requests and objectives of the day	During previous interviews I had asked each teacher to state would they would like to work on in the coming workshop/s. The list below is shared with the teachers on PowerPoint and I will explain how I devised the programme of the day. ▪ gain more resources to be used in classrooms ▪ create activities about specific topics ▪ use inquiry based learning ▪ obtain basic information on chemistry content ▪ share ideas and experiences ▪ conduct experiments ▪ develop lesson plans ▪ learn how to explain abstract concepts ▪ start from application based problems leading to scientific theory ▪ starter activities to introduce lessons ▪ discuss what resources were applied in class after the Inset By integrating their requests and the programme of the day includes: ▪ Getting to know each other ▪ Starter activities in science ▪ Discussion, lesson planning and sharing ideas ▪ Case study: Working together ▪ Reflecting on our experiences

Brainstorming task about the use of starter activities in science lessons	Two tasks are carried out. Teachers are asked (1) to give their views about the purpose of using starter activities in science lessons and (2) to reflect on what makes an effective starter activity. All their ideas are recorded on the board. Starter activities are part of the 5 E inquiry based learning strategy, thus inquiry based learning is used to teach science.
Laboratory session: Conducting starter experiments	Starting with a short demonstration experiment using red berry tea as acid and alkali indicator we discuss the versatility of starter activities in science lessons. 10 short experiments are set up which include: 1. Lose some mass – it's a gas – comparison of rate of evaporation of water and alcohol 2. Cool it, pool it – condensation of water 3. Molecules in motion – diffusion of colours in cold and hot water 4. Hot air, cold air – expansion of air in hot water and contraction when in cold water 5. Concentrated and dilute acid 6. An effervescent universal indicator rainbow 7. Neutralisation circles 8. Decomposition of hydrogen peroxide 9. Disappearing polystyrene 10. Moving colours Teachers work in pairs or in groups of three and rotate from one station to another. A booklet of these activities is provided. Teachers have to answer the questions related to each activity, to help them revise the SMK related to these activities.
Lesson planning	Teachers choose a particular starter activity and plan a lesson. Each lesson plan is then shared with the rest of the group, encouraging feedback from other participants.
Case study: Teachers reflecting about their teaching, collaborative work and the professional development experience at INSET	A case study is presented to instil reflection about a number of issues. The case study is based on data collected from the INSET. This will be an opportunity for teachers to share their experiences and beliefs when teaching outside specialism and to reflect on how they are feeling as they are participating in the professional development programme. Teachers read the text and highlight the phrases that they can connect to. Then they share and discuss their thoughts. The aim of the case study is to gauge whether teachers are ready to collaborate with each other by sharing their own work and resources, thus giving more ownership in their learning.

Reflection on the days' activity and planning of the next workshop	Teachers fill in the reflection sheet based on the following prompt questions: ▪ *How did you feel throughout this day?* ▪ *Did you develop any new ideas whilst engaging in practical work? Give examples.* ▪ *Did you develop any new ideas whilst participating in discussions during lesson planning? Give examples.* ▪ *How did you feel working in the small groups?* ▪ *How did you feel sharing your experiences within the larger group?* ▪ *Did today's workshops meet your expectations? Explain.* ▪ *What are your expectations for future workshops?* ▪ *How are these sessions helping you in your teaching?* ▪ *How are you feeling working with the researcher?* After setting a date for the next workshop we discuss possible ideas for the second workshop.

An example of a starter activity from the resource booklet:

S.9 An Effervescent Universal indicator 'rainbow'

Sodium carbonate solution is added to a burette containing a little hydrochloric acid and Universal Indicator. The two solutions react, with effervescence, and the liquid in the burette shows a 'rainbow' of all the colours of Universal Indicator from red through orange, yellow, green and blue to purple.

This experiment will take around five minutes.

You will need:

eye protection
50 cm^3 burette
retort stand with boss and clamp
cotton wool plug
few cm^3 of universal indicator solution [low hazard]
about 10 cm^3 hydrochloric acid solution (2 mol dm^{-3}) [irritant]
about 20 cm^3 sodium carbonate solution (1 mol dm^{-3}) [low hazard]
funnel
2 beakers (100ml)
distilled water

What to do:

1. Clamp the burette vertically. Add about 0.5 cm^3 of the Universal indicator solution followed by about 10 cm^3 of the hydrochloric acid to give a clearly visible red colour.
2. Now add about 20 cm^3 of the sodium carbonate solution.
3. Insert a loose plug of cotton wool in the top of the burette.
4. A white background will show the colours to best advantage.

How it works?

The sodium carbonate and hydrochloric acid react, with effervescence, and the burette will be filled with liquid showing a 'rainbow' of all the colours of Universal indicator from red through orange, yellow, green and blue to purple.

http://www.rsc.org/learn-chemistry/resource/res00000701/an-effervescent-universal-indicator-rainbow

Case Study: Teachers reflecting about preparing lessons, discussion with colleagues and reflections on the experiences of the July inset

Lesson Preparation: *When I work on lessons especially ones which are not topics of my area of specialism I can sometimes get overwhelmed. I don't know where to start from and how to 'fit in' all the ideas I get from the syllabus, Internet, the students' books and other resources. I also would want to make it tailored to the students I teach. Sometimes I feel like there's too much out there but not in the form I need to be able to use.*

- ✓ Do you experience a similar situation whilst preparing your lessons? Can you elaborate on this?
- ✓ How do you cope with this situation?

From the July Inset: *I found the assessment probes useful as they can be used to elicit prior knowledge and to get students talking about a subject. I can take into account their prior knowledge while teaching. Also the experiments that we did helped me because I realised how important it is to get students to practice certain skills and stimulate their thinking. Short experiments can be used with my students to gain science skills but also to help accustom them to team work. They are effective at the beginning of a topic to get the students thinking about certain ideas. Also the investigations are fun and get students to think outside the box.*

- ✓ Which ideas did you gain and include in lessons?

Discussing with colleagues: *When reading about activities online/ on books etc. I sometimes have queries, which I cannot ask the author of that resource. When I listen to others speak about their own activities I can ask them my queries directly. In a small group of people I can trust, I feel comfortable asking even the 'silly' questions like how to handle certain chemicals, or how to split the students into groups, things that may go wrong in the activity and how to avoid/ manage these problems. This is an extremely valuable opportunity to me. Tackling my queries is empowering to me and I feel more confident about implementing new ideas in my class.*

When I can voice my ideas and queries with my colleagues or friends who may be interested they can sometimes see things I do not (for example if what I am doing will not be clear to students) or may see alternatives that only someone with a fresh mind can see e.g. more effective ways of developing my ideas with my students. I then can improve on my planning and feel more confident in class when I do the lesson. They can also have enthusiastic remarks (e.g.' what fun') that can encourage me. Sometimes it also helps me to talk to someone after a new lesson that I have just tried out as I can reflect on it out loud. Someone who listens can give me constructive feedback so that the next time I carry out the lesson I can do things more effectively.

- ✓ How do you feel discussing within this team?
- ✓ How do you feel sharing ideas with this team in future workshops?

Designing Workshop 2: Personal reflections

In the previous workshop teachers discussed possible ideas for the next workshop. On the feedback form the teachers listed that they wanted:

- *to include lesson planning,*
- *to continue on building lesson ideas and discuss our difficulties,*
- *to continue gaining new resources, new ideas and solving problems encountered in class,*
- *other resources that don't include experiments,*
- *to have the opportunity to share interesting ideas in order to make my teaching and learning experience a more enjoyable one,*
- *more experiments/ activities which can be applied,*
- *sharing more interesting ideas/ lesson plans/ resources which can be used during the lesson.*

Teachers wished to continue gaining new resources, activities, experiments and discuss their concerns or difficulties encountered whilst teaching. I also asked the teachers what they wanted to learn in the second workshop during the one to one interviews. Amy suggested that within the community teachers "*can actually bring our own resources and discuss how to go about certain topics.*" Maria looked forward to *"continue building on lessons ideas and discuss our difficulties."* She further suggested that teachers could work on lesson planning by bringing their own work, discuss it and then *"we sort of polish it together."* Teachers agreed with these suggestions. They looked forward to share work and obtain suggestions and feedback from the other members of the learning community. From their discussions and from the case study used in workshop 1, it seemed that teachers were now ready to share their own material because they felt comfortable working with each other, giving feedback and reacting to each other's ideas. Therefore the first session in the second workshop will be completely led by the teachers. Each teacher will bring 1 to 2 lesson plans. A reflection sheet will be sent to the teachers prior to this session to help them reflect on significant events of this lesson. This is an opportunity for teachers to be self-critical about their own work by discussing their success stories, their dilemmas and disappointments in their lesson. The groups' interaction will support them to be more reflective about their decisions taken during the planning and teaching process. They will help each other to extend their thinking and reflective process whilst teaching their non-specialist area.

For the second session, teachers wished to keep on working together to generate further knowledge. Collaborative lesson planning in the previous session encouraged teachers to generate further ideas. They looked forward to more lesson planning activities since they could discuss ideas and improve them when discussing in groups. Thus lesson planning was another opportunity for teachers to widen their PCK. In fact Karen suggested that in the sessions we should do:

> *...something similar to what we did in the last session when we were in groups and planned a lesson... Can we work more on 5E lesson planning? I like the 5E and would like to plan my lessons in that way. I won't mind it. It is more practice!*

I decided to keep on focussing on an inquiry-based approach to teach chemistry but this time I introduced the 'predict, observe and explain' (POE) learning strategy. Some of the teachers were already using this strategy in teaching their subject specialism. I wanted to encourage them to use this strategy in the teaching of chemistry to provide time for students to think about their explanations. A resource pack that includes many POE activities related to the chemistry topics within the integrated science syllabus is given. Most of the activities were taken or adapted from the following book:

Haysom, J., & Bowen, M. (2010). *Predict, Observe, Explain: Activities Enhancing Scientific Understanding*. NSTA Press.

Teachers are asked to choose one activity and design a lesson plan. Then they share the lesson plan with the other teachers.

Programme of Workshop 2: 12th February 2015	
Introductory activity	Ice breaker activity: Human knot. Teachers form a circle, close their eyes and grab each other's hands. After opening their eyes the goal is to untangle themselves and form a circle without releasing their hands. Teachers discuss their feelings during this exercise. This experience is compared to how teachers feel when teaching outside specialism.
Sharing the objectives of the day	<u>Objectives of the day:</u> ▪ Reflecting on our experiences – Journal writing ▪ Inquiry activities ▪ Planning lessons using inquiry activities ▪ Reflection of the day
Sharing of lesson plans and reflections	Prior to this session teachers were asked to write their reflections about two lessons using a template provided. The points included in the template aim to help the teachers to unpack their thinking and reflect on significant events, potential challenges and difficulties encountered. Teachers also had to reflect on how they could overcome their difficulties. These lesson plans and reflections are shared in the first session of the workshop.
Inquiry based activities – Predict Observe Explain (POE) activities	During the one-one meeting some teachers expressed the wish to use more inquiry based activities. 'Predict, observe, explain' (POE) activities are introduced and these are based on the constructivist approach of teaching and learning. A demonstration is carried out to model how POE activities can be used in the classroom. A petri dish is filled with water. Some crystals of potassium iodide are placed at one end and some crystals of lead (II) nitrate are placed at the other end. The teachers have to first predict what will happen. The experiment is carried out and they observe results. Then they are asked to explain why a bright yellow powder formed midway between the two reagents. This will be another opportunity to revise their SMK.
Lesson planning using POE activities; sharing of lesson plans.	Teacher chose a POE activity from the given pack and they plan a lesson using this activity. Each lesson plan is shared with the rest of the group and feedback is given.
Reflection on the days' activity and planning of the next workshop	Teachers fill in a reflection sheet, using these questions as prompts 1. *Why did you opt to join in the research process?* 2. *How do they feel you are getting on in this journey?* 3. *How did you feel in the second workshop? Express your thoughts, ideas, comments……* 4. *Ideas for the next workshop……….* 5. *How are these sessions helping you in your teaching?* Set a date for the next workshop, discuss possible ideas for 2nd workshop.

Journal – Reflective Practice – 12th February 2015

Date: ____________________ Class: _____________

Topic: ____ Time: _________min

Teaching objectives:	
Briefly describe the lesson plan.	
Describe events that you believe are significant	
Describe potential challenges that you encountered during the lesson	
Describe any difficulties that students encountered	
Comment on what you have learned personally from this lesson. What would you do or try differently next time?	

Further comments, thoughts and reflections........

An example of a POE activity from the resource booklet:

Chemical changes[8]

What is the difference between:

a) Fat melting and an egg frying?
b) Clothes drying and paint drying?
c) A cup falling (and breaking) and a leaf falling?

In chemical changes, something new is made. New chemicals are formed. Chemical changes are usually difficult to reverse.

Predict

Have a look at the experiments below and mark them with a **C** if you think a chemical change will take place.

Some Experiments

Observe them carefully. Do you see any signs of a chemical change?

Predict	Experiment	Observe signs
	Baking soda plus water add drops of water to a teaspoon of baking soda	
	Baking soda plus vinegar add drops of vinegar to a teaspoon of baking soda	
	Cleaning a copper coin with salt and vinegar cover the coin with a mixture of salt and vinegar	
	Heat gently some candle wax on a tin lid (don't let it catch fire!)	
	Heating a piece of bread on a tin lid (don't let it catch fire)	
	Heating a piece of steel wool using tongs.	

Explain

Try to explain to a friend how to tell if a chemical change takes place.

What do you think are chemical changes?

How about milk turning sour? Y / N   Iron rusting? Y/ N   Nail polish drying? Y/N?

[8] P.243 - Haysom, J., & Bowen, M. (2010). *Predict, Observe, Explain: Activities Enhancing Scientific Understanding*. NSTA Press.

Designing Workshop 3: Personal reflection

Since this is going to be last workshop of the year I thought using an ice breaker activity to help teachers reflect on their progress or maybe even lack of progress in this professional learning journey. I devised an activity called 'Snakes and Ladders' using the teachers' feedback gathered during the workshops, the one-to-one interviews and the statements in the questionnaire. In general the teachers are saying that they are gaining confidence in teaching chemistry based topics and they are becoming more confident in planning lessons. I would like to explore whether all teachers are feeling in this manner and give them space to explain why they are feeling more confident in teaching chemistry based topics. This exercise can help them reflect on and assess their growth and development. Teachers read the statements of the 'Snakes and Ladders' handout and they write their reflections and assess their progress. Afterwards they share their reflections with the whole group. Teachers form a line in the middle of the room. If they feel that they have improved, (thus climbing up a ladder) they can move a maximum of 3 steps forward depending on their self-assessment. If they think that they have regressed (that is sliding down a snake) they move backwards a maximum of 3 steps. If they did not improve or regress, they stay in the same position.

In the previous workshop teachers discussed possible ideas for the next workshop. On the feedback form the teachers listed to include:

- *sharing of ideas and resources*
- *similar to today (2nd workshop) would be great*
- *sources of information, concept cartoons, videos, good quality books*
- *more experiments which can be used in class and more lesson planning*
- *more resources, more lesson planning and IBL activities, more discussions. Basically similar to what has been done so far. If possible more ideas related to the Maltese context.*

From their feedback the teachers kept asking to include more ideas and resources as we went along in the journey. I was also probing during the one-to-one interviews what they wanted to learn in the sessions. Karen explained that they had tackled various aspects in the INSET and workshops such as: "*we tackled misconceptions, inquiry based learning, experiments, practical skills. We tackled many aspects and we are moving on well. I am very satisfied* *what we have been doing in the sessions."* Teacher felt appreciated and valued when they shared their lesson plans and reflections in the last session. They felt as Sarah explains as *"contributors to their own professional learning*" hence they wanted to repeat this type of session. In fact Karen stated that:

> *It was really interesting. Everyone tackled different topics, so you see how these topics were tackled in different ways. At times they mentioned something that you do in class and at times they mentioned other things that you don't think about. I liked it as an activity so I don't mind that we do something like that again.*

Karen also suggested in the reflection sheets teachers could list *"type of questions that students can ask"* because she wanted to focus on *"common questions that student ask."* This was one of the main challenges that teachers faced when teaching outside specialism. Thus Karen wanted to feel more prepared to answer particular questions. As a result the reflection sheet was amended according to Karen's proposal and sent to the teachers prior to the third session.

For the first session as per the teachers' request, the teachers share their own lesson plans and reflect on their work. This session is an opportunity for teacher to question, comment and add further insights to colleagues' thoughts and ideas. The aim of this exercise is to encourage teachers to engage in reflective practice, to consider different methods of devising a lesson, discuss ways of tackling students' difficulties and adapting the lesson to their needs, thus enriching their PCK.

In preparation for the second session during the one-to-one interviews Laura suggested that it would be beneficial to develop a topic plan for the chemistry topics. Similarly Christine suggested for teachers to work on a topic they don't feel comfortable teaching and discuss how it can be developed. Therefore for the second session I thought that the teachers could work on topic planning. The teachers can draw a mind map to explain how they each develop the topic and then share their ideas within the group. The topic plan can provide a framework indicating how the concepts can be organised and interlinked thus illustrating how the big ideas within the topic fit together.

As teachers kept asking for more resources and examples of experiments I decided to include some examples of Investigations. However although this activity was planned in the programme, very little time was left in the session. I went through the reflective cycle to explain how investigations could be carried out at Year 7 and 8. Some examples of chemistry investigations were provided using the steps given in the research cycle which included: asking questions about the natural environment, collecting ideas and hypothesis, trying things out and conducting the experiment, observing and describing, documenting results and discussing results.

<table>
<tr><th colspan="2">Programme of Workshop 3: 5th May 2015</th></tr>
<tr><td>Introductory activity:

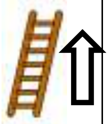
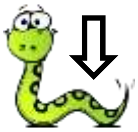
Snakes and Ladders: personal reflection on changes within one's classroom practice</td><td>The Snakes and Ladder activity is carried out to help teachers reflect and evaluate their growth and development throughout the professional learning journey. For each statement teachers have to state whether they have improved (so climbing the ladder) by moving a maximum of 3 steps forwards or moving backwards a maximum of 3 steps (descending the ladder) showing regression or staying in the same position.

The statements include: I……
▪ feel more confident teaching chemistry based topics.
▪ have gained more ideas and resources related to chemistry topics.
▪ have used some of the resources, lesson plans in my teaching.
▪ feel more confident planning and coming up with activities in chemistry lessons.
▪ feel more confident planning and conducting chemistry experiments.
▪ feel more confident in answering students' questions.
▪ more able to relate different aspects of subject knowledge within different chemistry topics.
▪ can identify misconceptions in chemistry based topics and design activities to challenge these ideas.
▪ feel that I have developed more subject matter knowledge in chemistry.
▪ more comfortable sharing my classroom experiences (including successes and difficulties) within the group.
▪ have seen an improvement in my teaching style and techniques in chemistry lessons.

After working individually on this exercise the teachers form a line and they move forwards or backwards or stay in the same position. At the same time share an explanation related to each statement.</td></tr>
<tr><td>Sharing the objectives of the day</td><td><u>Objectives of the day</u>
▪ Reflecting on our experiences – Journal writing
▪ Overview of development of a chemistry topic
▪ Discussion of topic overviews
▪ Planning an investigation
▪ Reflection of the day</td></tr>
</table>

Sharing of lesson plans and reflections	Like in workshop 2 teachers prepare two lesson plans and their reflections and they share their work in the community of learners.
Topic planning and sharing of work	Teachers work in pairs. Each group selects a topic. Each teacher constructs a mind map to explain how s/he develops a particular chemistry topic by drawing connections and links between the different areas. Then they share it and compare it with that of their colleague to learn whether they use different approaches in planning chemistry topics. The teachers share the work with the other teachers in the community so that they can learn about different ways of developing a topic.
Planning an investigation	The reflective cycle of approaching an investigation is introduced. The cycle involves asking questions about the natural environment, collecting ideas and hypothesis, trying things out and conducting experiments, observing and describing, documenting results and discussing results. Teachers work in pairs and they have to select an investigation from the topic plan they had produced and devise an investigation.
Reflection on the day and on the professional learning experience	An independent researcher conducts a focus group interview with the teachers asking them a number of questions. For this focus group interview I will not be in the room. The independent researcher can ask them about how they are experiencing the professional learning journey, discuss how what they have learnt and achieved or not achieved in the process. She invites them to describe their relationship with the researcher. The following prompt questions are used by the independent researcher: ▪ *Talk to me about the process that you have been involved in throughout the year.* ▪ *What have you learned in the process?* ▪ *How did you feel working together and with the researcher?* ▪ *If you had to describe your relationship with the researcher, how would you describe it?* ▪ *What do you feel that you have achieved/not achieved from the process?*

Snakes and Ladders

I …..	Explain			
▪ feel more confident teaching chemistry based topics.				
▪ have gained more ideas and resources related to chemistry topics.				
▪ have used some of the resources, lesson plans in my teaching.				
▪ feel more confident planning and coming up with activities in chemistry lessons.				
▪ feel more confident planning and conducting chemistry experiments.				
▪ feel more confident in answering students' questions.				
▪ am more able to relate different aspects of subject knowledge within different chemistry topics.				
▪ can identify misconceptions in chemistry based topics and design activities to challenge these ideas.				
▪ feel that I have developed more subject matter knowledge in chemistry.				
▪ am more comfortable sharing my classroom experiences (including successes and difficulties) within the group.				
▪ have seen an improvement in my teaching style and techniques in chemistry lessons.				

Journal – Reflective Practice – 5th May 2015

Date: ____________________ Class: ______________

Topic: ____ Time: _________min

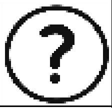
Teaching objectives:	
Briefly describe the lesson plan.	
Describe events that you believe are significant	
Describe potential challenges that you encountered during the lesson	
What are the typical questions that students ask in this lesson?	
Describe any difficulties that students encountered	
Comment on what you have learned personally from this lesson. What would you do or try differently next time?	

Further comments, thoughts and reflections........

An example of an investigation from the resource booklet

C.3 Polishing Pennies

Pennies are made from bright, shiny copper, but they don't stay bright forever, because the copper reacts slowly with oxygen from the air to create a coating of copper oxides. The copper oxides are dull and dark.
What is the best way to make pennies shine like new again?

Ask Question to investigate	**Which common liquids can be used to clean dull pennies?** 
 **Collect ideas and hypothesis**	Which liquids found in the home are commonly used to clean coins? Why are these used? Students suggest some household items. These liquids are generally acidic. Choose five liquids which can be used in this investigation.
Try things out and conduct experiment 	Usually dull coins are placed in coca cola to clean them up. Other liquids like lemon and vinegar can be used to clean the metal. So in this experiment dull coins are placed in different liquids to find out which is the best liquid to clean the coins. 1. Label the cups: lemon juice, cola, detergent, vinegar, and water or any other liquid. 2. Place a coin in each of the cups. 3. Pour enough water, lemon juice, cola, vinegar, and detergent into the labelled cups so that each coin is completely covered. 4. Wait 3 to 5 minutes. 5. Use a plastic spoon to remove the coin from the "lemon juice" cup and observe how it looks. 6. Polish the coin with a paper towel. Observe what happens and write your observation. Look at the paper towel. What colour is the material that you rubbed off? 7. Place the coin on the work surface in front of the cup from which it was removed. 8. Repeat steps 5 -7 for each of the coins in the other liquids, and record your observations. 9. Wait about 5 minutes after all coins are out of their solutions and observe them again. Rinse the coins with water, and dry them. 10. Try This… Conduct your experiment again, using vinegar mixed with a few shakes of table salt. Also, try vinegar with a pinch of cream of tartar, a pinch of table salt, and a drop of dishwashing detergent. Find out whether a solution of baking soda is a good penny cleaner.

<table>
<tr>
<td>Observe and describe
</td>
<td>
<table>
<tr><th>Liquid</th><th>Lemon Juice</th><th>Coca Cola</th><th>Detergent</th><th>Vinegar</th><th>Water</th></tr>
<tr><td>Change in appearance of coin</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Change in colour of liquid</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Observations on paper towel</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td>
</tr>
<tr>
<td>Document results
</td>
<td>The best liquid to clean the coin is ___________________

The worst liquid to clean the coin is __________________</td>
</tr>
<tr>
<td>Discuss results
</td>
<td>Not all liquids are the same. In this case, the liquids that were acidic were better cleaners than the ones that were not. Lemon juice contains citric acid, coca cola contains phosphoric acid, and vinegar contains ethanoic acid. The detergent and the water are not acidic at all. The acids in the lemon juice, the cola, and the vinegar react with the copper underneath the oxides on the outside of the coin to form new materials. These newly formed materials dissolve in the liquid and are washed away. So, what is left behind is a very thin coating of copper oxides that you can easily rub away.</td>
</tr>
</table>

References:
http://www.acs.org/content/dam/acsorg/education/resources/k-8/science-activities/chemicalphysicalchange/chemicalreactions/polishing-pennies.pdf

Appendix 3: Call for application in the INSET catalogue 2014

COURSE NO:	**VK 04/14**
TITLE:	**Teaching Chemistry Based Topics In the Integrated Science syllabus**
AIMS & OBJECTIVES:	The course aims : • to support teachers who are non-chemistry specialists teaching the strand 'Materials and their Properties' in the Form 1 and 2 Integrated Science syllabus. Participants will be given the opportunity to: • review key concepts in the strand 'Materials and their properties' in the Form 1 and 2 Integrated Science syllabus. • plan and conduct experiments related to this strand. • develop an understanding of students' misconceptions of key ideas and plan activities to address them. ▪ experience the use of inquiry based learning techniques
EXPECTED OUTCOMES:	The course will enable participants to: • gain more confidence, skills and expertise in preparing lessons and conducting lab-based activities in chemistry topics. • have an opportunity to share and discuss their teaching and learning experiences. • be empowered to teach their non-specialist area. • improve knowledge and understanding of chemistry and the teaching of practical work. ▪ be provided with further support through networking
CO-ORDINATOR:	Ms. Doreen Mizzi Head of Department , Chemistry Secretariat for Catholic Education Email: [redacted] Guest speakers from the School of Chemistry; University of Bristol will be present during this programme. **Application Forms are to be sent by post to:** **Ms. Marisa Schembri** **Training & Professional Development Unit, Room 313, Great Siege Road Floriana VLT 2000** **or Fax: 2598 2124 / 2598 2228 Tel: 2598 2233 / 2598 2710**
PARTICIPANTS:	Teachers of Science teaching Form 1 and 2 from State and non-State schools who are non-chemistry specialists.
DATES:	7th, 8th, 9th July 2014
TIME :	08.30 – 12.30
VENUE:	Chemistry Department at the Faculty of Science – University of Malta

Appendix 4: Permission letters to carry out research, Information sheet, Consent form

Letter from the Secretariat of Catholic Education to conduct research

MALTESE EPISCOPAL CONFERENCE
Secretariat for Catholic Education

The Head
All Church Schools

8th August, 2013

Ms Doreen Mizzi, currently reading a Ph.D at The University of Malta, requests permission to conduct a questionnaire with Integrated Science Teachers in all Church Secondary Schools.

The Secretariat for Catholic Education finds no objection for Ms Doreen Mizzi to carry out the stated exercise subject to adhering to the policies and directives of the school concerned.

Rev Dr. Charles Mallia
Delegate for Catholic Education

Letter from the Secretariat of Catholic Education to head of schools

MALTESE EPISCOPAL CONFERENCE
Secretariat for Catholic Education

The Head

10th September, 2014

Ms Doreen Mizzi, currently reading a Ph.D, at The University of Malta, requests permission to conduct interviews and class observations with Integrated Science Teachers at the above mentioned schools.

The Secretariat for Catholic Education finds no objection for Ms Doreen Mizzi to carry out the stated exercise subject to adhering to the policies and directives of the school concerned.

Rev Dr. Charles Mallia
Delegate for Catholic Education

Information Letter

Dear Science Teacher

I would like to invite you to participate in a research study that I am conducting with science teachers teaching Form 1 and 2 Integrated Science. This research is part of my Ph.D. studies at the University of Malta. Prof. Deborah A. Chetcuti is my research supervisor. The main aims of the study are (1) to explore the challenges faced by Integrated Science teachers, who are not Chemistry specialists, when they have to teach Chemistry topics as part of the Integrated Science syllabus, and (2) to develop a support programme for science teachers who are not Chemistry specialists, to help them teach Chemistry based topics at Form 1 and 2 level.

The study will be of interest to you if:

1. You teach Integrated Science.
2. You are a Chemistry non-specialist (that is you do not have Chemistry at Advanced or Degree level).
3. You would like to develop skills and expertise in teaching Chemistry topics within the Integrated Science syllabus.
4. You would like to form part of a learning community of practice which will provide you with resources and support for your continual professional development.

If you would like to participate in the study you will be asked to:

1. Participate in a professional development course that will be organised during the INSET days in July 2014.
2. Respond to a questionnaire, participate in a number of interviews /focus group interviews, agree that a lesson/s will be observed.
3. Agree to form part of a professional learning community throughout the academic year 2014/2015.
4. Participate in a workshop at the end of each term.

The professional development programme and the continual support in the learning community throughout the year will be very beneficial to you as a science teacher as it will provide you with resources, ideas, the support of a Chemistry professional, the support of peers and online materials. This will enable you to develop expertise in teaching of Chemistry topics and enable you to continue to grow professionally.

I would really appreciate if you take part in this study. Should you have any difficulties in participating in this research study, kindly contact me for further detail at [redacted] or on [redacted]

Yours sincerely

Doreen Mizzi

Consent Form

I am conducting a research study amongst teachers teaching Integrated Science at Form 1 and 2 level, as part of my Ph.D. studies at the University of Malta. Prof. Deborah A. Chetcuti is my research supervisor. The aim of the research study is to identify the challenges encountered when teaching science topics outside one's area of specialism, that is teaching a subject area that one has not studied at a Degree or Advanced level. As part of this research study, a support programme will be developed for non-specialist chemistry teachers to help them teach Chemistry based topics at Form 1 and 2 level. By participating in this research study one will gain more skills and confidence when teaching topics outside his/her subject specialism.

This support programme will entail attending for a professional development course that will take place during the INSET days of July 2014, which marks the beginning of the study. A questionnaire will be administered to identify the challenges, perceptions and views when teaching outside subject specialism. Interviews will also be held after the INSET which will be audio recorded.

Further support will be provided during the scholastic year of 2014–2015. You will form part of a learning community of practice. One-to-one meetings and lesson observations will be held. Interviews will be conducted during meetings and after lesson observations to gather the teacher's views and these will be audio recorded. The learning community of practice will meet during workshops that will be held at the end of each term.

I would really appreciate if you agree to take part of this research study. Although you will be attending the INSET course, you can still accept or refuse to participate in the research study. Therefore, if you would like to take part in this research study kindly complete the consent form.

You may be assured that your identity will remain preserved in the study. Data collected will remain confidential and will be used only for research purposes. You also reserve the right to withdraw from the study at any point without giving any justification. In the case, that you decide to withdraw from the study, your personal records and information will be destroyed. Upon completion of the study the outcomes of this research will be communicated to you in writing. Data will be destroyed upon completion of the research study.

In the case of any difficulty, do not hesitate to contact me on [redacted] or on [redacted]

Yours sincerely

Doreen Mizzi

Consent Form

I , _____________________________ agree to **participate in the research study by** attending the three day INSET course in July 2014 and form part of a learning community of practice throughout the scholastic year 2014/15.

During the scholastic year 2014/15 I agree:

- to form part of a learning community of practice, ☐
- to participate in one-to-one meetings, ☐
- that a lesson(s) will be observed, ☐
- to participate in audio recorded interviews carried out during the meetings, ☐
- to participate in audio recoded interviews after lesson observations, ☐
- to participate in end of term workshops. ☐

Kindly note that the names of the participant teachers and their respective schools will not be mentioned in any part of the study.

Signature: ___________________________ Date: ________________

Appendix 5: Questionnaire

Teaching Integrated Science Topics Outside Area of Specialism

7th July 2014

Dear Science Teacher

I am conducting a research study amongst science teachers teaching Form 1 and 2, as part of my Ph.D. studies at the University of Malta. The area of research focuses on teaching science topics outside one's area of specialism that is teaching a subject area that one has not studied at a Degree or Advanced level. Through this questionnaire, I would like to explore teachers' perceptions, challenges, issues and the levels of confidence in teaching topics within and outside their area of specialism. It will also provide an insight how teachers deal with such challenges, as well as identify key areas in which teachers would like to have further support when teaching outside subject specialism.

It would be greatly appreciated if you can complete this questionnaire as truthful as possible. You may be assured that your responses will be anonymous and the data collected will remain confidential.

I would like to thank you for your time to fill in this questionnaire and your co-operation is greatly appreciated.

Yours sincerely

Doreen Mizzi

Section A: Background Information

Kindly fill in the following information and/or tick where appropriate.

School	State School ☐ Church School ☐ Independent school ☐
Type of school	Boys' school ☐ Girls' School ☐ Co - Ed ☐
Gender	Male ☐ Female ☐
Age	
How many years have you been teaching?	
How many years have you been teaching Integrated Science?	

Qualifications obtained

Degree	B.Ed (Hons) ☐ B.Sc (Hons) ☐ PGCE ☐ Other Degree ______________________________
Area of Specialisation	Physics ☐ Chemistry ☐ Biology ☐ Science ☐ Other: ______________________

Advanced level in	Physics ☐	Chemistry ☐	Biology ☐	Other ____________
Intermediate level in	Physics ☐	Chemistry ☐	Biology ☐	Other ____________
SEC / O level in	Physics ☐	Chemistry ☐	Biology ☐	
Never studied subject at secondary level	Physics ☐	Chemistry ☐	Biology ☐	

<u>Teaching load during this scholastic year</u>

Fill in the subjects and levels taught in this scholastic year 2013 / 14:

Subject	Form

Section B: Form 1 and 2 Units

1. The following is a list of topics found in the Form 1 and 2 curriculum.

- Indicate your level of confidence in teaching each unit in the tables below.
- By ticking **1** it shows that you are **most confident** and by ticking **5** it shows that you are **least confident** in teaching this topic.
- Fill in both tables if you teach or previously taught both Forms and one table if you teach or taught one Form. If the topic is not part of your school syllabus do not tick a box.

most confident → *least confident*

Form 1 Units	**1**	**2**	**3**	**4**	**5**
Sci 7.1 Young Scientist At Work	☐	☐	☐	☐	☐
Sci 7.2 Safety First	☐	☐	☐	☐	☐
Sci 7.3 Living Things	☐	☐	☐	☐	☐
Sci 7.4 Our Environment	☐	☐	☐	☐	☐
Sci 7.5 Understanding Matter	☐	☐	☐	☐	☐
Sci 7.6 Energy Around Us	☐	☐	☐	☐	☐
Sci 7.7 Electricity	☐	☐	☐	☐	☐
Sci 7.8 On The Move	☐	☐	☐	☐	☐
Sci 7.9 Acids And Alkalis	☐	☐	☐	☐	☐
Sci 7.10 Chemical Changes	☐	☐	☐	☐	☐
Sci 7.11 Cells And Body Systems	☐	☐	☐	☐	☐
Sci 7.12 Increasing In Numbers	☐	☐	☐	☐	☐

most confident → *least confident*

Form 2 Units	**1**	**2**	**3**	**4**	**5**
SCI 8.1 Healthy Living (I) – Go for Everest.	☐	☐	☐	☐	☐
SCI 8.2 Healthy Living (II) – Life Cycle Challenge	☐	☐	☐	☐	☐
SCI 8.3 Elements, Compounds and Mixtures (I)	☐	☐	☐	☐	☐
SCI 8.4 Elements, Compounds and Mixtures (II)	☐	☐	☐	☐	☐
SCI 8.5 Separating Mixtures	☐	☐	☐	☐	☐
SCI 8.6 Light and Sound	☐	☐	☐	☐	☐
SCI 8.7 Ecological Relationships	☐	☐	☐	☐	☐
SCI 8.8 Forensic Science	☐	☐	☐	☐	☐
SCI 8.9 Climate Change (I) – Energy for the Environment	☐	☐	☐	☐	☐
SCI 8.10 Climate Change (II)- Environmental Chemistry	☐	☐	☐	☐	☐
SCI 8.11 Earth and Space (I)	☐	☐	☐	☐	☐
SCI 8.12 Earth and Space (II)	☐	☐	☐	☐	☐

2. Give **reasons** why **you feel very confident** to teach the units that you have ticked on page 3.

3. Give **reasons** why **you feel less confident** to teach the units that you have ticked on page 3.

4. List the topic/s from the Integrated Science syllabus in which you feel that you require support.

5. Describe which forms of support you would like to have in the topics that were mentioned in question 4.

6. The following statements are about subject knowledge within and outside areas of specialism and level of confidence. Please indicate the degree to which you agree or disagree with each statement below by circling the appropriate letters to the right of each statement.

SA – Strongly Agree A – Agree UN – uncertain D- Disagree SD – Strongly Disagree

	SA	**A**	**UN**	**D**	**SD**
1. I prefer to teach topics within my area of specialism	SA	A	UN	D	SD
2. I am more confident when teaching topics related to my area of specialism.	SA	A	UN	D	SD
3. I am not so confident in answering questions related to my non-specialist area.	SA	A	UN	D	SD
4. I find it challenging to set up and explain a practical experiment related to my non-specialist area.	SA	A	UN	D	SD
5. I do not mind teaching topics outside my area of specialism.	SA	A	UN	D	SD
6. I find it difficult to explain concepts outside area of specialism.	SA	A	UN	D	SD
7. I am more able to relate different aspects of subject knowledge within my area of expertise as I have more elaborate knowledge.	SA	A	UN	D	SD
8. I am less confident when teaching topics outside my area of specialism.	SA	A	UN	D	SD
9. I find it more challenging to come up with activities when planning lessons outside my area of specialism.	SA	A	UN	D	SD
10. I enjoy learning new subject knowledge outside area of specialism.	SA	A	UN	D	SD
11. I am more confident in answering students' questions in greater detail within my area of expertise.	SA	A	UN	D	SD
12. I feel more confident in planning lessons and creating activities within my area of expertise.	SA	A	UN	D	SD
13. I am continually seeking better ways to teach topics within my non-specialist area.	SA	A	UN	D	SD
14. I am able to anticipate and identify easily students' misconceptions in my subject specialism.	SA	A	UN	D	SD
15. I find it more challenging to draw up the potential links between topics outside my area of specialism due to my limited background knowledge in the subject.	SA	A	UN	D	SD
16. I find it difficult to explain why science experiments fail to work outside my area of expertise.	SA	A	UN	D	SD
17. I find it difficult to identify students' misconceptions when teaching outside area of expertise.	SA	A	UN	D	SD
18. Teaching experience has helped me gain confidence when teaching outside area of expertise.	SA	A	UN	D	SD
19. I find it challenging to simplify complex ideas related to my non-specialist area.	SA	A	UN	D	SD
20. I still feel like a novice teachers when teaching outside subject specialism even though I have teaching experience.	SA	A	UN	D	SD

7. Teachers may use a range of strategies for planning and developing lessons **in their specialist and non-specialist subject area.** From the list tick which strategies you generally, often, occasionally and/or never make use of:

	IN SPECIALIST AREA			
	Generally	**Often**	**Occasionally**	**Never**
Reading text books and making notes to revise subject matter knowledge.	☐	☐	☐	☐
Looking for activities, analogies and illustrations from books or internet to help develop students' scientific understanding.	☐	☐	☐	☐
Searching on the internet to revise subject matter knowledge.	☐	☐	☐	☐
Read the curriculum document and making use of the proposed activities.	☐	☐	☐	☐
Asking for help from colleagues at school who are specialists in their area.	☐	☐	☐	☐
Working out questions or exam papers	☐	☐	☐	☐
Reading misconception literature.	☐	☐	☐	☐
Conducting the experiment beforehand.	☐	☐	☐	☐
Asking for help in the set-up of experiments.	☐	☐	☐	☐
Discussing with teachers during departmental meetings.	☐	☐	☐	☐
Develop the lesson plan with a colleague.	☐	☐	☐	☐

	NON-SPECIALIST AREA			
	Generally	Often	Occasionally	Never
Reading text books and making notes to revise subject matter knowledge.	☐	☐	☐	☐
Looking for activities, analogies and illustrations from books or internet to help develop students' scientific understanding.	☐	☐	☐	☐
Searching on the internet to revise subject matter knowledge.	☐	☐	☐	☐
Read the curriculum document and making use of the proposed activities.	☐	☐	☐	☐
Asking for help from colleagues at school who are specialists in their area.	☐	☐	☐	☐
Working out questions or exam papers	☐	☐	☐	☐
Reading misconception literature.	☐	☐	☐	☐
Conducting the experiment beforehand.	☐	☐	☐	☐
Asking for help in the set-up of experiments.	☐	☐	☐	☐
Discussing with teachers during departmental meetings.	☐	☐	☐	☐
Develop the lesson plan with a colleague.	☐	☐	☐	☐

Thank you for your time in completing this questionnaire

Paired statements used in questionnaire.

	Paired Statements
Area of preference	▪ I prefer to teach topics within my area of specialism. ▪ I do not mind teaching topics outside area of specialism.
Confidence	▪ I am more confident when teaching topics related to my area of specialism. ▪ I am less confident when teaching topics outside my area of specialism.
Answering questions	▪ I am more confident in answering students' questions in greater detail within my area of expertise. ▪ I am not so confident in answering questions related to my non-specialist area.
Setting up experiments	▪ I find it challenging to set up and explain a practical experiment related to my non-specialist area. ▪ I find it difficult to explain why science experiments fail to work outside my area of expertise.
Explaining and elaboration of concepts	▪ I find it difficult to explain concepts outside area of specialism. ▪ I find it challenging to simplify complex ideas in my non- specialist area.
Drawing links between different concepts	▪ I am more able to relate different aspects of subject knowledge within my area of expertise as I have more elaborate knowledge. ▪ I find it more challenging to draw up the potential links between topics outside my area of specialism due to limited background knowledge in the subject.
Planning of lessons	▪ I find it more challenging to come up with activities when planning lessons outside my area of specialism. ▪ I feel more confident in planning lessons and creating activities within my area of expertise.
Attitude	▪ I enjoy learning new subject knowledge outside area of specialism. ▪ I am continually seeking better ways to teach topics within my non-specialist area.
Misconceptions	▪ I am able to anticipate and identify easily students' misconceptions in my subject specialism. ▪ I find it difficult to identify students' misconceptions when teaching outside area of expertise.
Effect of experience	▪ Teaching experience has helped me gain confidence when teaching outside area of expertise. ▪ I still feel like a novice teacher when teaching outside subject specialism even though I have more than 5 years of teaching experience.

Appendix 6: Interview Schedules

One-to-one interviews held between October – November 2014

The purpose of the first interview was to get to know the participants and find out how they were feeling when teaching within and outside specialism. A set of questions was prepared for each teacher based on the profile built from the questionnaire. Here are the questions asked in the first interview to one of the participants. Similar questions were asked to the other participants. The interview schedule was tailor-made for each participant depending on the responses given in the questionnaire and on their feedback at the INSET.

1. In the questionnaire you said that you prefer to teach topics within your specialism but do not mind teaching topics outside your specialism. Can you elaborate a bit more on this?

2. When teaching within specialism you said that you were undecided about the following: to relate difference aspects with the subject and in planning lessons and creating activities. How do you feel teaching your subject specialism?

3. When teaching outside area of expertise you were undecided about a number of factors such as:
   - setting up and explaining an experiment,
   - explaining when experiments fail to work,
   - finding it difficult to explain concepts,
   - finding it challenging to simplify complex ideas and
   - finding it more challenging to draw potential links between topics.

   How do you feel teaching topics outside specialism?

4. In your feedback at the INSET you mentioned that you increased your confidence in teaching chemistry topics. What helped you increase this confidence?

5. What do you look forward to when we meet at the end of term workshop (tentative date: first week of December 2014)?

Interviews held during the year (October 2014 to May 2015) after lesson observation

An interview was carried out after the lesson observation. The purpose of this interview is to clarify particular aspects of the lesson and to prompt teachers to reflect on their lesson. The questions were designed mainly during lesson observation and they generally focused on:

a. exploring the teachers' knowledge about the subject especially on particular concepts noticed during the lesson,
b. exploring the teachers' knowledge about which concepts are easy or difficult to explain,
c. exploring teachers' knowledge of students' difficulties, that is identifying areas that students find difficult to understand and identifying misconceptions in the lesson
d. exploring what activities and why such activities were chosen by the teacher in the lesson.
e. finding out how teachers tackled students' questions.
f. any particular issue/ incident related to that lesson observation.

Interviews followed an unstructured to a semi-structured approach depending on the lesson observation. The following questions were used as prompts to initiate the discussion after lesson observation:

- How did you feel in the lesson? (Describe your thoughts and feelings in the lesson)
- What were the lesson objectives? Do you think that have been achieved?
- What were you most pleased with? Why?
- Were there any surprises in the lesson? How did you tackle them?
- Why did you choose such particular activities in your lessons?
- Which difficulties did the students encounter in this lesson?
- What are the typical difficulties encountered by students when you teach this particular topic?
- Which difficulties/ challenges did you encounter as a teacher during this lesson? How did you solve them?
- How did you feel handling the students' questions?
- What do you think the pupils learnt?
- What did you learn in this lesson?
- If you did this lesson again, would you do anything different?
- What will you do I the follow up lesson?

Teachers were also asked to share their experiences about the professional development programme:

- What are your experiences of the previous professional development sessions?
- How are feeling when working with others within the learning community?
- What you would like to discuss / work on in the next workshop?
- Any other comments…..

Final one-to-one interview held in May 2015

The main question included:

I am interested in listening to your story, your experiences as a teacher before and after the professional development programme…..What are your experiences?

Prompt questions:

- How do you describe yourself as a teacher?
- Why did you opt to participate in this professional development programme?
- How do you feel teaching your non-specialist area?
- What are the main challenges that you encounter when teaching chemistry based topics? How do you tackle such challenges?
- Describe your experience as you participated with other teachers in the professional development sessions.
- What are your views about this type of ongoing support programme?
- Which activities did you find most valuable to support you in teaching chemistry topics?
- Can you elaborate on how these may have helped you?
- Following this experience describe how you will modify the teaching strategies in your lessons?
- Describe your views and perceptions of teaching chemistry before and after this experience.
- Following the experience and knowledge gained from the professional development programme how did you see yourself changing along the year?

Interview held a year after the professional development (May to June 2016)

An interview was held with the participant teachers a year after the professional development programme.

Prompt questions:

- How do you see yourself as a teacher a year after the professional development experience when teaching outside subject specialism?
- What did you take most from the professional development experience last year?
- Did you implement any changes when teaching chemistry topics this year?
- Did you develop any deeper understanding of concepts?
- How do you rate your level of confidence when teaching chemistry based topic this year?
- If you have gaps in knowledge or understanding whom do you ask today?
- Did you miss the learning community this year? In what ways?

Focus group interviews held during the INSET 7th to 9th July 2019

First focus group interview in INSET focussed on the questions posed in the case study:

1. Did you experience a similar situation? Can you describe it?

2. Identify one particular chemistry topic in which you felt that it was fairly easy and straight forward to teach.
   a. Explain why.
   b. How did you go about it?

3. Identify one particular chemistry topic which you considered as challenging to teach.
   a. Explain why.
   b. How did you go about dealing with such a situation?

Second focus group interview held during the INSET at the end of Day 3.

We have started out journey in this professional development course and we have been working together for 3 mornings. I particularly interested in listening to your experience gained so far. I would like to start by asking you:

1. Did you develop any new ideas whilst participating in discussions? Give examples.
2. Did you develop any new ideas whilst engaging in practical work? Give examples.
3. What did you learn during the past days?
4. If you had to complete the statement "I used to think… but now I know…"
5. What will I take back to the classroom?
6. After hearing your colleagues, would you like to add some further ideas?
7. If you had to design a plan of action what would you tackle?
8. What made you participate in this learning community?
9. How did you feel working in the groups?
10. Did the sessions meet your expectations?
11. What do you look forward for next year as we keep on meeting through the year?

Focus group interview: Concluding the PD programme: 16th June 2015

Programme of 16th June 2015	
Introductory activity	Welcome! Thank you for coming to the final meeting. We have been meeting for a whole scholastic year and we have walked together throughout this journey. As an ice breaker exercise find words related to the word 'journey' especially related to this experience. Then share it with the whole group.
Sharing reflections about the learning community	A focus group interview will be conducted to capture the feelings, experiences and reflections about the professional learning journey and the learning community. The following questions will be used to start off the discussion: ▪ Describe your experiences and feelings throughout this journey. It is important that you say what you feel and share an honest opinion about this. How did you feel working and sharing experiences within the group? ▪ Did you feel we managed to build a community? Do you think that this was a learning community? Why? The following questions can be used as probes whilst listening to the teachers' stories: ▪ *What you understand by the term 'learning community?* ▪ *What were the goals of this learning community?* ▪ *What philosophy or beliefs guided our work in the learning community?* ▪ *Why did you choose to belong to this learning community?* ▪ *What are the strengths of this learning community?* ▪ *What are the weaknesses of this learning community?* ▪ *Do you feel comfortable sharing your views and opinions within this learning community? Explain.* ▪ *What resources and tools have you found helpful during collaborative work? In what way did you find these useful?* ▪ *How did the groups' work, interaction and dialogue influence you (a) personally and (b) your classroom practice?* ▪ *In your views what have we accomplished in this learning community?* ▪ *How do you see the learning community developing from here?* ▪ *Anything else you would like to comment about the learning community….*
Conclusion: Presenting a booklet with the teachers' work.	All of the teachers' lesson plans designed throughout the different workshops and all the lesson plans presented during workshop 2 and 3 were collated as a booklet (after gaining the teacher's permission). This resource that will be presented to the teachers to celebrate their effort and their work throughout the learning journey.

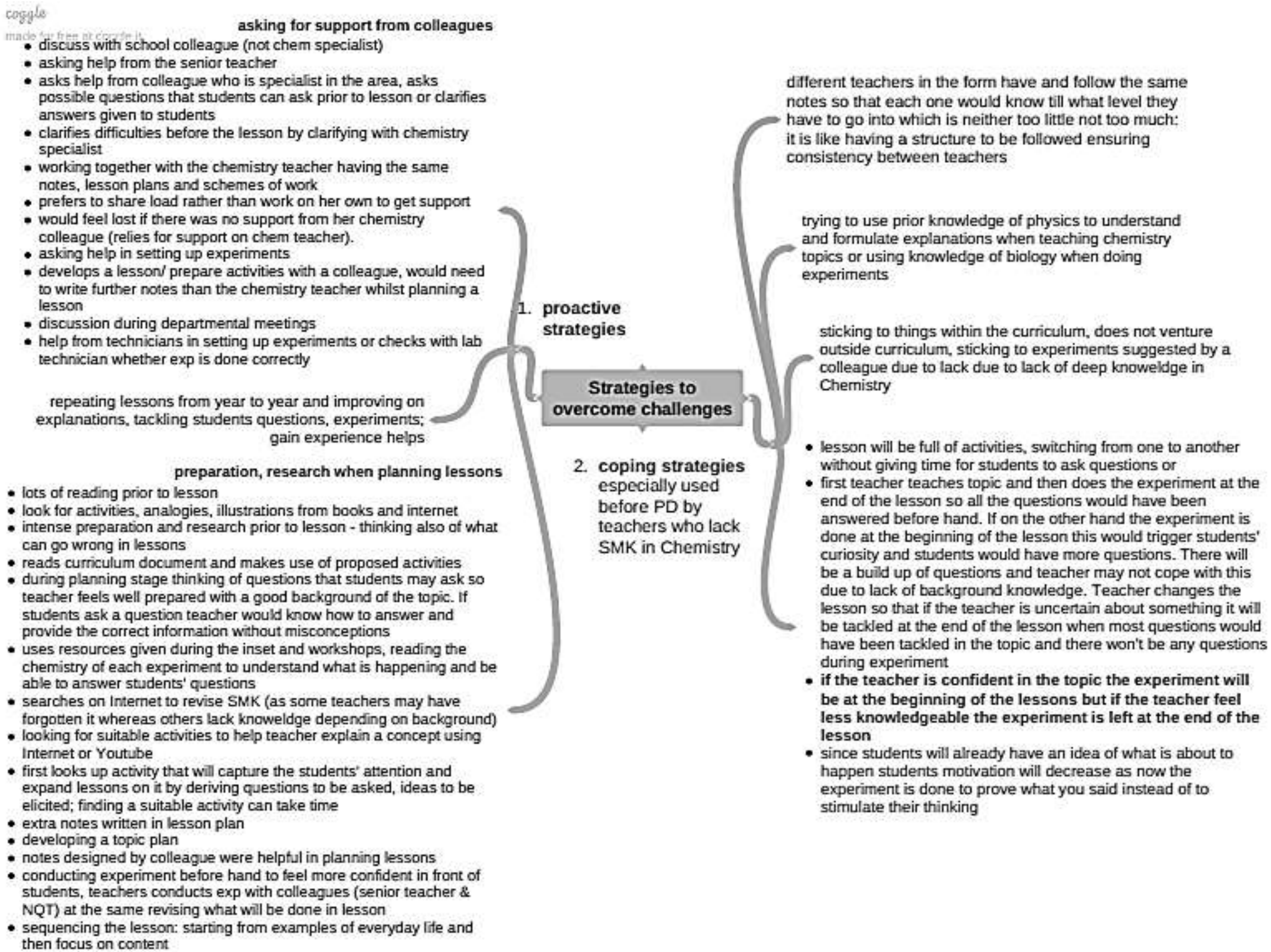
Appendix 7: Coding data

Excerpt from final interview with Laura

	Code	Reference
before the INSET ….. I did not feel very confident when teaching chemistry…. It could have also been because I only had one year experience prior to the INSET. Everything was new and I did not feel that comfortable when teaching chemistry	not confident teaching chemistry before inset	INT4.1. LAURA.8JUNE
and then the INSET was helpful because through it I got to know about more activities which can be integrated, students' misconceptions, what can be done to challenge them …. Hmm it was nice because everyone was sharing their experiences …. Maybe in the INSET not as much as recently in the other seminars… but overall I felt it was interesting because I got a lot of ideas and it was very helpful ……	feedback on PD	INT4.2. LAURA.8JUNE
then this year, started the year as usual …. chemistry units I felt more comfortable because I had more activities which could be done. I anticipated the questions which my students would be asking me, so I already had an idea of how to answer them and what to do ….. Was a bit restricted with time so unfortunately I could not do as many activities as I wanted to … But overall I felt much more comfortable this year…. And the topic which I taught elements, compounds and mixtures was the one which gave me most trouble last year, because last year then there was separation techniques which I did not teach because of student teacher this year… but at the same time separation techniques is pretty straight forward because you have methods and you follow them. They are something which can be seen. The topics which are most tedious are the ones which are abstract and elements, compounds and mixtures is quite an abstract topic. So in that way I felt comfortable teaching chemistry units.	more comfortable teaching Chemistry during year of research	INT4.3. LAURA.8JUNE
The seminars were helpful to me because we were smaller groups and the people were the same…. Most of them were biology specialists like me and therefore I could relate more to them so it was good.	building relationship in community due to similar identity	INT4.4. LAURA.8JUNE
and also the fact that we were reflecting on our lessons and discussing, then coming up with lessons to teach particular topics; these were all very helpful and I appreciated them very much [did it help you to reflect more?] yes on what I did and maybe what I could have done better, what I could have improved, maybe what I did which other people did not do and it was good.	reflecting and planning lessons in PD	INT4.5. LAURA.8JUNE

	Code	Reference
overall I felt much better this year … but then again it could be because now I am more experienced so with experience you gain confidence.	gain in confidence due to increased experience	INT4.6. LAURA.8JUNE
in my first year I was not sure about what detail we had to go into and this year the fact that we came up with notes and we all had the same notes, it was good because we knew till where or till what detail we had to go into, so that really helped me, I think	same notes ensures consistency	INT4.7. LAURA.8JUNE
… and even the fact that I could discuss with colleagues, other maybe the new teachers who are teaching this year, maybe how they did certain things was also good …	opportunities to discuss with school colleagues	INT4.8. LAURA.8JUNE
more than my perception of chemistry, more like my perceptions of teaching chemistry because perceptions of chemistry I don't feel that I have a good chemistry background. I think that the basics you either get them when you are at school… later on … it is true I got an A in the intermediate … I think I studied a lot for it … I don't think I actually understood, even valencies and things like that I don't know them you know the basics; things which I should have learnt at O level and then they were lost. So I don't feel that I have a very good chemistry….My knowledge of chemistry is very limited.	poor Chemistry background	INT4.9. LAURA.8JUNE
My knowledge of chemistry is very limited, but at the same time the fact I know what activities I can do to portray certain concepts. I know till what detail I have to go into my science lessons, now I know how to answer some questions which students would ask. Overall I feel much more confident even though I still don't feel I have the background, the basics which are taken for granted…Now if we keep doing the same topics I know how to go about teaching them	able to do lessons in Chemistry even though she has a poor background knowledge	INT4.10. LAURA.8JUNE
the fact that I am weak in the subject maybe makes it better because I understand my students when they have a problem so I relate to them.	understand students better due to weak SMK	INT4.11. LAURA.8JUNE
the fact that I am weak in the subject …..At the same time I pay more attention to how I am saying certain things to make sure I don't pass on misconceptions….	aware of limitations of weak SMK	INT4.12. LAURA.8JUNE

An example of a mind map summarising one of the themes



Appendix 8: Results from questionnaire

Results of paired statements from questionnaire

Area of preference	Strongly agree/ Agree	Strongly disagree/ Disagree	Undecided
▪ I prefer to teach topics within my area of specialism.	7	1	0
	Amy, Christine, Daniela, Laura, Maria, Robert, Sarah	*Karen*	
▪ I do not mind teaching topics outside area of specialism.	4	2	2
	Amy, Karen, Maria Sarah	*Laura, Daniela*	*Christine, Robert*

Confidence	Strongly agree/ Agree	Strongly disagree/ Disagree	Undecided
▪ I am more confident when teaching topics related to my area of specialism.	7	1	0
	Amy, Christine, Daniela, Laura, Maria, Robert, Sarah	*Karen*	
▪ I am less confident when teaching topics outside my area of specialism.	7	0	1
	Amy, Christine, Daniela, Laura, Maria, Robert, Sarah		*Karen*

Answering questions	Strongly agree/ Agree	Strongly disagree/ Disagree	Undecided
▪ I am more confident in answering students' questions in greater detail within my area of expertise.	8	0	0
	Amy, Christine, Daniela, Karen, Laura, Maria, Robert, Sarah		
▪ I am not so confident in answering questions related to my non-specialist area.	5	2	1
	Amy, Christine, Laura, Maria, Robert	*Daniela*	*Karen, Sarah*

Setting up experiments	Strongly agree/ Agree	Strongly disagree/ Disagree	Undecided
▪ I find it challenging to set up and explain a practical experiment related to my non-specialist area.	5	1	2
	Christine, Karen Laura, Maria, Sarah	*Robert*	*Amy, Daniela*
▪ I find it difficult to explain why science experiments fail to work outside my area of expertise	4	2	2
	Amy, Christine, Laura, Sarah	*Karen, Maria*	*Daniela, Robert*

Explaining and elaboration of concepts	Strongly agree/ Agree	Strongly disagree/ Disagree	Undecided
▪ I find it difficult to explain concepts outside area of specialism.	2	1	5
	Laura, Maria	*Robert*	*Amy, Christine, Daniela, Karen Sarah*
▪ I find it challenging to simplify complex ideas in my non-specialist area.	5	1	2
	Christine, Karen, Maria, Robert, Sarah	*Daniela*	*Amy, Laura*

Drawing links between different concepts	Strongly agree/ Agree	Strongly disagree/ Disagree	Undecided
▪ I am more able to relate different aspects of subject knowledge within my area of expertise as I have more elaborate knowledge.	7	0	1
	Christine, Daniela, Karen, Laura, Maria Robert, Sarah		*Amy*
▪ I find it more challenging to draw up the potential links between topics outside my area of specialism due to limited background knowledge in the subject	6	0	2
	Christine, Daniela, Laura, Maria, Robert, Sarah		*Amy, Karen*

Planning of lessons	Strongly agree/ Agree	Strongly disagree/ Disagree	Undecided
▪ I feel more confident in planning lessons and creating activities within my area of expertise.	7	0	1
	Christine, Daniela, Karen, Laura, Maria, Robert, Sarah		*Amy*
▪ I find it more challenging to come up with activities when planning lessons outside my area of specialism.	7	1	0
	Amy, Daniela, Karen, Laura, Maria, Robert, Sarah	*Christine*	

Attitude	Strongly agree/ Agree	Strongly disagree/ Disagree	Undecided
▪ I enjoy learning new subject knowledge outside area of specialism.	7	0	1
	Amy, Christine, Daniela, Karen, Maria, Robert, Sarah		*Laura*
▪ I am continually seeking better ways to teach topics within my non-specialist area.	8	0	0
	Amy, Christine, Daniela, Karen, Laura, Maria, Robert, Sarah		

Misconceptions	Strongly agree/ Agree	Strongly disagree/ Disagree	Undecided
▪ I am able to anticipate and identify easily students' misconceptions in my subject specialism.	8	0	0
	Amy, Christine, Daniela, Karen, Laura, Maria, Robert, Sarah		
▪ I find it difficult to identify students' misconceptions when teaching outside area of expertise.	7	0	1
	Amy, Christine, Daniela, Laura, Maria, Robert, Sarah		*Karen*

Effect of experience	Strongly agree/ Agree	Strongly disagree/ Disagree	Undecided
▪ Teaching experience has helped me gain confidence when teaching outside area of expertise.	3	1	4
	Amy, Christine, Karen	*Laura*	*Daniela, Maria Robert, Sarah*
▪ I still feel like a novice teacher when teaching outside subject specialism even though I have more than 5 years of teaching experience.	4	1	3
	Daniela, Karen Laura, Sarah	*Christine*	*Amy, Maria, Robert*

Results of strategies used when teaching within and outside specialism (questionnaire)

	IN SPECIALIST AREA				NON-SPECIALIST AREA			
	Generally	Often	Occasionally	Never	Generally	Often	Occasionally	Never
Reading text books and making notes to revise subject matter knowledge.	0	4	2	2	2	3	2	1
Looking for activities, analogies and illustrations from books or internet to help develop students' scientific understanding.	5	1	2	0	5	2	1	0
Searching on the internet to revise subject matter knowledge.	0	6	2	0	5	3	0	0
Read the curriculum document and making use of the proposed activities.	3	3	1	1	4	3	0	1
Asking for help from colleagues at school who are specialists in their area.	0	3	5	0	3	4	1	0
Working out questions or exam papers	4	0	1	3	4	0	2	2
Reading misconception literature.	0	1	4	3	1	1	3	3
Conducting the experiment beforehand.	4	0	4	0	5	1	2	0
Asking for help in the set-up of experiments.	0	4	2	2	3	4	1	0
Discussing with teachers during departmental meetings.	2	3	3	0	3	3	2	0
Develop the lesson plan with a colleague.	2	1	4	1	3	2	2	1

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